Universität Bremen

cognitivesystems

Defense of Doctoral Thesis

Schematisation in Hardcopy Tactile Orientation Maps

Christian Graf

Co-advised by

Prof. Christian Freksa, Ph.D   Prof. Nicholas A. Giudice, Ph.D

December 11, 2013
Rotunde, University of Bremen

Executive Summary

Results about the sensory quality of hardcopy tactile map

→ Recommendations for tactile map production with a tactile printer.

Less detailed information in a tactile orientation map could facilitate map understanding.

→ Simplification beyond technical nessicity

Finding positions in a tactile orientation map can be supported best by using indicators at the frame.

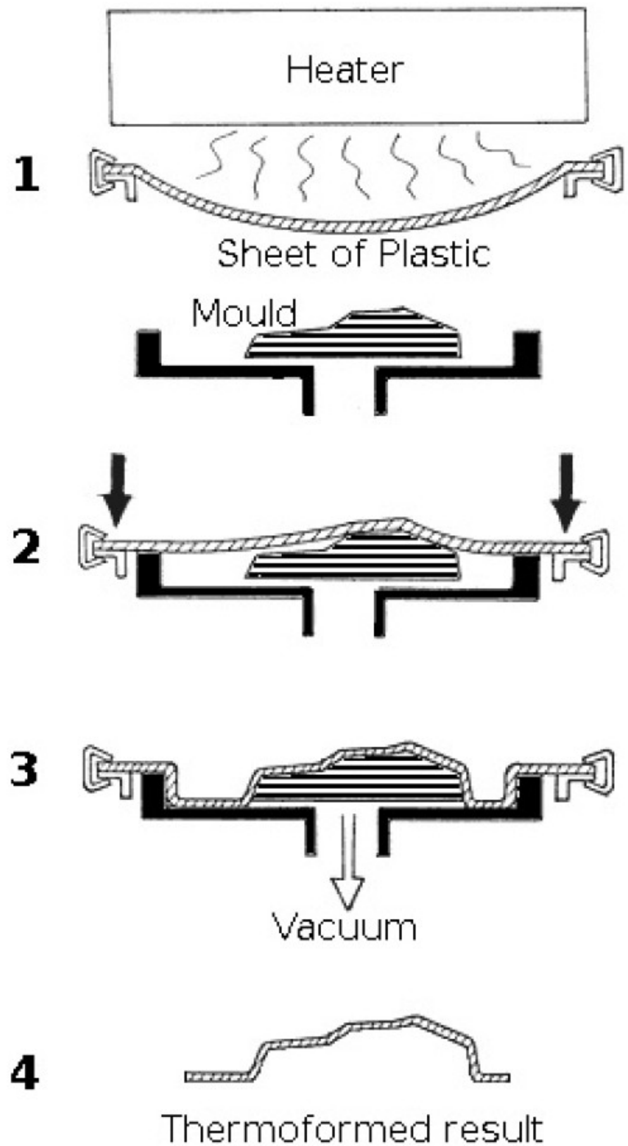
Structure

1. Introduction
2. Focus of Work
3. User Studies
4. Conclusions

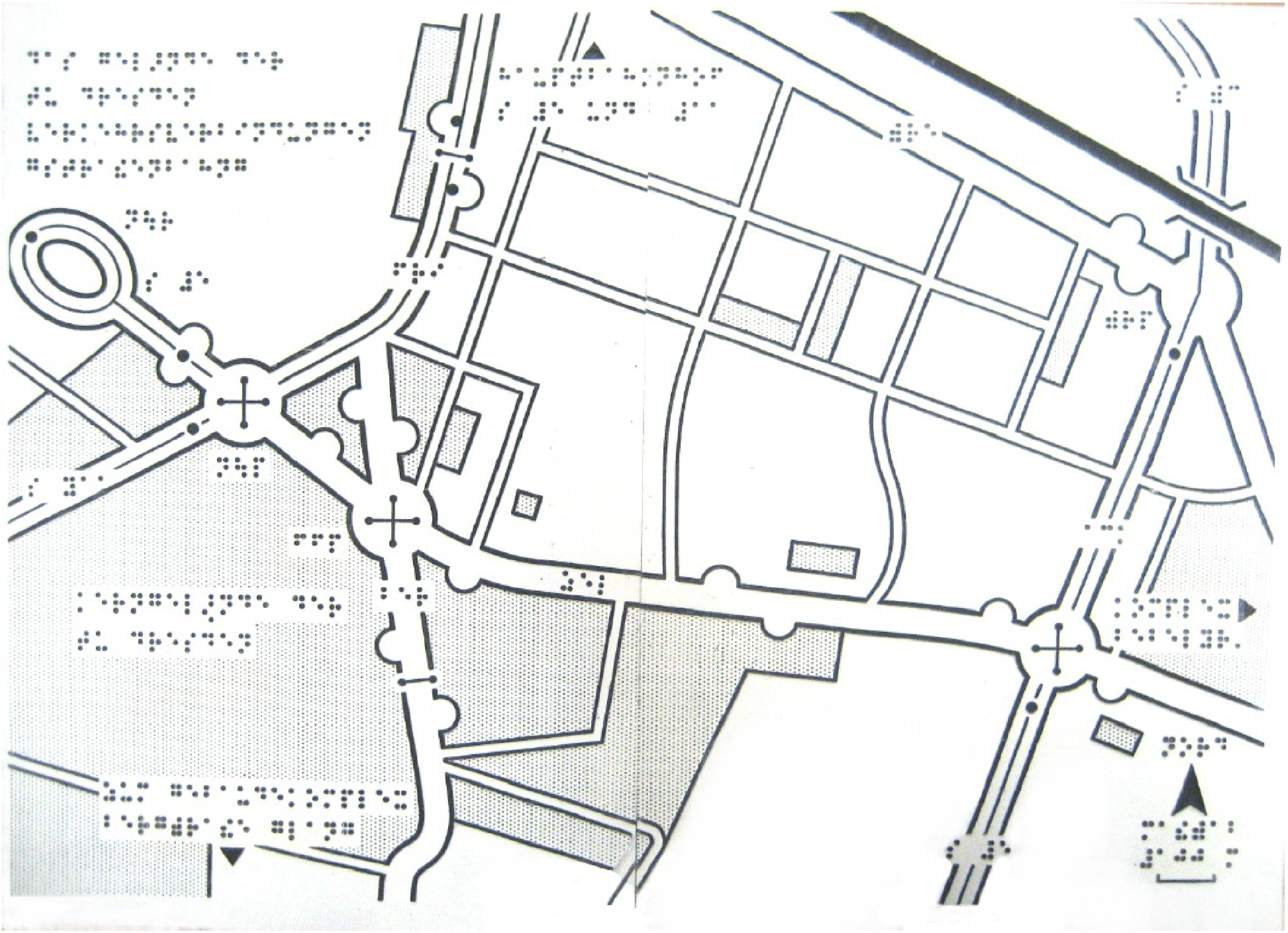
Introduction


STANDORT
SCHLACHT
HOF


NEW SOUTH WALES
Sydney
Canberra
VICTORIA
Tasmans
Straße
Tasmanien

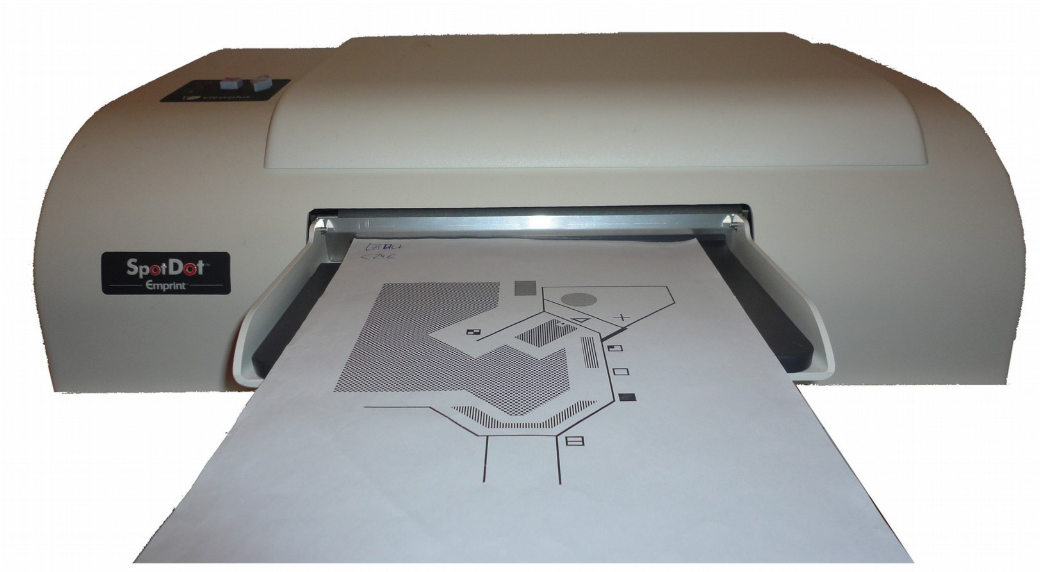

Heater
1
Sheet of Plastic
Mould
2
3
Vacuum
4
Thermoformed result

