Automated schematization for thematic maps

Good afternoon!

☀️

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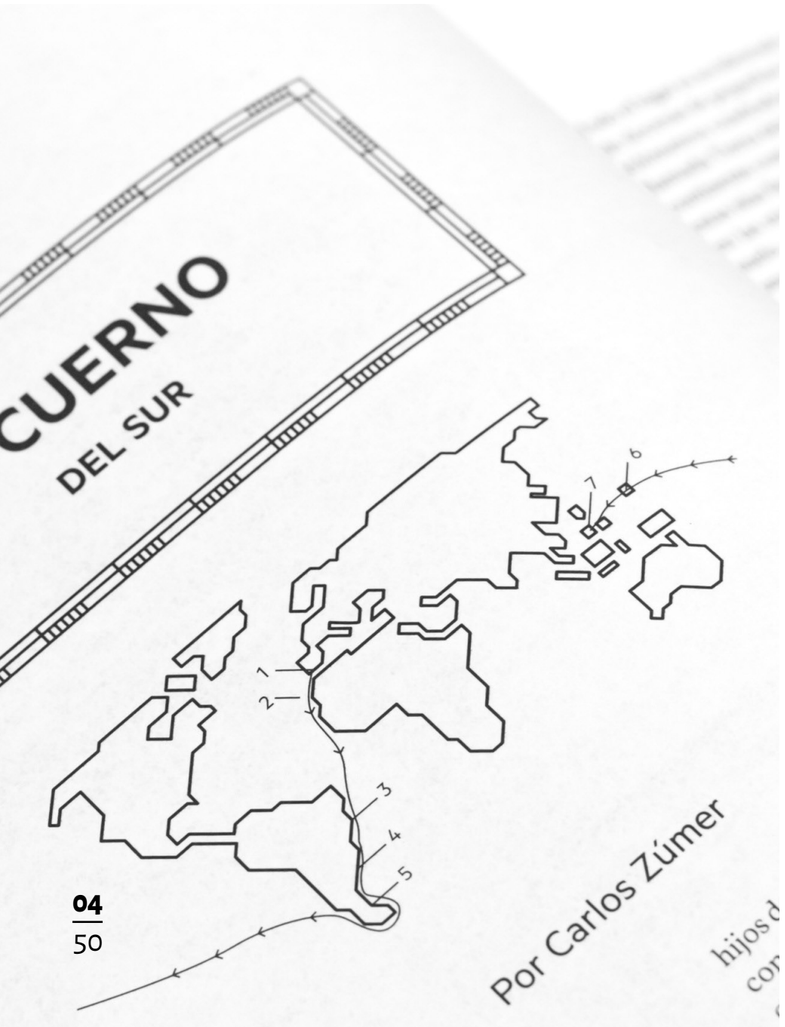
Defense

M.Sc. Cartography, University of Twente
October 25th, 2021

1– Motivation

Motivation

relajaelcoco.com



@thegeographypin

studiomuti.co.za/

»A good schematic map requires a lot of work by a graphic artist.«

Avelar, S. (2002)

› **Avelar, S.** (2002). Schematic maps on demand: Design, modeling and visualization [ETH Zurich]

2– Objectives

Main research objective

Create a prototype of an interactive, web-based map schematization tool.

Main research objective

Create a prototype of an interactive, web-based map schematization tool.

Sub-objectives

Ⓐ

Define cartographic requirements for schematized thematic maps.

Ⓑ

Define software requirements for a web-based schematization tool.

Ⓒ

Compare algorithms and approaches for schematization.

Ⓓ

Implement a suitable algorithm into a web-based **prototype**.

3– Results

Research question Ⓐ

What are **best practices** for **designing** the **geographic layer of thematic maps** and how are they **compatible** with the properties of **schematized maps?**

Method literature review

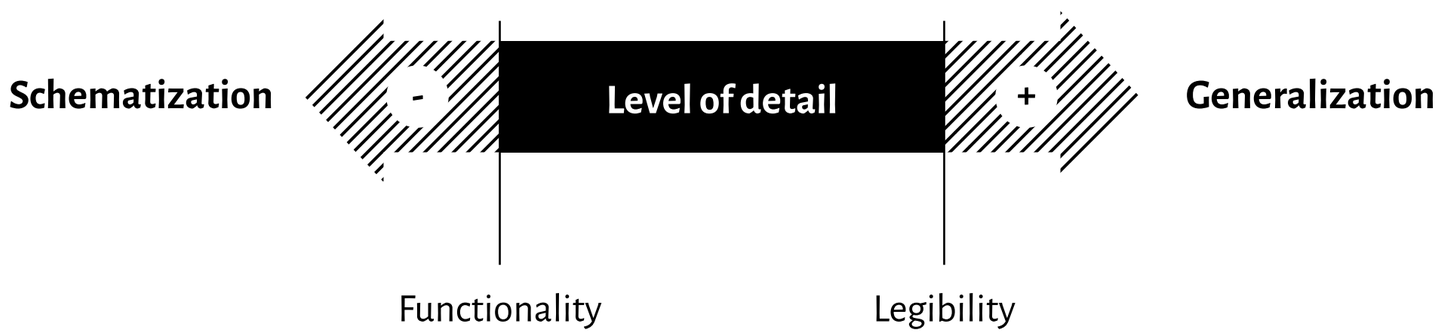
Defining schematization

"... a process that uses cartographic generalisation operators in such a way as to produce maps of a lower graphical complexity compared to maps of the same scale;"

› **Mackaness, W., & Reimer, A.** (2014). Generalisation in the Context of Schematised Maps. In D. Burghardt, C. Duchêne, & W. Mackaness (Eds.), Abstracting Geographic Information in a Data Rich World: Methodologies and Applications of Map Generalisation (pp. 299–328). Springer International Publishing. https://doi.org/10.1007/978-3-319-00203-3_10

Defining schematization

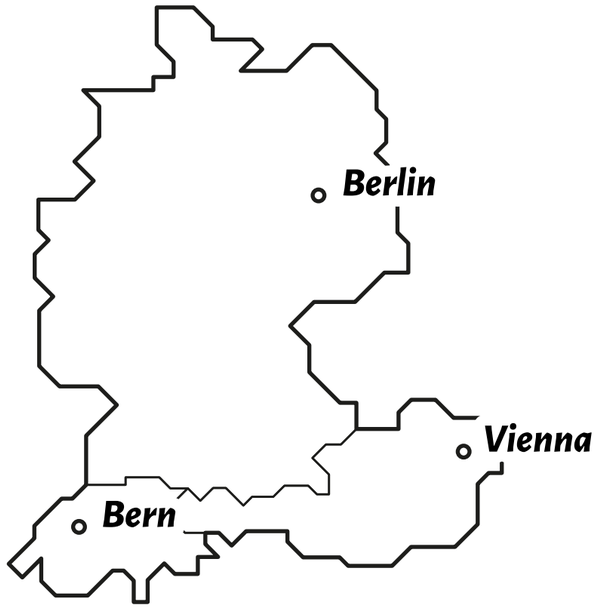
schematization and generalization are driven and bound by diverging itentions



› **Meulemans, W.** (2014). Similarity measures and algorithms for cartographic schematization [Technische Universiteit Eindhoven].

Properties of schematized maps

- low visual complexity
- simple geometric shapes
- preservation of geographic relations
- geometric shapes match the reader's mental picture



› **Meulemans, W.** (2014). Similarity measures and algorithms for cartographic schematization [Technische Universiteit Eindhoven].

Thematic maps and legibility

—implement a visual hierarchy based on an intellectual hierarchy of map elements

—contrast as mean to establish such a hierarchy

—geographic layer sets the stage for the thematic overlay

—formalized by Bertin (1967) as 3 rules of legibility

› **Bertin, J.** (2011). Semiology of graphics: Diagrams, networks, maps (W. J. Berg, Trans.). ESRI Press.

