Automated polygon schematization for thematic maps

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***Abstract*—Schematization is a powerful means of communication. Therefore, it is widely applied in cartographic practice. Despite their frequent use, schematized maps, particularly in the context of thematic mapping, are usually still drawn by hand: a slow and tedious process. This is mainly due to the lack of accessible tools facilitating automated polygon schematization. And yet numerous algorithmic approaches to generate schematized maps have been published over the last two decades. None of these algorithms have been implemented into an accessible working cartographic service. This research focuses on prototyping such a service demonstrating that the proposed web-based schematization tool is feasible. Computational time constraints and the tool's robustness remain an issue.**

***Index Terms*—schematization, generalization, thematic mapping, automated cartography, cartographic web services**

I. Introduction

Besides topographic maps, schematized maps [1], more precisely transit maps, are in the spotlight of research on map generalization: publications concern their usability and techniques to automate their generation [2]–[5]. Cartographers use schematization, an extreme type of simplification, for maps which "are narrow in their function and task" [1, p. 300]. Examples are maps in newspapers and fare zones in transit maps. Despite the amount of research carried out regarding schematized transit maps, blank spots on how to generalize for schematized thematic maps may remain on the cartographic research-map [6]. This research focuses on polygon schematization for thematic mapping.

II. Scope

We implement a proof-of-concept prototype (see Fig. 1) for a web-based schematization tool and aim to evaluate the tool's practical feasibility. To this end, cartographic requirements for using schematized regions in thematic maps were examined. They regard the contrast between the thematic maps' base layer and the overlayed thematic layer. The underlying design principles concern legibility by contrast in detail and also by shape. Then, a suitable schematization approach was chosen, based on comparing existing algorithmic approaches regarding geometric and computational properties. Additionally, crucial software requirements for a web-based schematization tool were specified. Finally, the prototype was evaluated on the basis of these requirements.

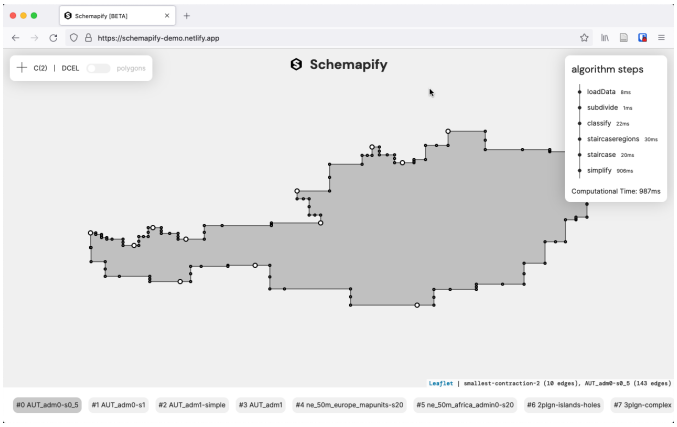

Fig. 1. A screenshot of the proof-of-concept prototype.

A literature review was conducted to identify characteristics of polygon schematization. By means of these characteristics, existing approaches were systematically compared. These approaches lead to different schematization results (see Fig. 2) Furthermore, the prototyping method was applied in combination with a simplified software-requirement-engineering process [7]. Using prototyping as a method implies an iterative development. The visual design revisions of a singular component of the graphical user interface are an example for this iterative design process. The chosen algorithm was implemented within a technical and incremental proof-of-concept prototype, using JavaScript (TypeScript). For this, requirements were used to outline aspects which need to be considered from a technical but particularly from a cartographic point of view, i.e., the design principles. These requirements contain several levels of requirement information and build the basis for the concluding prototype evaluation in the requirement verification.

III. Results

General cartographic design principles concerning thematic mapping are in line with characteristics schematized regions expose. Nevertheless, literature shows as well that schematization is only one mean of designing maps, which on its own cannot guarantee a legible, efficiently designed map. The

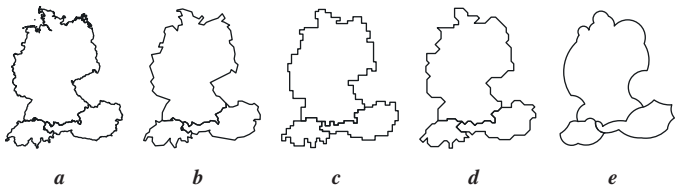

Fig. 2. The Germany-Austria-Switzerland region (***a***), simplified (***b***) and in a rectilinear (***c***), octilinear (***d***) and curved (***e***) schematization.

systematic comparison demonstrates that existing algorithmic approaches cover various schematization styles and exhibit heterogeneous geometric properties. Nevertheless, only few preserve area and topology, which is indispensable for many cartographic purposes.

Furthermore, the computational complexity resulting in long running times for complex input data poses a technical constraint. The *Area-Preserving Simplification and Schematization of Polygonal Subdivisions* approach by Buchin et al. [8] was chosen because it has comparatively low computational complexity. It is also flexible regarding the schematization style. This approach enables C-oriented schematizations, i.e., all lines of the resulting region adhere to a limited set C of directions. C consists of a minimum of 2 up to typically 8 directions. The specified software requirements expose that validating input data for geometric particularities is a crucial preliminary for a stable system. Moreover, they reflect the need to consider error sources, particularly for the orientation-restriction algorithm, originating from the input data's geometry. The remaining requirements concern handling projections (and respectively handling data which is not projected but in a geographic coordinate reference system), and the design of an interface which provides meaningful feedback to the user and allows an efficient setup of the schematization parameters. The evaluation, conducted with the requirement verification, particularly reveals shortcomings on system capabilities and the current graphical user interface implementation. Therefore, upcoming development and prototyping steps will focus on these aspects.

IV. Discussion

The results of the requirement verification, together with the release scope and the functional requirements, form the basis for a road map towards a release of the schematization tool. The ideally iterative nature of such a software development process requires further work on the carried-out prototype. This includes thoroughly validating the software requirements and conducting a user test on the proposed interface design. Such a user feedback can be relevant for two identified user groups: in the GIS domain and the visual design domain. If iteratively applied, it could e.g. reveal specific needs per user group or for particular tasks.

Implementing this algorithm in an accessible web-based cartographic service embodies a series of challenges regarding robustness, performance and usability. This research points out these challenges. Further research on the intersection between the theoretical design of schematization algorithms and their practical implementation is needed. It may thus include implementing and systematically comparing schematization approaches: by computationally benchmarking and visually analysing results.

V. Conclusion

Given the growing interest for automated schematizations concerning network as well as polygon schematization on the one hand and the time-consuming process of manual schematization on the other, the need for a practical application of published algorithms is evident. Throughout this research project, aspects of this implementation process were addressed. The carried-out results aim to fill this gap in cartographic literature on map schematization. The outlined process together with the prototype's evaluation shows that the proposed web-based schematization tool is feasible. Nevertheless, computational time constraints decreased performance and, above all, the tool's robustness needs further attention. Upon overcoming these issues, the approach can be applied in a useful tool, which blends into common map-making workflows smoothly.

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