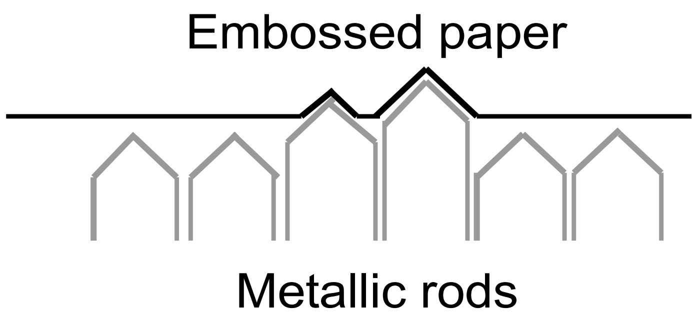
1 m

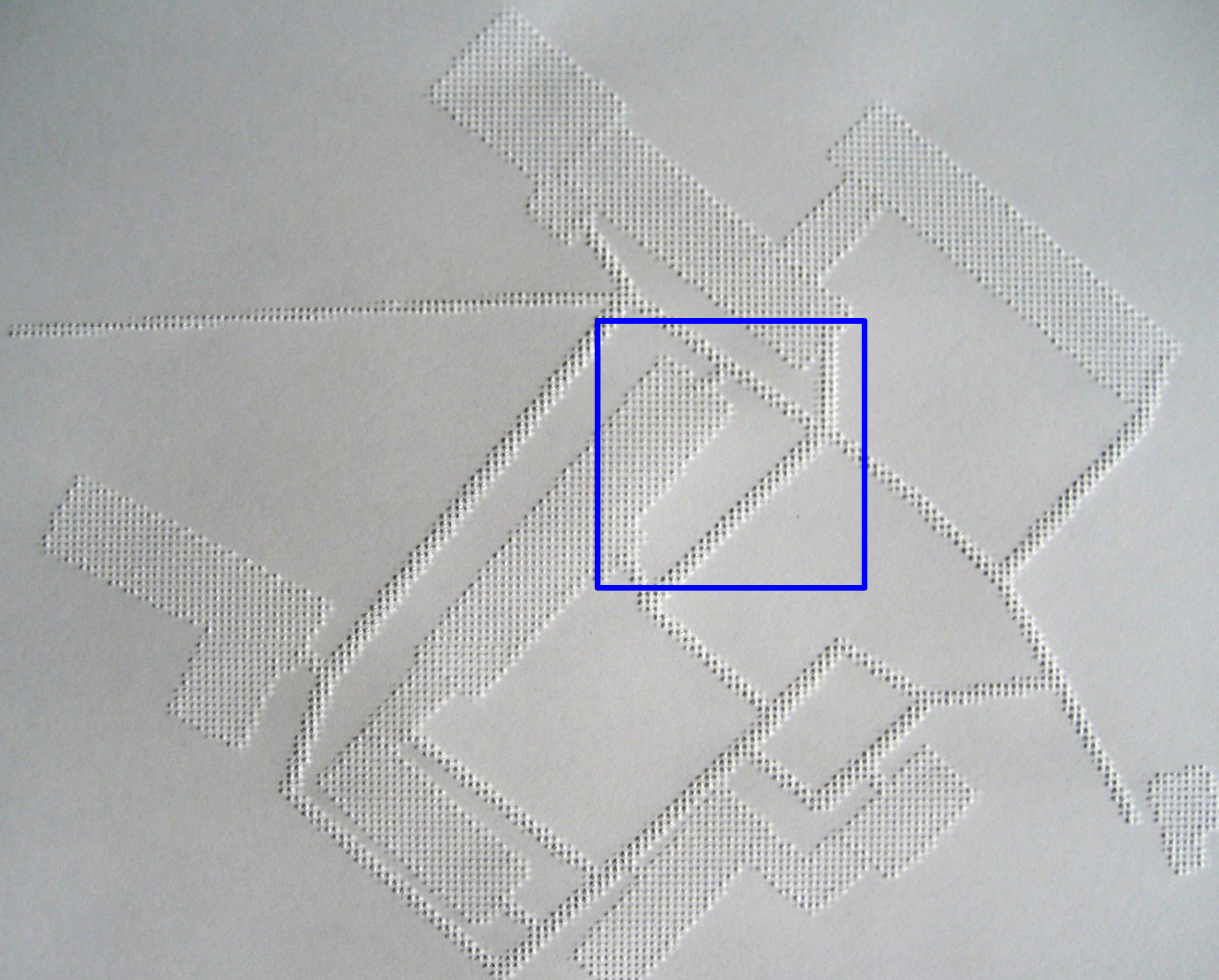


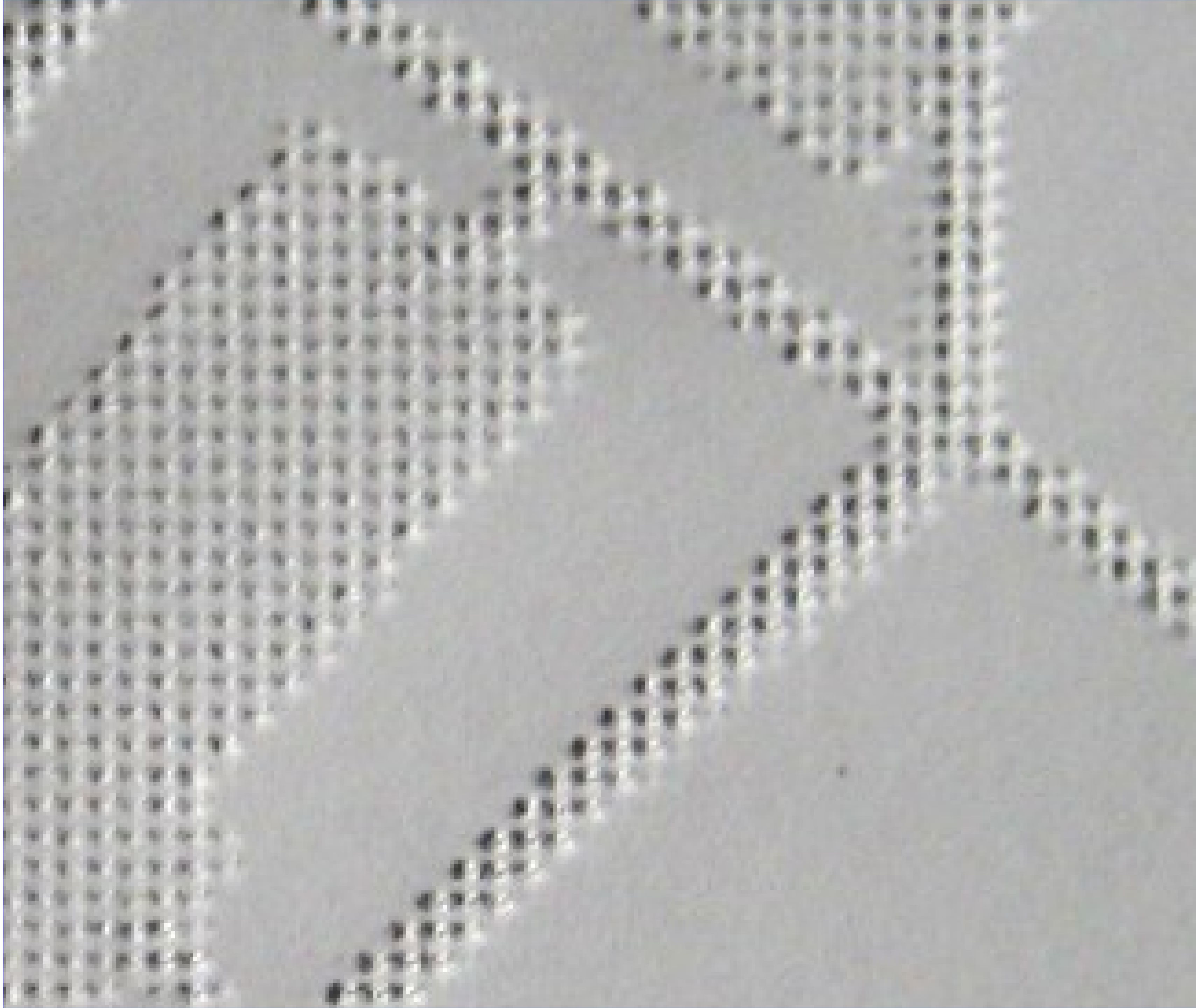

RICOH FUSER
MAIN
START

Tactile Printing aka Embossing



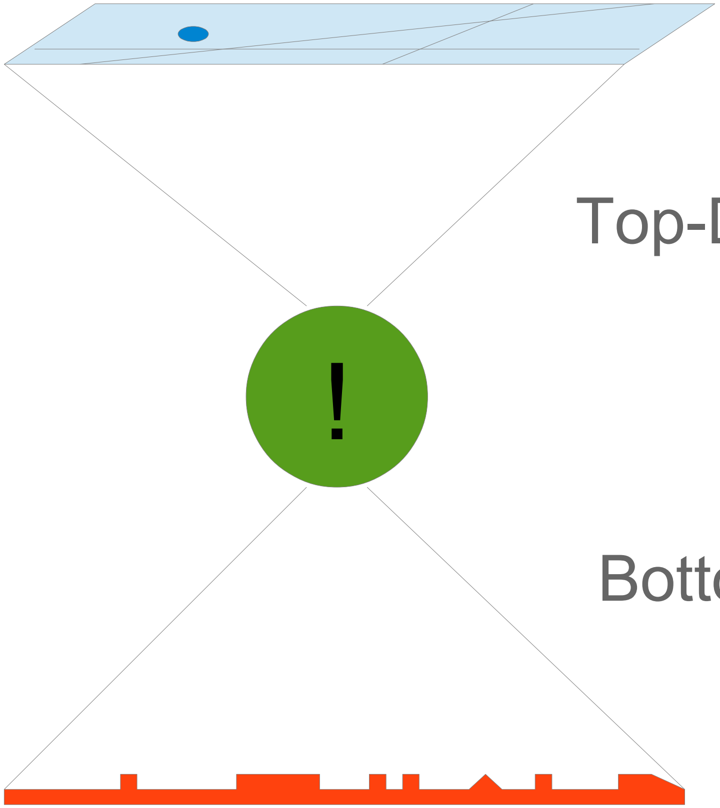






Problem

Tactile map-reading is a cognitive challenge



Visual map

Top-Down Process

Bottom-Up Process

Tactile map

Focus of Thesis

Goal

Understand the technology constraints in hardcopy tactile maps

Understand the sensory constraints in reading hardcopy tactile maps

Understand approaches to simplification in hardcopy tactile orientation maps

Find recommendations to ease reading of tactile orientation maps

Approach

Simplify by reducing the number of map objects → Abstraction

Simplify tactile maps beyond technical necessity → *Schematisation* (Klippel et al. 2005)

Abstraction is quantatitive, Schematisation is qualitative

Abstraction sets base level, Schematisation refines

Assumption: Schematisation holds advantages for tactile map-reading

Focus