› **Dent, B. D., Torguson, J., & Hodler, T. W.** (2009). Cartography: Thematic map design (6th ed). McGraw-Hill Higher Education.

› **Imhof, E. (1972). Thematische Kartographie (1st edition). de Gruyter.**

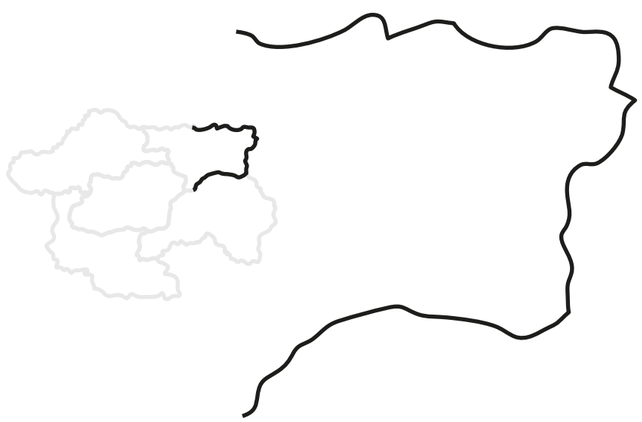
› **Kraak, M. J., & Ormeling, F.** (2010). Cartography: Visualization of geospatial data (3rd ed). Prentice Hall.

› **Slocum, T. A., McMaster, R. B., Kessler, F. C., & Howard, H. H.** (2008). Thematic Cartography and Geovisualization, 3rd Edition (3rd edition). Pearson.

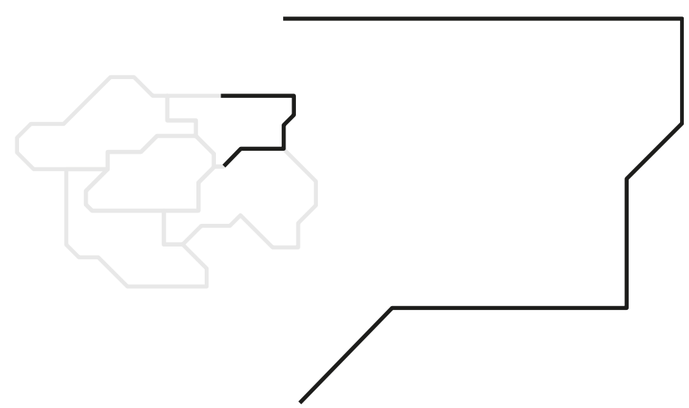
› **Tyner, J. A.** (2010). Principles of map design. Guilford Press.

Legibility regarding the base layer

—greater angles, enclosed by longer edges
—less detail, less focus

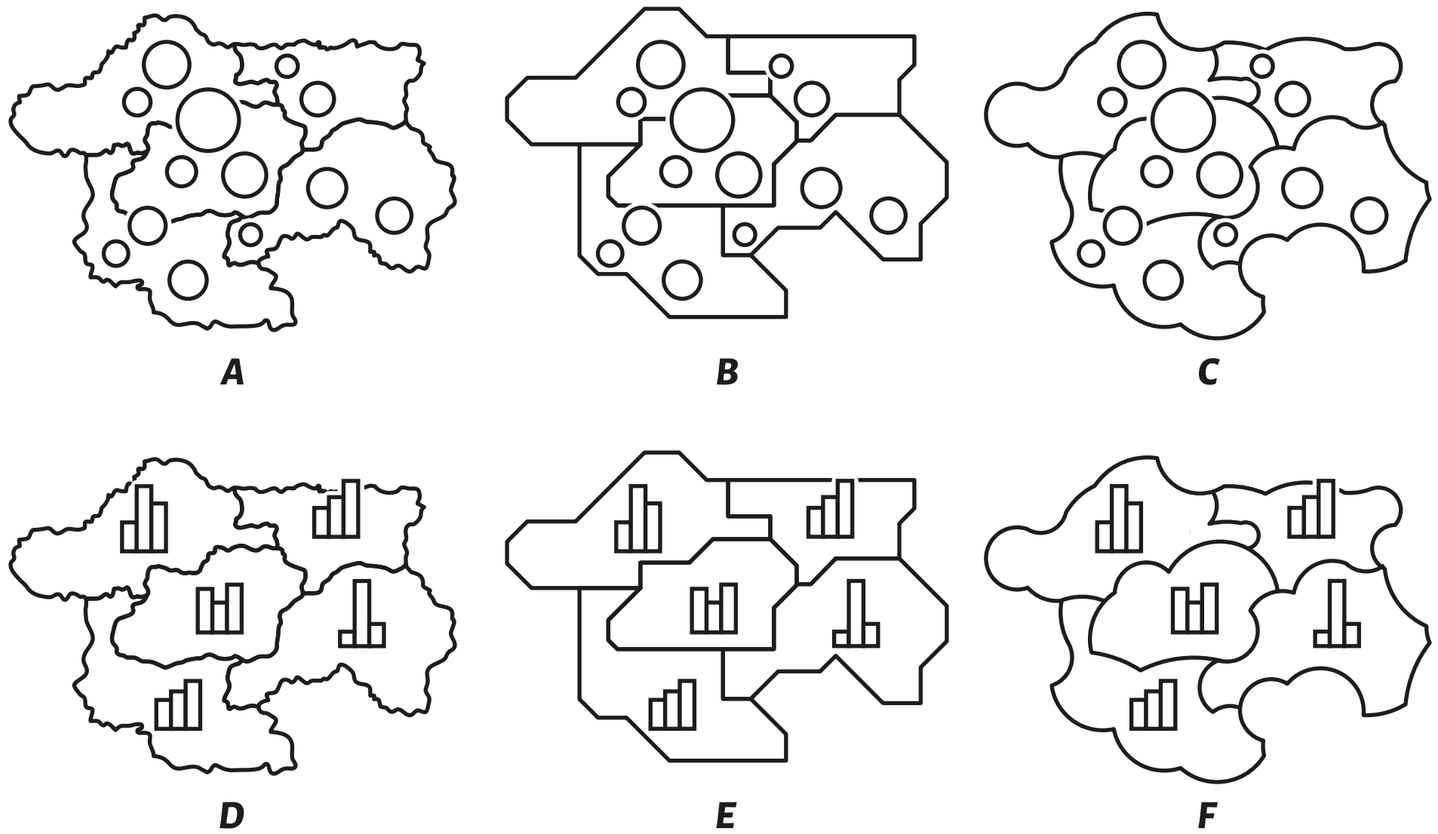


A



B

Base and thematic layer



Research question Ⓐ

What are **best practices** for **designing** the **geographic layer of thematic maps** and how are they **compatible** with the properties of **schematized maps?**

High contrasts in angles, density, and level of detail increase map legibility.

Schematization promotes them.

Yet, schematization on its own cannot guarantee such contrasts.

Research question Ⓒ

Which **types of automated schematization** exist and what are their cartographic *(visual)* and technical *(software)* characteristics?