Map-reading: the combination of behaviour (exploring the map with the fingertips) and cognitive processes (integration of the touch points) to extract knowledge (to some form of cognitive representation) from a tactile map

Tactile Orientation Map: a survey map as tactile artifact that shows some environment from a bird's eye perspective

Activities with schematised tactile maps:

- Survey mapping: Ex-situ map-reading
- (Self-)Localisation: Find certain positions

Potential of Schematisation in Maps

Previous work about visual maps

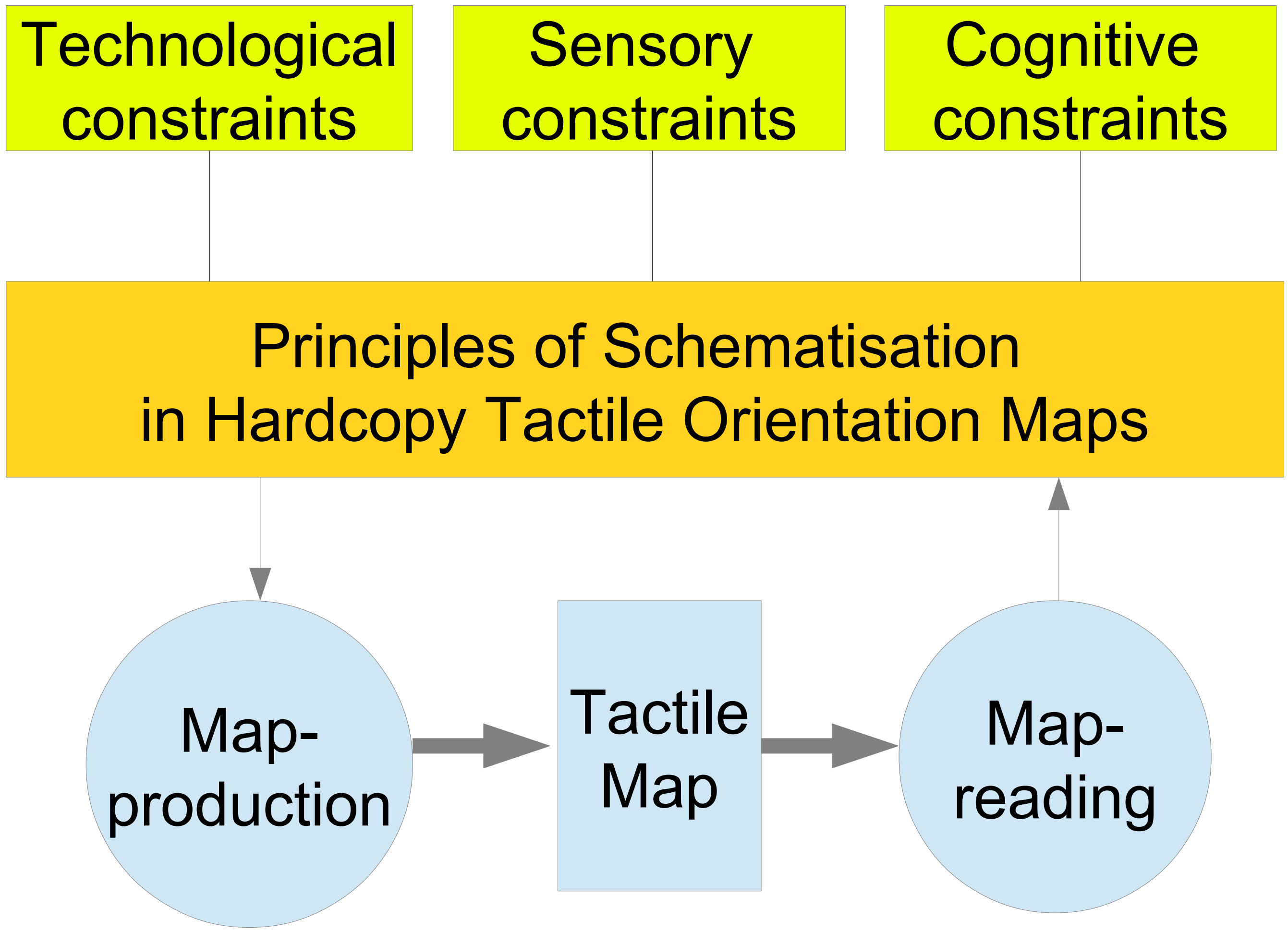
Name	Schematisation Concept
LineDrive	Shorten segments based on activity
Focus Map	Hide entities based on distance
μMaps	Show or hide entities based on prior knowledge
Route Aware Maps	Show alternatives
Route Aware Maps	Recess contextual information
YAH^{x}Maps	Show details based on succession & prior knowledge
YAH^{x}Maps	Show stable frame of reference
Halo & Wedges	Show off-screen POI
ZoneZoom	Use fixed grid to determine next zoom
Focus Line	Emphasise important entities

Source: Graf & Schmid (2010), Graf (2013)

Research Questions

1. Which schematisation pinciples used in the construction of a hardcopy tactile map ease the comprehension of the map?

2. In which ways do the principles of schematisation have to be customized to the production technology to result in a usable tactile map?


Technological constraints
Sensory constraints
Cognitive constraints
Principles of Schematisation
in Hardcopy Tactile Orientation Maps
Map-production
Tactile Map
Map-reading

User Studies
(a selection)

Schematisation Study: Schematisation Strategies for Better Map Understanding

Schematisation Study: Research Question

„Does schematisation contribute to the usability of a tactile orientation map?“

Usability of maps includes memorability and subjective satisfaction

Schematisation applied here:

- Shape of Segments
- Shape of Intersection

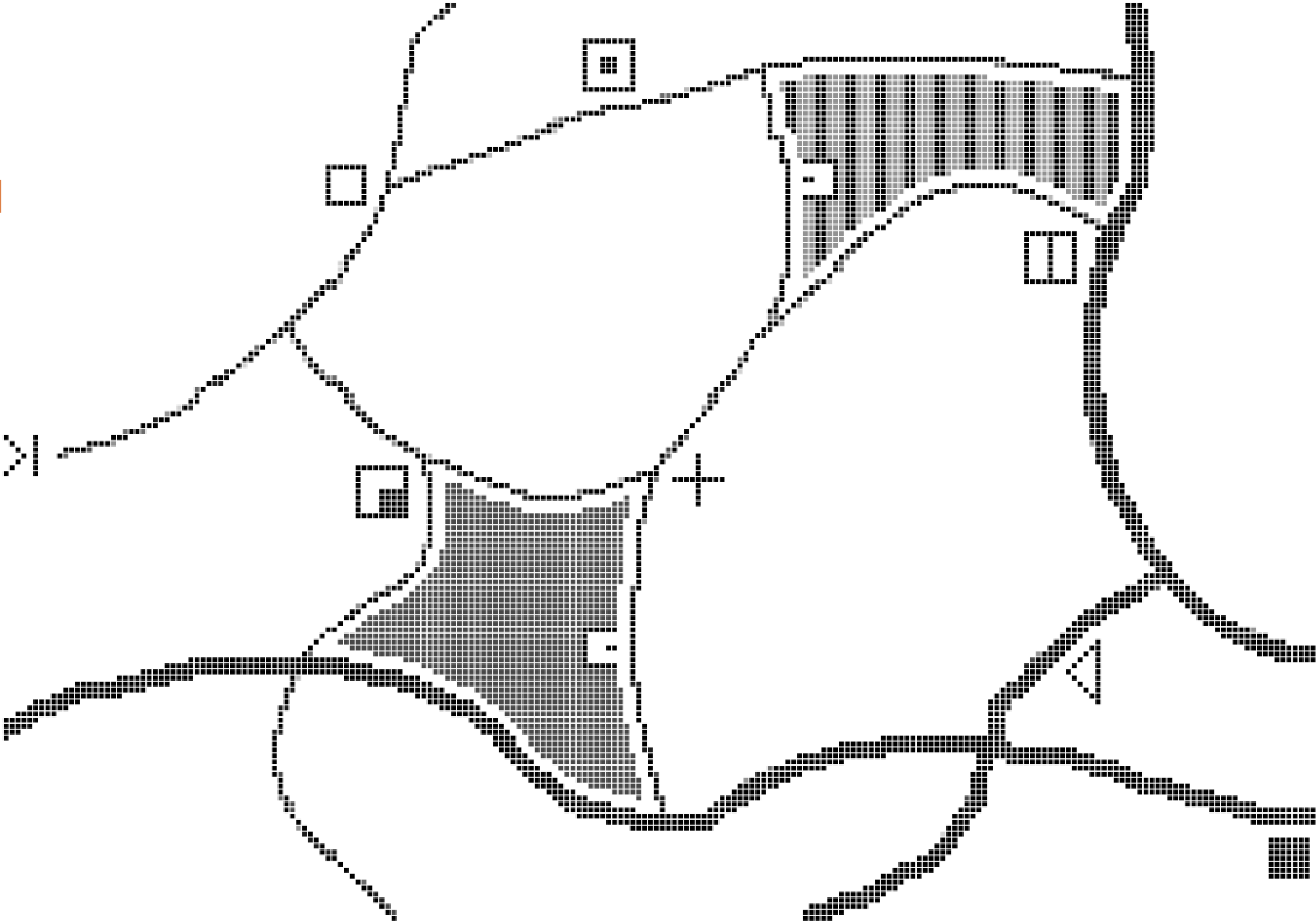
Schematisation Study: Methodology

3 conditions

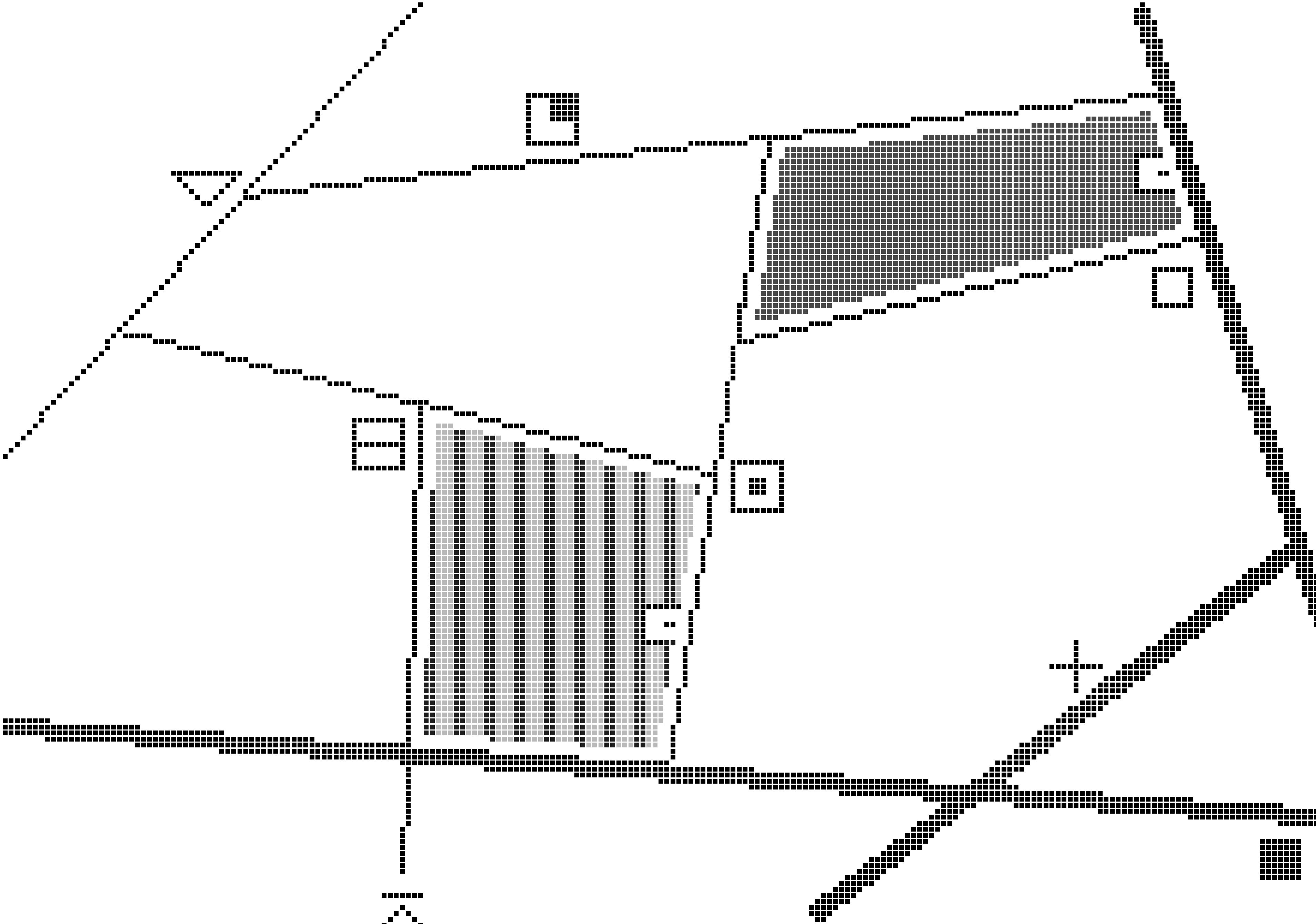
- „Non-abstract“
- „Low-abstract“
- „High-abstract“