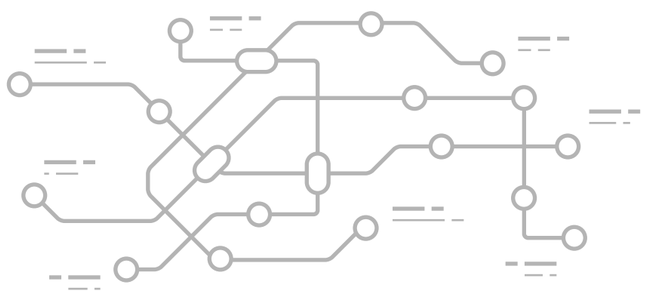
Method literature review

Methodology ©

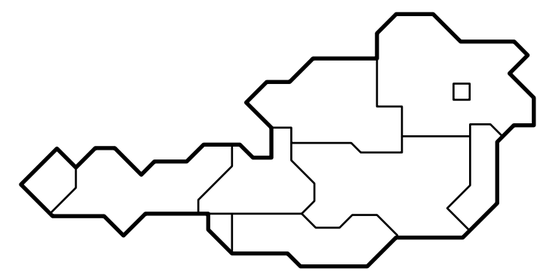
- systematic comparison based on literature review
  - geometric properties
  - computational complexity

Schematization types

—by input geometry



network

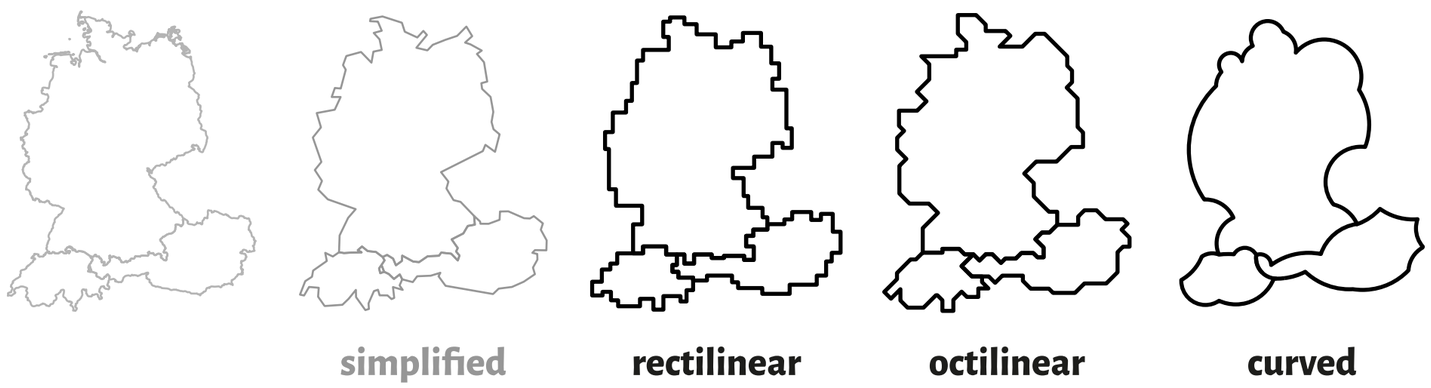


region

› **Meulemans, W.** (2014). Similarity measures and algorithms for cartographic schematization [Technische Universiteit Eindhoven].

Schematization types

—by style, the visual appearance
—depends on geometric properties

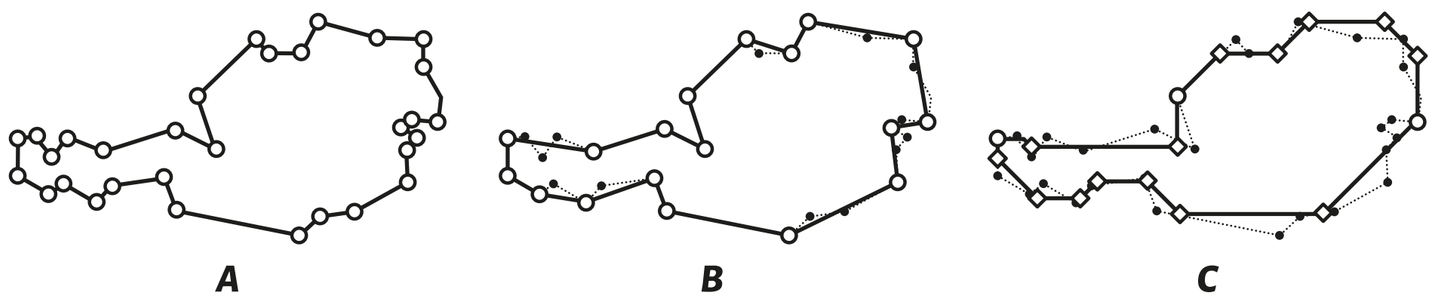


› **Meulemans, W.** (2014). Similarity measures and algorithms for cartographic schematization [Technische Universiteit Eindhoven].

Geometric schematization properties

—vertex restriction

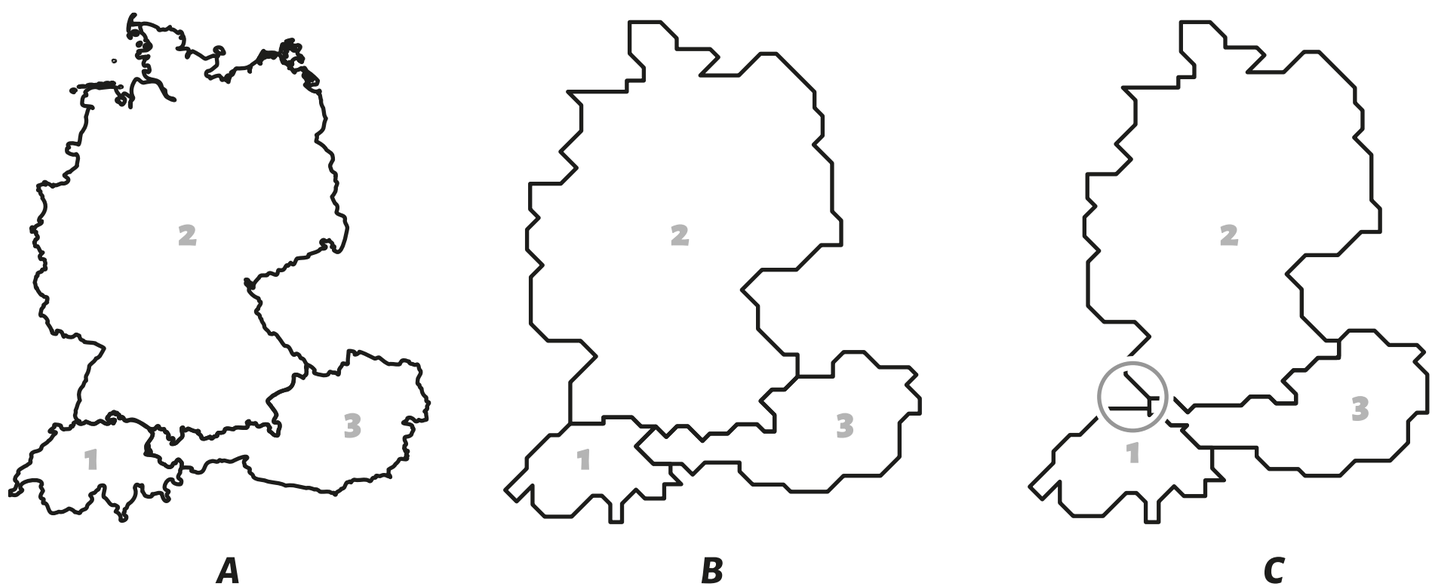
—flexibility vs. complexity



› **Meulemans, W.** (2014). Similarity measures and algorithms for cartographic schematization [Technische Universiteit Eindhoven].

Geometric schematization properties

—topologically safe by preserving face-to-face adjacencies
—required for cartographic purposes

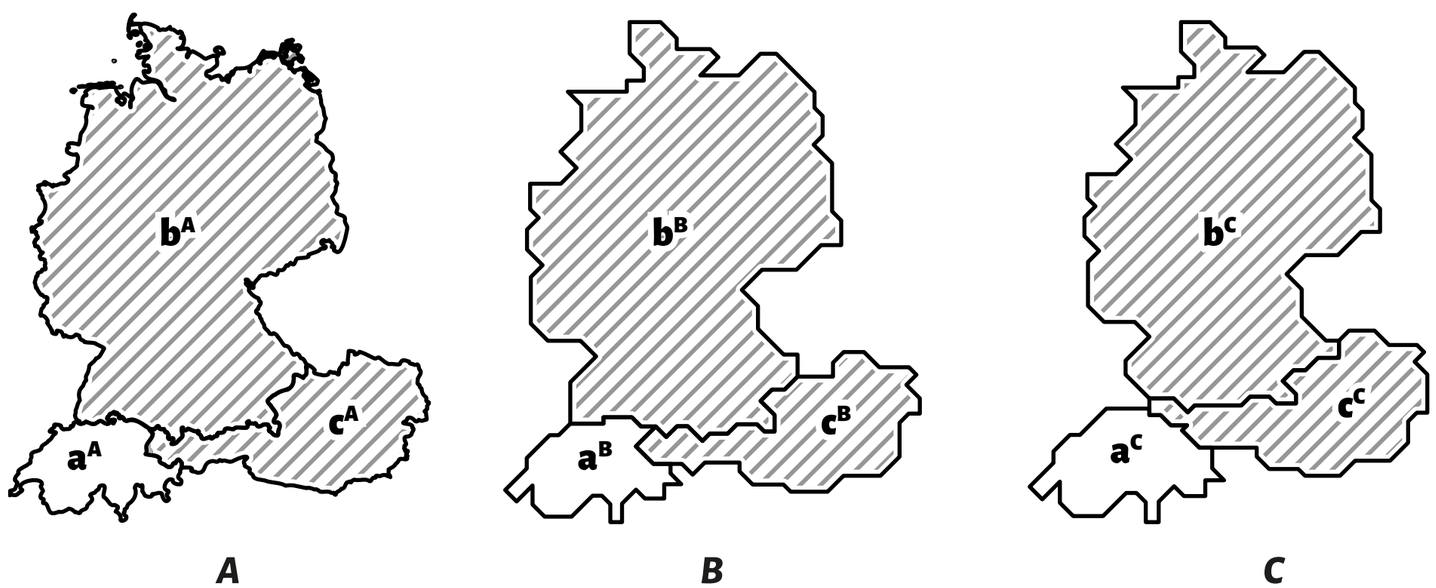


› **Meulemans, W.** (2014). Similarity measures and algorithms for cartographic schematization [Technische Universiteit Eindhoven].

Geometric schematization properties

—area preserving: $b^A:c^A = b^B:c^B$, but $b^A:c^A <> b^C:c^C$

—relevant in the context of area preserving projections



› **Meulemans, W.** (2014). Similarity measures and algorithms for cartographic schematization [Technische Universiteit Eindhoven].

Examined approaches

Author(s)	Year	Style	A	T	V	Complexity
Meulemans et al.	2021	C-Oriented	-	+	-	p, $O(n^2 + m\ n)$
Buchin et al.	2016	C-Oriented	+	+	-	p, $O(n^2)$
Meulemans	2016	C-Oriented	+	+	-	np-complete
Meulemans	2016	C-Oriented	+	+	-	np-complete
van Goethem et al.	2015	Arcs	+	+	-	p, $O(n^2)$
van Dijk et al.	2014	Arcs	-	+	-	p, $O(n^2\ h \log n)$
van Goethem et al.	2013	Arcs, Bezier Curves	+	+	+	p, $O(n^3\ k)$
Cicerone and Cermignani	2012	C-Oriented	-	-	-	p, $O(m\ n^2 \log)$
Reimer and Meulemanns	2011	Parallelism	-	-	-	np-hard
Meulemans et al.	2010	C-Oriented	+	+	-	p, $O(n^2)$
Heimlich and Held	2008	Circular Biarcs	-	+	-	p, $O(n \log n)$

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Buchin et al.	2016	C-Oriented	+	+	-	p, $O(n^2)$
Meulemans	2016	C-Oriented	+	+	-	np-complete
Meulemans	2016	C-Oriented	+	+	-	np-complete
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van Dijk et al.	2014	Arcs	-	+	-	p, $O(n^2 h \log n)$
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Cicerone and Cermignani	2012	C-Oriented	-	-	-	p, $O(m\ n^2 \log)$
Reimer and Meulemanns	2011	Parallelism	-	-	-	np-hard
Meulemans et al.	2010	C-Oriented	+	+	-	p, $O(n^2)$
Heimlich and Held	2008	Circular Biarcs	-	+	-	p, $O(n \log n)$

Research question Ⓒ

Which **types of automated schematization** exist and what are their cartographic *(visual)* and technical *(software)* characteristics?

Schematization algorithms generate various styles and exhibit various geometric properties.

Few preserve area and topology.

The *C*-oriented approach by Buchin et al. (2016) has low computional complexity but is flexible regarding output.

Research question Ⓑ

What are the **system** features, requirements, **quality attributes**, and possible other **requirements**?

Method requirement engineering

Methodology Ⓑ

— requirement engineering processes
  — elicitation → documentation, validation → verification

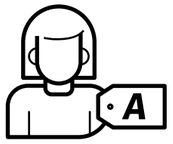
— different levels of requirement information
  — from general to specific
  — business → user → functional

› **Wiegers, K. E., & Beatty, J. (2013).** Software Requirements (3rd edition). Microsoft Press.

User types

—starting point for user scenario

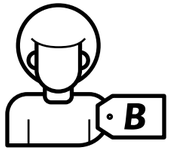
—basis for features and functional requirements