Conditions differ in

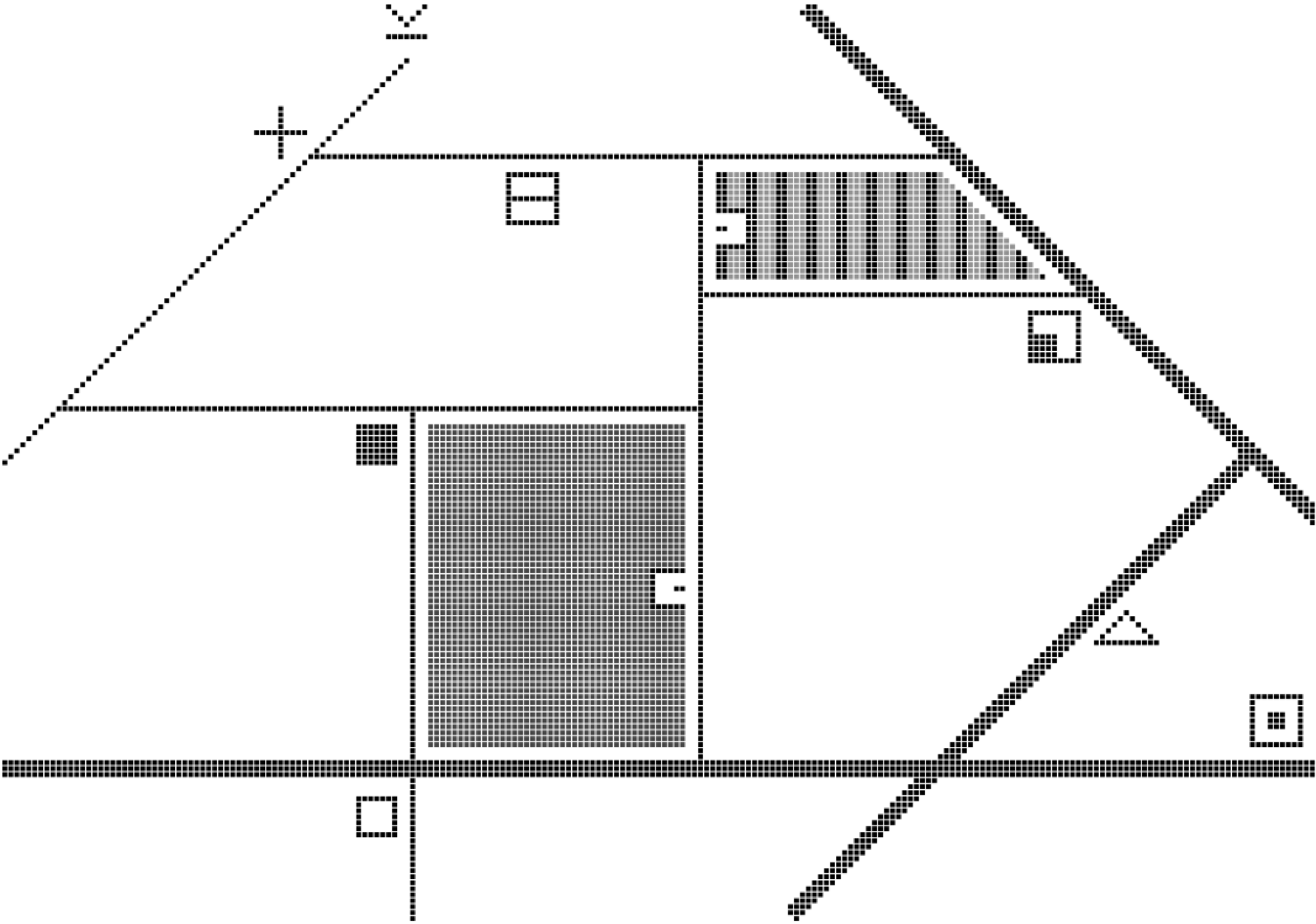
- Level of veridicality of intersection shapes
- Level of veridicality of line (representing streets)



Source: Graf (2013)



Source: Graf (2013)



Source: Graf (2013)

Schematisation Study: Methodology

4 participants, all legally blind

Trials counterweighted & randomised

Reproduction by survey descriptions, route directions

Qualitative assessment about the subjective usability of the maps

Schematisation Study: Results

High-abstract maps were fastest to read.

Map-type	AR	MN	HH	JM
Non-abstract	12:20	15:00	01:45	10:04
Low-Abstract	05:50	17:00	02:10	02:00
High-Abstract	06:27	16:00	01:39	05:10

Source: Graf (2013)

High-abstract map was considered most usable.

	MN	HH	JM
Similarity of map types	3	3	3 (medium)
Best map type	High-Abstract	Non-abstract, as bends and curves provide helpful details when walking the streets	High-Abstract
Worst map type	Non-abstract	High-Abstract	Non-abstract
Intent to use	yes, both types!	yes, best would be as close too reality as possible	yes, for an overview in the same way as with a city map, might by helpful and advantageous
Intent to recom-mend	yes	yes, to ease navigation, to have a survey, to know what's out there & how objects are dispersed over the area, to schedule a trip to different targets, to facilitate route finding	yes, to have a graphical depiction as support that provides hints (for navigation)

Source: Graf (2013)

Schematisation Study: Results

High-abstract maps were fastest to read.