Cartographer

—GIS workflow

—spatial focus

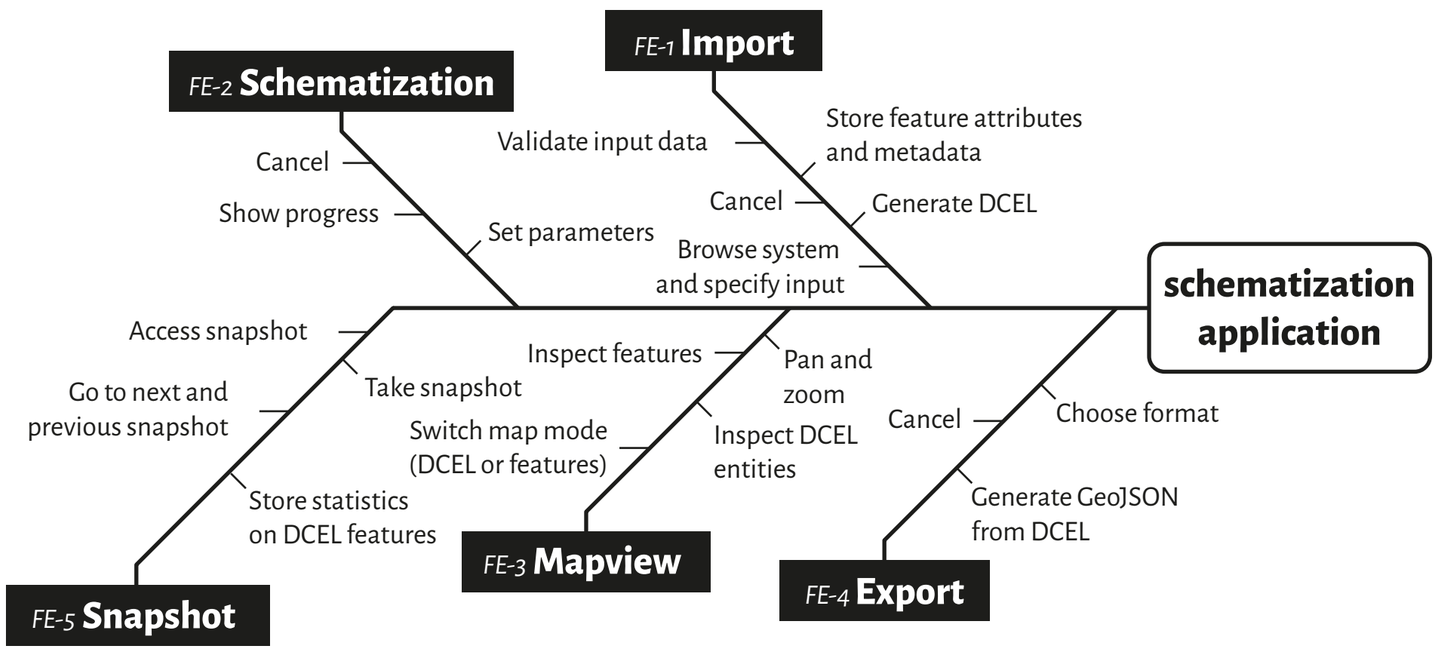


Information designer

—Graphic tools

—visual focus

Features


FE-1 Import
Validate input data
Store feature attributes and metadata
Cancel
Generate DCEL
Browse system and specify input
FE-2 Schematization
Cancel
Show progress
Set parameters
schematization application
FE-5 Snapshot
Access snapshot
Take snapshot
Go to next and previous snapshot
Store statistics on DCEL features
FE-3 Mapview
Inspect features
Pan and zoom
Switch map mode (DCEL or features)
Inspect DCEL entities
FE-4 Export
Cancel
Choose format
Generate GeoJSON from DCEL

Functional requirements

Functional requirements

02-a	**03-a**	04-a	05-a	06-a	07-a
08-a	09-a	10-a	11-a	17-a	22-a
01-b	02-b	11-b	12-b	13-b	14-b
15-b	16-b	18-b	19-b	20-b	21-b
23-b	24-b	25-b	28-b	29-rc	26-rc
27-rc	30-rc	31-rc			

If the input data is not a region (geometry type "polygon" or "multipolygon") the program shall exit and inform the user on valid input data types.

Research question Ⓑ

What are the **system** features, (**data** requirements), **external interface** requirements, **quality attributes**, and possible other **requirements**?

The system shall validate the input data's geometry and handle projections.

The user interface shall offer meaningful feedback and allow an efficient schematization setup.

Research question Ⓓ

To which extent does the **prototype** satisfy the specified **requirements**?

Method prototyping, requirement verification

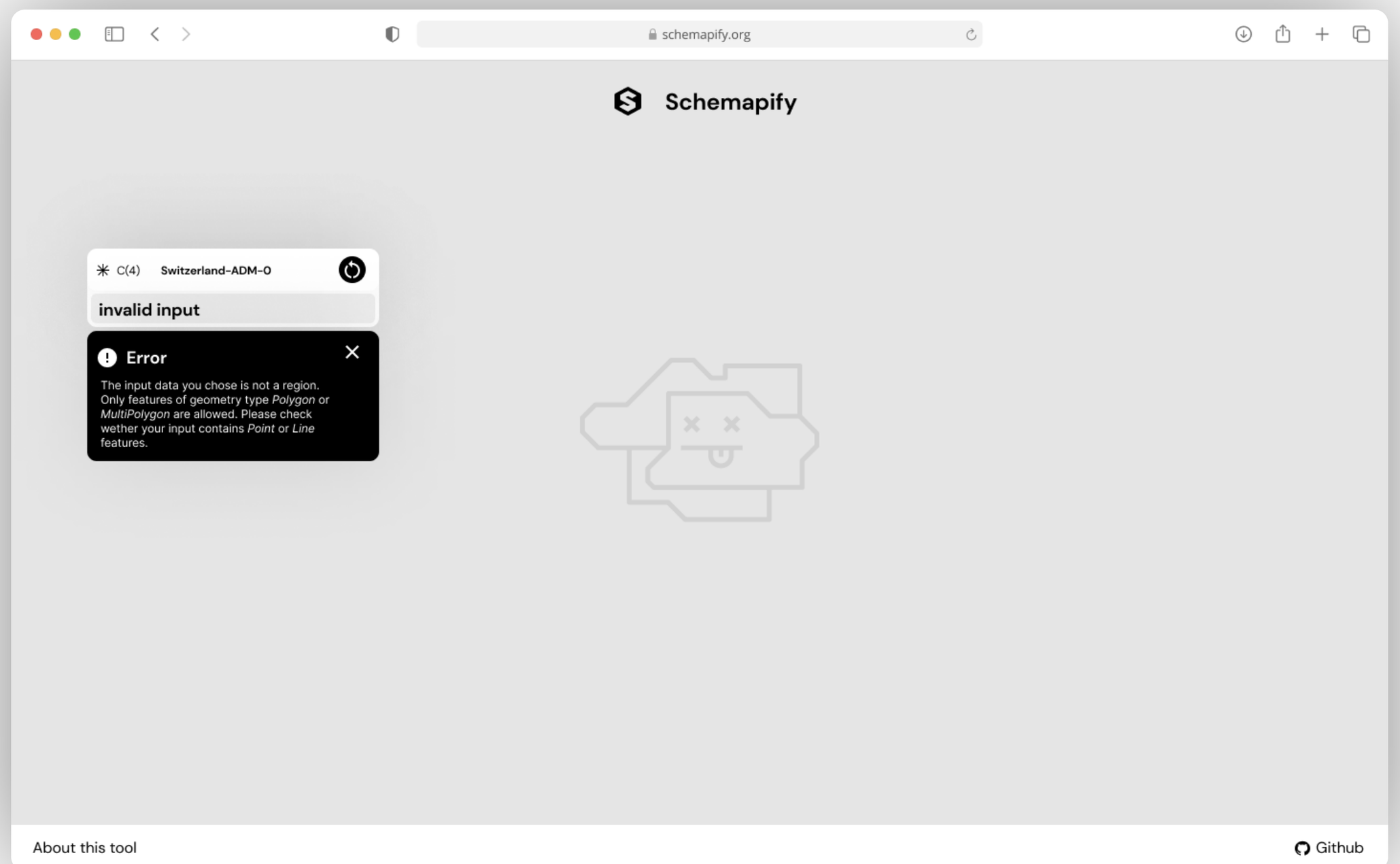
Methodology Ⓓ

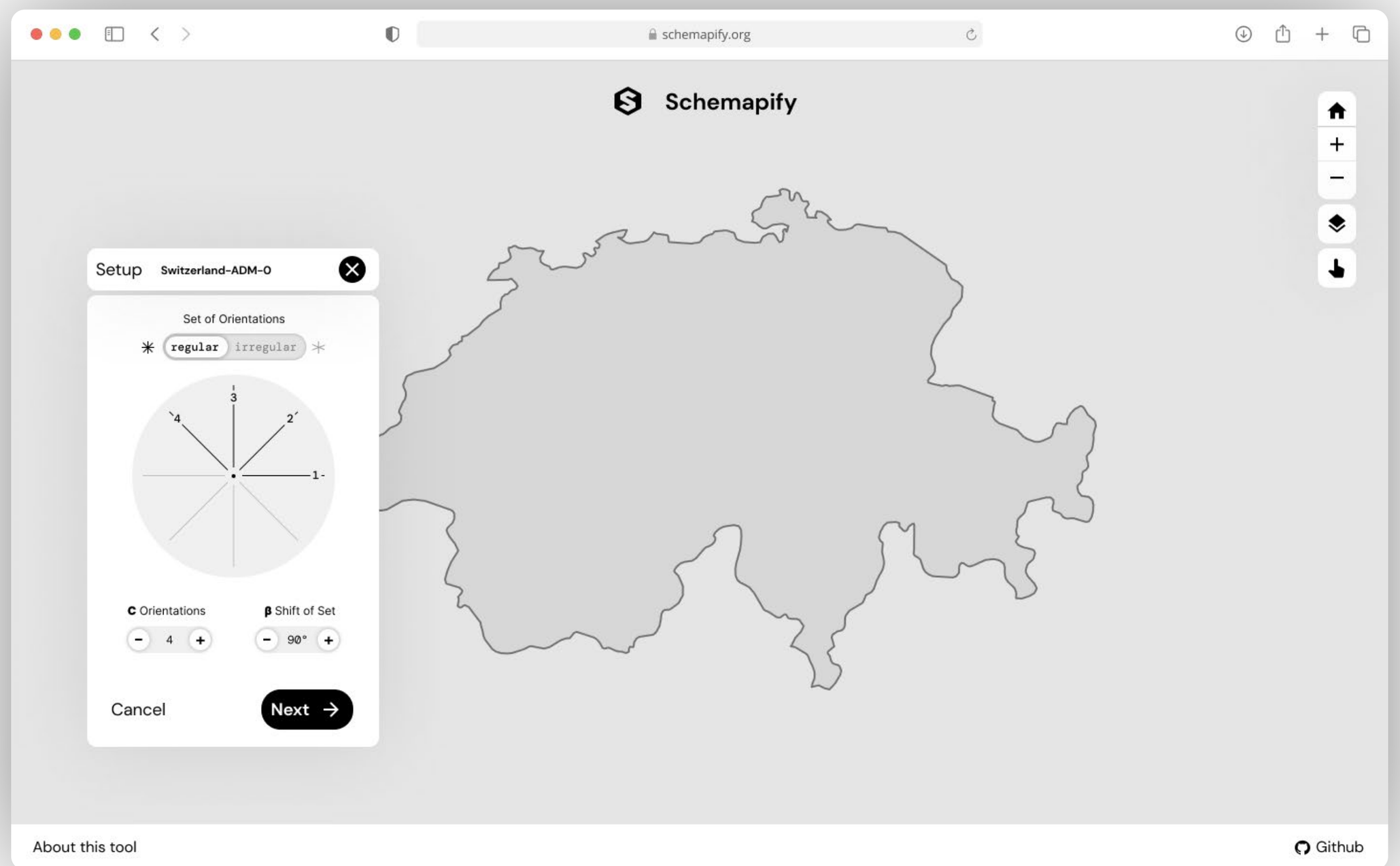
Prototyping

- mock-up prototype → horizontal
- proof-of-concept prototype → vertical

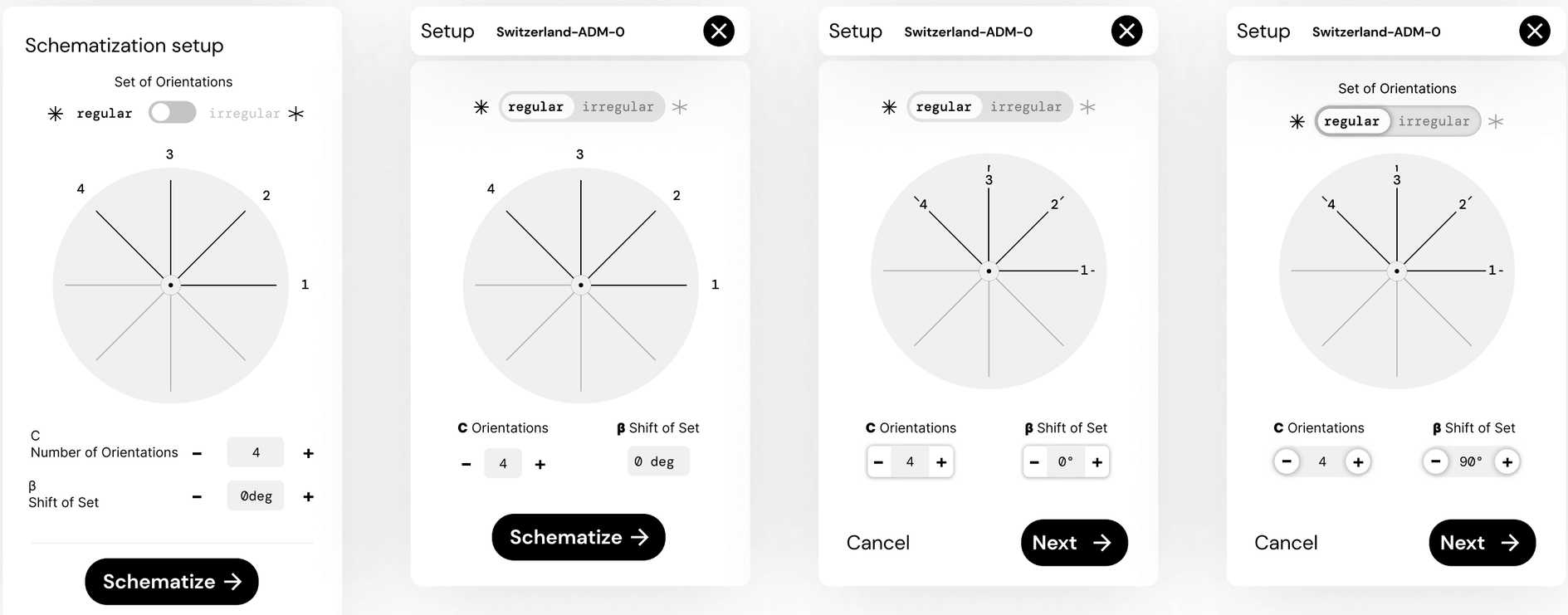
Verification

- automated and manual verification methods
- combination of automated unit tests and manual tests
- test protocol


schemapify.org
Schemapify
C(4)
Switzerland-ADM-0
invalid input
Error
The input data you chose is not a region. Only features of geometry type *Polygon* or *MultiPolygon* are allowed. Please check wether your input contains *Point* or *Line* features.
About this tool
Github