Map-type	AR	MN	HH	JM
Non-abstract	12:20	15:00	01:45	10:04
Low-Abstract	05:50	17:00	02:10	02:00
High-Abstract	06:27	16:00	01:39	05:10

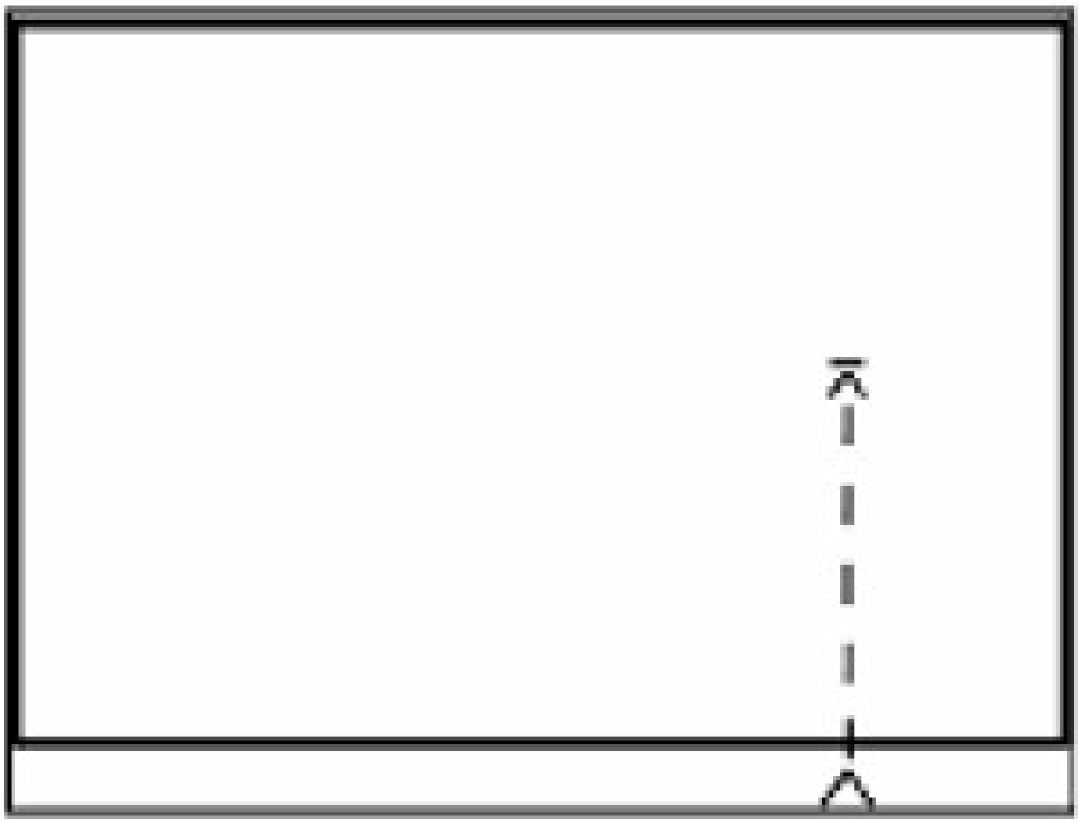
High-abstract map was considered most usable.

Map-reading happens in 3 phases:

1. Anchoring, 2. Overviewing, 3. Detailling

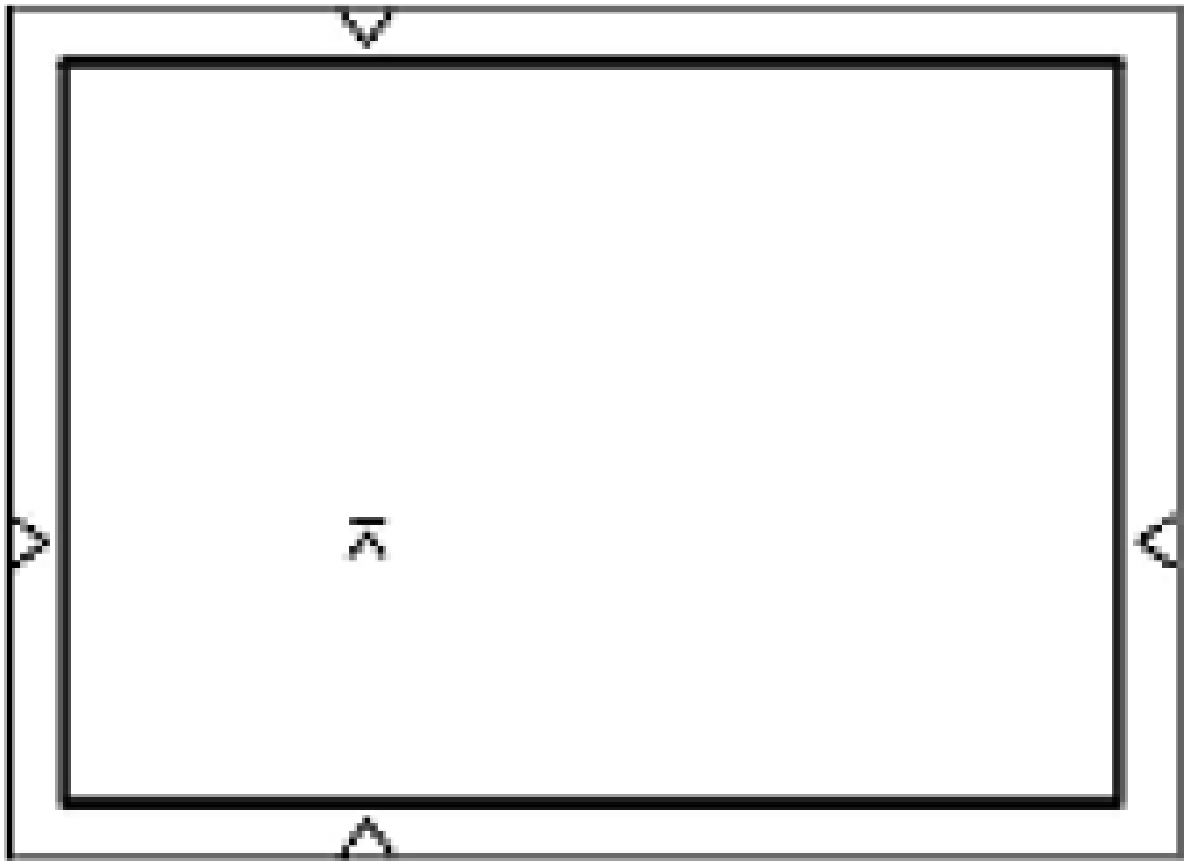
Map-use Study: Localisation Support for better Map usage

Indicator Line



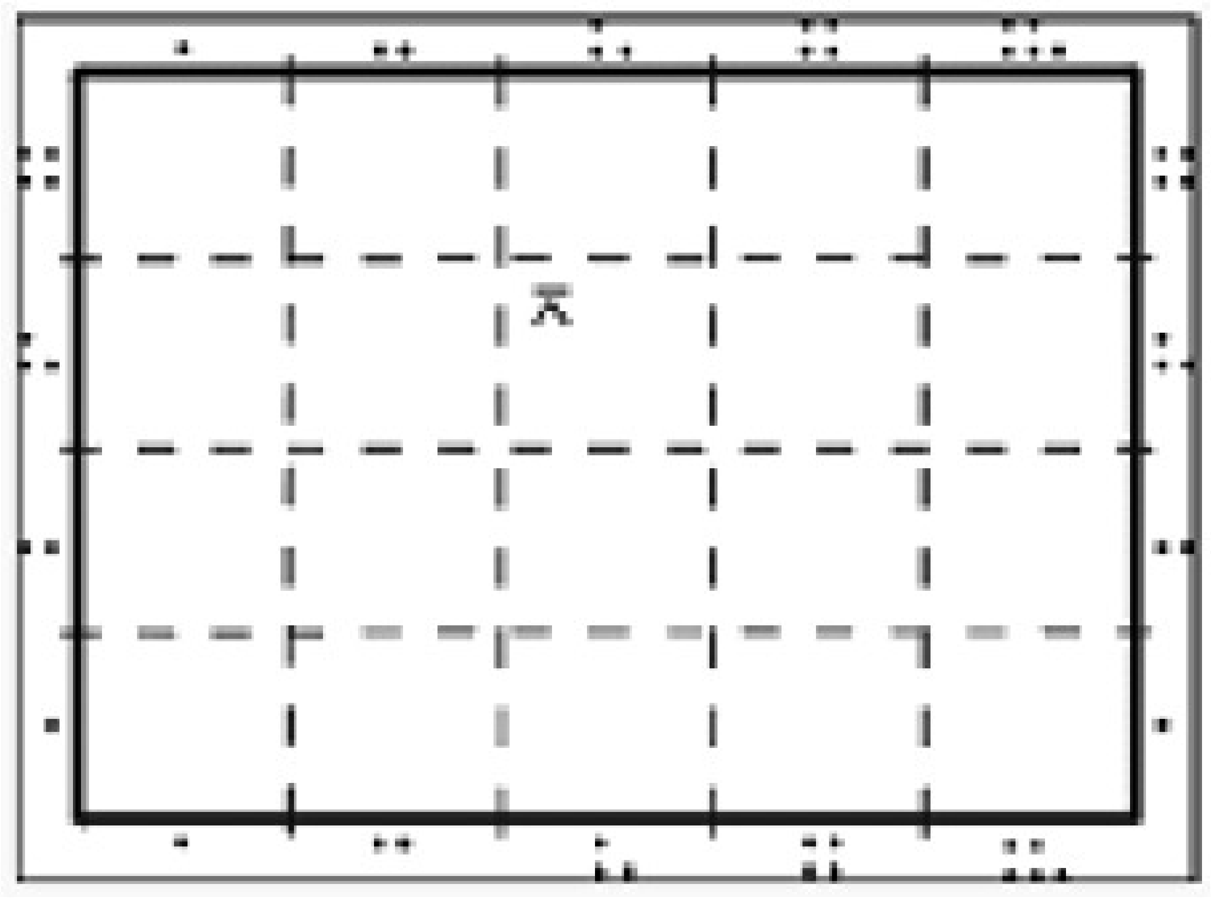
Source: Graf (2013)

Frame Marks



Source: Graf (2013)

Grid Indicator



Source: Graf (2013)

Map-use Study: Research Question

Conditions: Indicator Line, Frame Marks, Grid

Which type of indicator out of the three proposed is most effective for finding the YAH location in a computer-generated tactile orientation map?

Which type of indicator out of the three proposed most impedes the acquisition of spatial knowledge from a computer-generated tactile orientation map?

Map-use Study: Methodology

12 sighted individuals (4 male & 8 female, between 22 and 56)

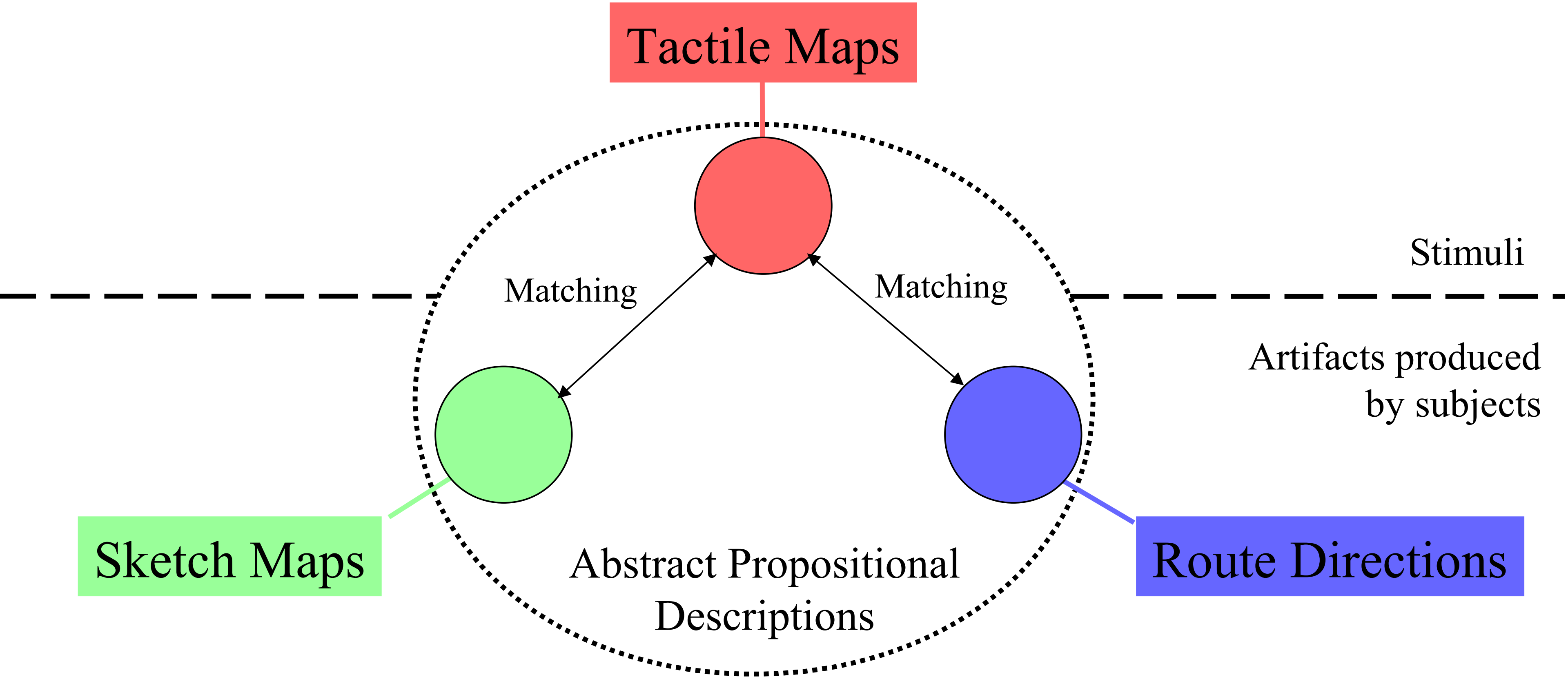
Usage Tasks:

- „FindYAHpoint“
- „ExploreMap“

Spatial Tasks:

- „ExplainRoute“
- „DrawMap“
- „RankMap“

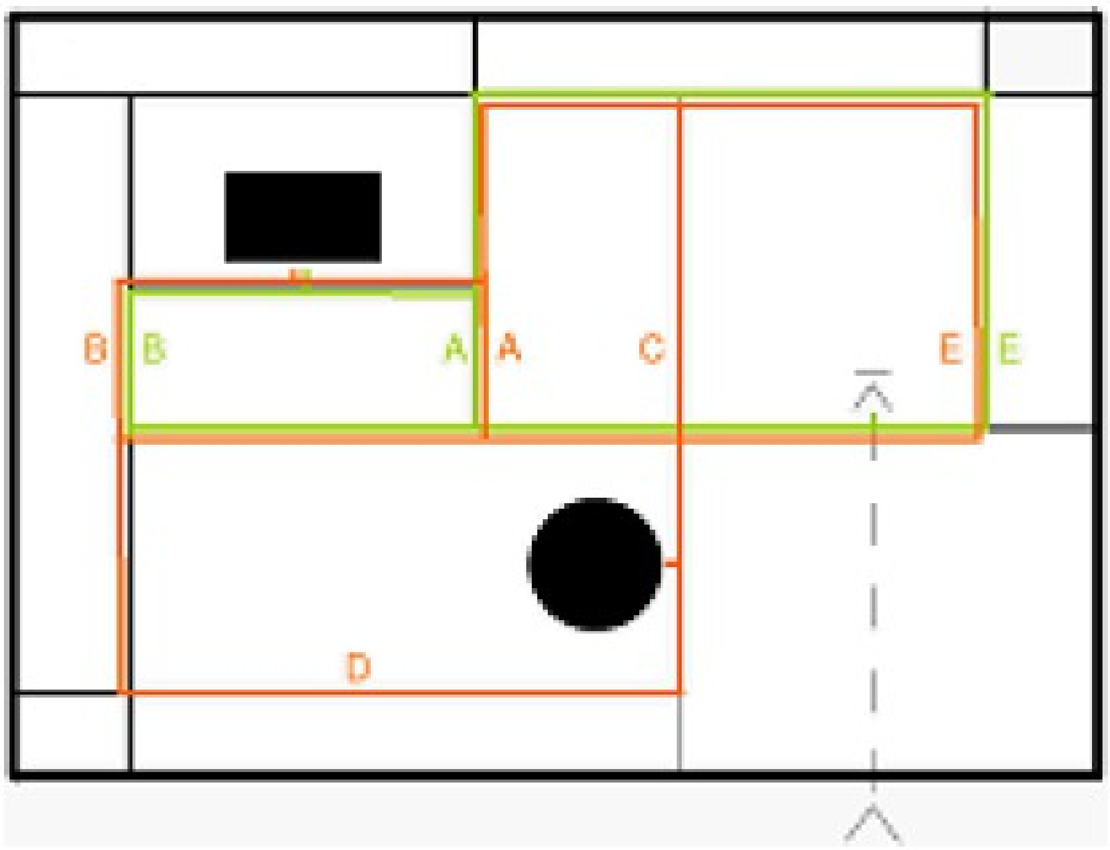
Methodology of Evaluation



External representations used in analyzing the data

Source: Graf (2013)