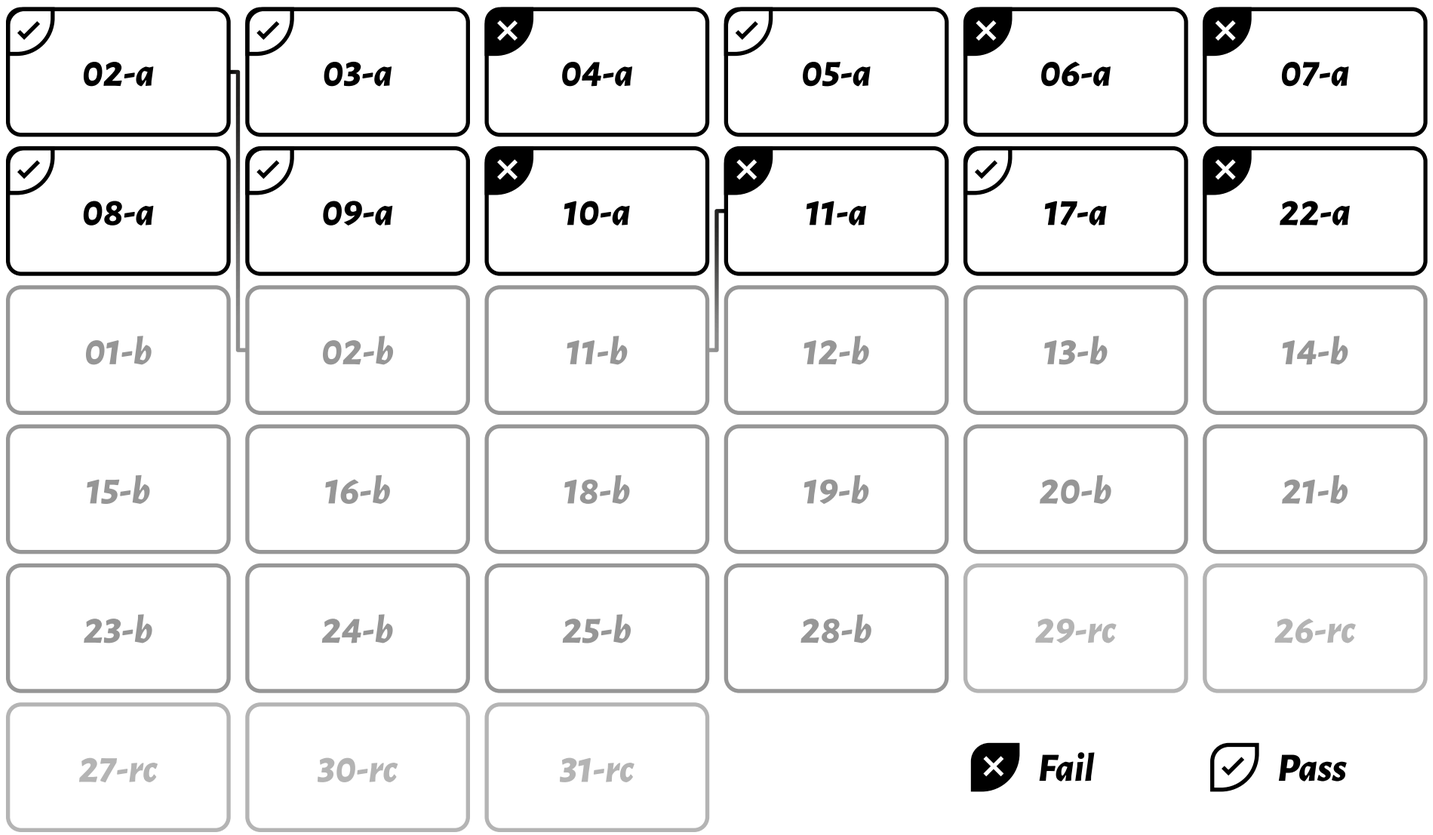

schemapify.org
Schemapify
Setup
Switzerland-ADM-0
Set of Orientations
regular
irregular
3
2
1
4
C Orientations
4
β Shift of Set
90°
Cancel
Next
About this tool
Github

Design iterations



Demo Time!

Verification results



Research question Ⓓ

To which extent does the **prototype** satisfy the specified **requirements**?

Met 6 out of 12 requirements for alpha release.

Important system capabilities need to be implemented for further verification.

Focus on graphical user interface and user feedback.

4– Conclusion

Main research objective

Create a prototype of an interactive, web-based map schematization tool.

—such a tool is feasible

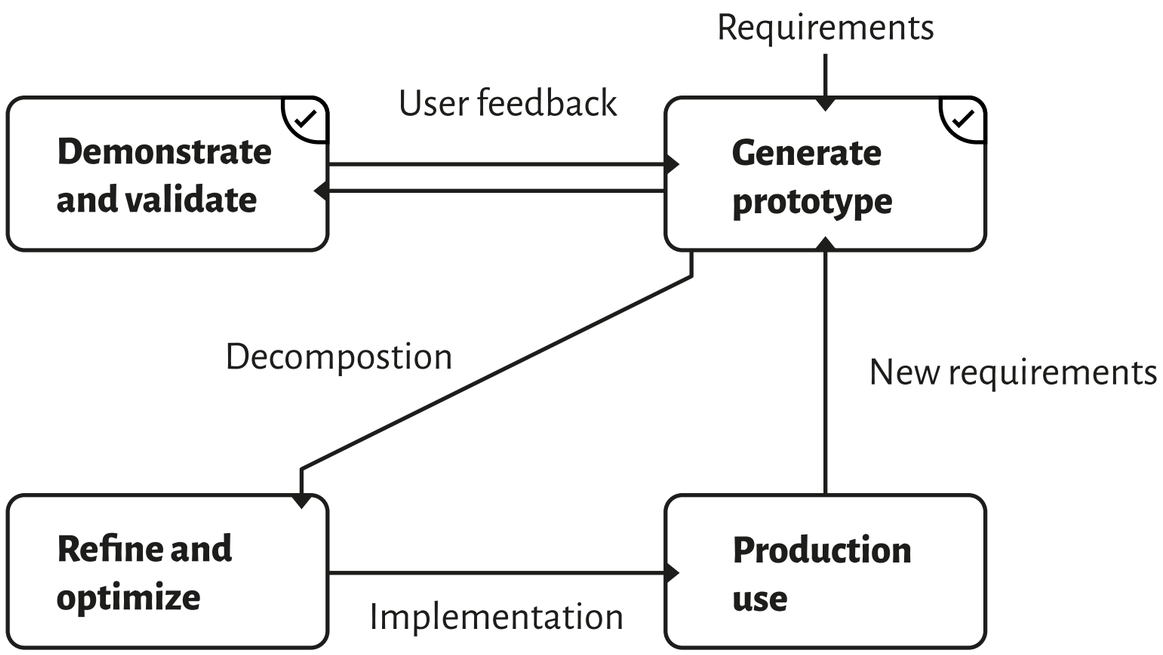
—computational time constraints decreased performance

— the tool's robustness needs further attention

Iterative process

—prototyping implies iterations

—thesis groundwork for such a process



5– Outlook

*»A good schematic map requires a ~~lot~~ **bit** of work by ~~a graphic artist~~ **anyone**.«*

Listabarth, J. (20??)

Future research

—Ⓐ schematize point features and in 3D space

—Ⓑ compare algorithmic implementations instead of literature-based comparison

—Ⓒ meaningful level of detail for input

—Ⓒ interfaces for integration into cartographic workflows

—Ⓓ examine the use of preview subsets

—Ⓓ suggest default values depending on input

—Ⓒ conduct suggested user study to validate requirements

—Ⓓ refine requirements

—Ⓓ implement simplification algorithm

References

- **Avelar, S.** (2002). Schematic maps on demand: Design, modeling and visualization (p. 130) [ETH Zurich; Application/pdf].
- **Bertin, J.** (2011). Semiology of graphics: Diagrams, networks, maps (W. J. Berg, Trans.). ESRI Press.
- **Buchin, K., Meulemans, W., Renssen, A. V., & Speckmann, B.** (2016). Area-Preserving Simplification and Schematization of Polygonal Subdivisions. ACM Transactions on Spatial Algorithms and Systems, 2(1), 1–36.
- **Dent, B. D., Torguson, J., & Hodler, T. W.** (2009). Cartography: Thematic map design (6th ed). McGraw-Hill Higher Education.
- **Imhof, E. (1972).** Thematische Kartographie (1st edition). de Gruyter.
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- **Tyner, J. A.** (2010). Principles of map design. Guilford Press.
- **Wiegers, K. E., & Beatty, J.** (2013). Software Requirements (3rd edition). Microsoft Press.

Questions?

Thank you for your time.

Happy to hear your thoughts,
ideas and suggestions. 🙂✨

UNIVERSITY OF TWENTE.

ITC

TECHNISCHE UNIVERSITÄT DRESDEN

Technical University of Munich

TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

Appendix

Links

Github

—www.figma.com/proto/TM2xmAQqVaF9K8P8EKFq7Q/Schemapify?scaling=contain

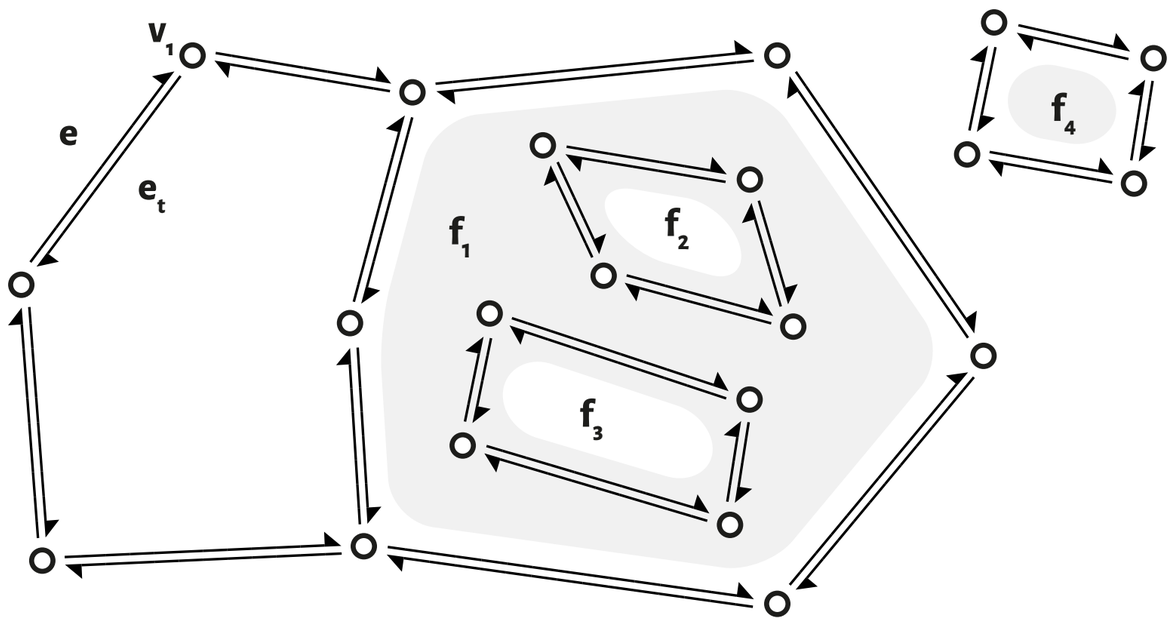
Mock-up prototype (figma)

—schemapify-demo.netlify.app/

Proof-of-concept prototpye

—github.com/jakoblistabarth/area-preserving-polygon-schematization

Doubly connected edge list (DCEL)



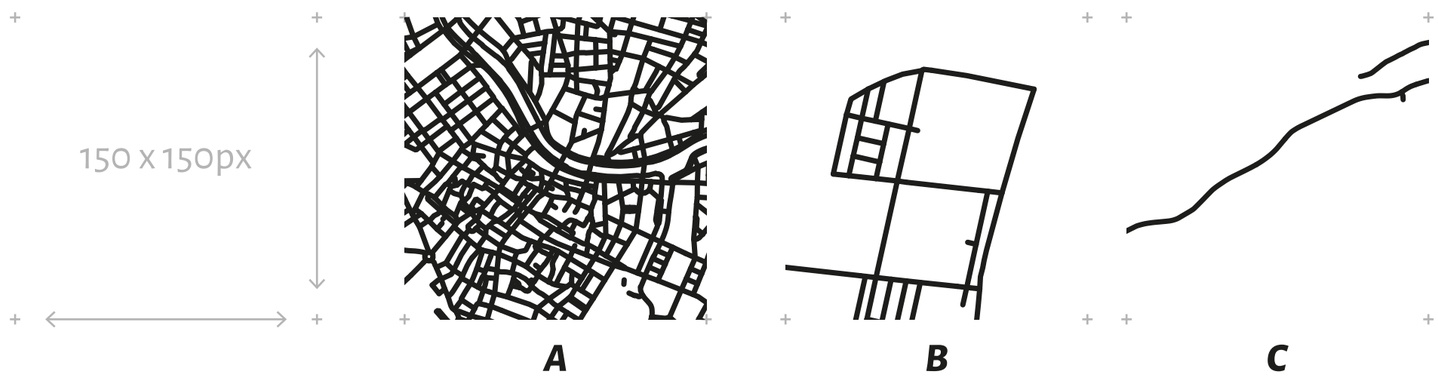
Results requirement verification

ID	Requirement	Met
2-a	The system shall be able to parse geoJSON as input data.	yes
3-a	If the input data is not a region (geometry type “polygon” or “multipolygon”) the program shall exit and inform the user on valid input data types.	yes
4-a	If the input data is not a valid geoJSON the program shall exit and the user shall be informed.	no
5-a	If the input data is too detailed, i.e., if it exceeds a maximum number of edges or vertices, the program shall exit and the user shall be informed.	yes
6-a	The system shall preserve potential attributes attached to the inputs features in the output.	no
7-a	The system shall preserve the number of features of the input in the output.	no
8-a	The system shall be able to generate a DCEL from a geoJSON.	yes
9-a	The system shall be able to generate a geoJSON from a DCEL.	yes
10-a	While the data is being processed, the user shall be informed that the application is processing.	no
11-a	The user shall be able to specify a regular set of directions (without beta-shift) of the schematization.	no
17-a	The system shall display the schematized region in the map view after the schematization is finished.	yes
22-a	The user shall be able to track the progress of the schematization.	no

Legibility and graphic density

—“an optimum number of marks per cm^2”

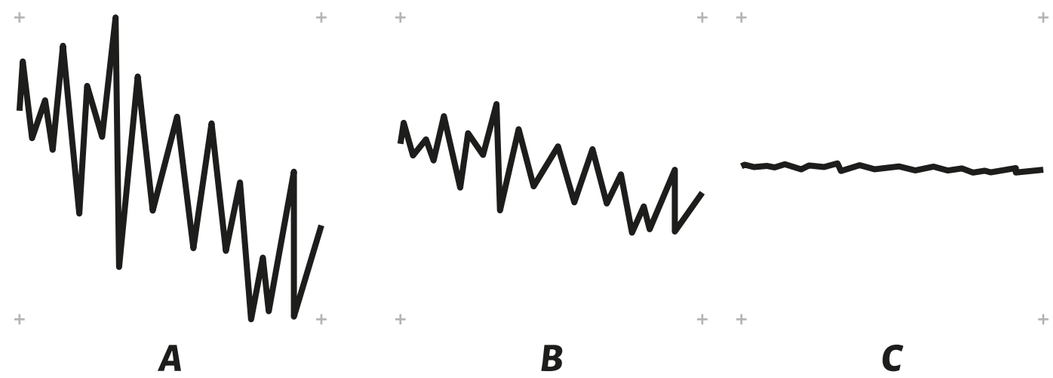
—graphic density as an factor of legibility



Legibility of angles

—angles close to 0° or 180° are less legible

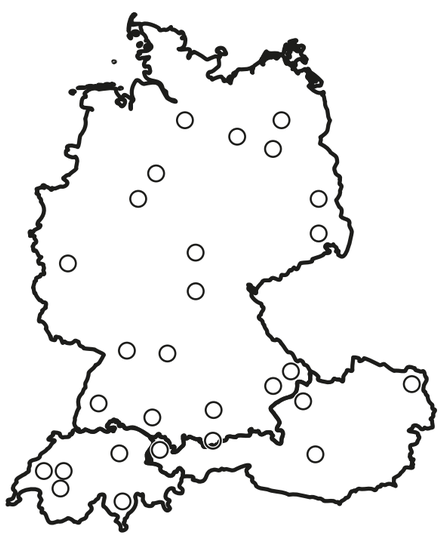
—angles enclosed by long edges are legible



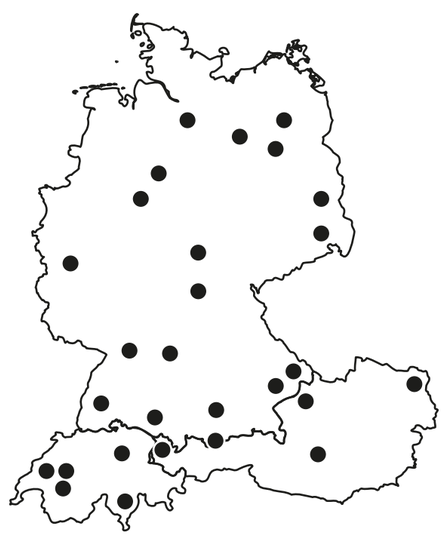
Legibility and retinal separation

—overall amount of ink

—ratio of ink for “the predictable” and “the unpredictable“



A



B