Map-Use study: Results for Route Descriptions



Source: Graf (2013)

Map-use Study: Results

	Mean time to find the YAH point (in s)	Mean time for exploring the map (in s)
IL	27.09	256.58
FI	19.36	328.50
GI	144.92	491.25

Task	Searching the YAH Point			Exploring the map		
Condition	IL	FI	GI	IL	FI	GI
Average Rank	1.50	1.25	3.00	2.00	1.00	3.00

Source: Graf (2013)

Map-use Study: Results

Frame marks best in performance

Indicator Line and frame marks preferred by subjects

Cond-ition	Finding the YAH point	Exploration of the map	Test Route Knowledge	Test Survey Knowledge	Subjective Ranking	TOTAL
IL	0.14	0.24	0.30 / 0.33	0.31 / 0.29	0.30	**0.256**
FI	0.10	0.31	0.31 / 0.35	0.30 / 0.31	0.19	**0.241**
GI	0.76	0.46	0.39 / 0.32	0.40 / 0.40	0.51	**0.502**

Source: Graf (2013)

Conclusion

Learnings

- Different sources of constraints: technological, sensory & cognitive
- Schematization as approach to cope with cognitive constraints → usable and comprehendable maps
- Topology, relevant landmarks and readable symbols essential for survey maps, metric properties are not
- Printing of comprehendable tactile (orientation) maps becomes possible

Contributions

1. A review of schematisation concepts from visual maps and an evaluation concerning their applicability to tactile maps.
2. A list of schematisation concepts customised to map production with a tactile printer.

a) Concepts that support the task of survey acquisition in tactile orientation maps.

b) Concepts that support the task of (self) localisation in tactile orientation maps.

3. Theoretically and practically backed guidelines for the schematisation of tactile orientation maps.

Publications – Peer Reviewed Papers & Edited Books

[2] Habel, C. & Graf, C. (2008). You-are-here Maps as Navigation Aids for Visually Impaired People. In Klippel, A. & Hirtle, S., Workshop Proceedings "You-Are-Here-Maps", pp. 1-10. Spatial Cognition 2008. September 15 - 19, 2008. Freiburg / Breisgau, Germany.

[7] Graf, C. (2010). Verbally Annotated Tactile Maps - Challenges and Approaches (2010). In: Hölscher et al., Spatial Cognition VII, Proceedings International Conference, Spatial Cognition 2010, Mt. Hood/Portland, OR, USA, August 15-19, 2010.

[9] Graf, C. (2010). From Visual Schematic to Tactile Schematic Maps. Proceedings YAH2 Workshop, Spatial Cognition 2010, Mt. Hood/Portland, OR, USA, August 15-19, 2010.

[14] Graf, C., Schmid, F., Giudice, N. (2012). Proceedings of Spatial Knowledge Acquisition Using Low Information Density Displays. Workshop held in conjunction with Spatial Cognition 2012, Kloster Seeon, Germany, August 31, 2012.

Publications – Presentations & Posters

[1] Graf, C. (2008). From Interaction between Language and Visual Representations to the Interaction between Language and Haptic Representations. Presented at the Workshop on the Interaction of Vision and Language in Cross-Modal Comprehension, CINACS Summer School 2008, 08 - 12 September, 2008. Hamburg, Germany.

[3] Graf, C. (2008). Design Concepts for Tactile Maps to Support Visually Impaired Persons. Presented at the Doctoral Colloquium. Spatial Cognition 2008. September 15 - 19 , 2008. Freiburg / Breisgau, Germany.

[4] Graf, C. (2008). You-are-here Maps For The Blind: First Experiments in Cognitive Design of Non-visual Spatial Representations. In Urbas, L., Goschke, T. & Velichkovsky, B., Tagungsband der 9.Fachtagung der Gesellschaft für Kognitionswissenschaft KogWis. Technische Universität Dresden : Dresden, p. 73. Presented in the Doctoral Colloquium, KogWis 2008. September 28 - October 1, 2008. Dresden, Germany.

[5] Graf, C. (2009). Towards Design Recommendations for Tactile Maps: Experiments about Locating Positions in Tactile Maps. Invited Talk, Center for Cognitive Science, University of Freiburg. July 1, 2009. Freiburg, Germany.

Publications – Presentations & Posters

[6] Graf, C. (2010). Principles of Cognitively-Adequate Tactile Maps. Invited Talk, Cognitive Systems, University of Bremen. March 17, 2010. Bremen, Germany.

[8] Graf, C. (2010). The Construction of Cognitively-Adequate Tactile Maps. Poster Session, Spatial Cognition 2010, Mt. Hood/Portland, OR, USA, August 15-19, 2010.

[10] Graf, C. (2010). Towards Cognitively Adequate Tactile Maps. KogWis 2010, Presentation at the Doctoral Colloquium.

[11] Graf, C. (2010). The Cognitively Adequate Construction of Tactile Maps: First Results. KogWis 2010, Poster.

[13] Graf, C. (2012). Spatial Information in Tactile Orientation Maps - The Users' Requirements. GI Zeitgeist (Münster, 16.-17.03.). Short Paper.

[15] Graf, C. (2013). What the Quest for Tactile Maps Can Teach Us about Making Interactive Maps. Presentation. GeoViz 2013 Conference. Hafen City University, Hamburg, Germany, March 09, 2013.

Future Work

Automatic generation of schematised maps

From mental navigation to real navigation

From uni-modal to multi-modal maps

Multipart maps for focus and context

Heterogenous abstraction & schematisation across the map

Individual spatial knowledge and spatial abilities of map-users

Take Home Message

Aside from ready to use tactile printers it is essential to provide optimized map layouts to yield comprehensible tactile maps. Optimisation has to take into account cognitive, sensory and technological constraints. Aside from the reduction in sensory richness, the understanding of a map improves with the degree of schematisation applied. Straightening of streets and typisation of intersection are two approaches that distort the metric properties but that do not break the topology of the map layout that is important for blind travellers.

Thank you for your attention.

Thank you CoSy & VemiLab for the fruitful collaboration.

Thanks to all participants in the studies.

Thanks to all supporters.

christian@maps4vips.info

www.maps4vips.info

Backup Slides

Study 1: Technological Constraints and Usability Requirements of Hardcopy Tactile Maps

Study 1: Motivation & Research Question

Requirements for hardcopy tactile orientation maps unknown → learn about the requirements for tactile maps

→ A. Readability of Tactile Hardcopies

„Which are the key dimensions of tactile printing with discrete entities to display objects that can be discriminated?“

→ B. Context of Use of Tactile Orientation Maps

„Which properties constitutes a useful tactile orientation map for blind users?“

Study 1.A: Readability of Tactile Hardcopies - Methodology

participants were 2 late-blind persons and 6 sighted person, 3 males and 5 females.

Study 1a: Readability of Tactile Hardcopies - Results

Study 1.B: Context of Use of Tact. Orient. Maps - Methodology

participants were 2 late-blind persons and 6 sighted person, 3 males and 5 females.

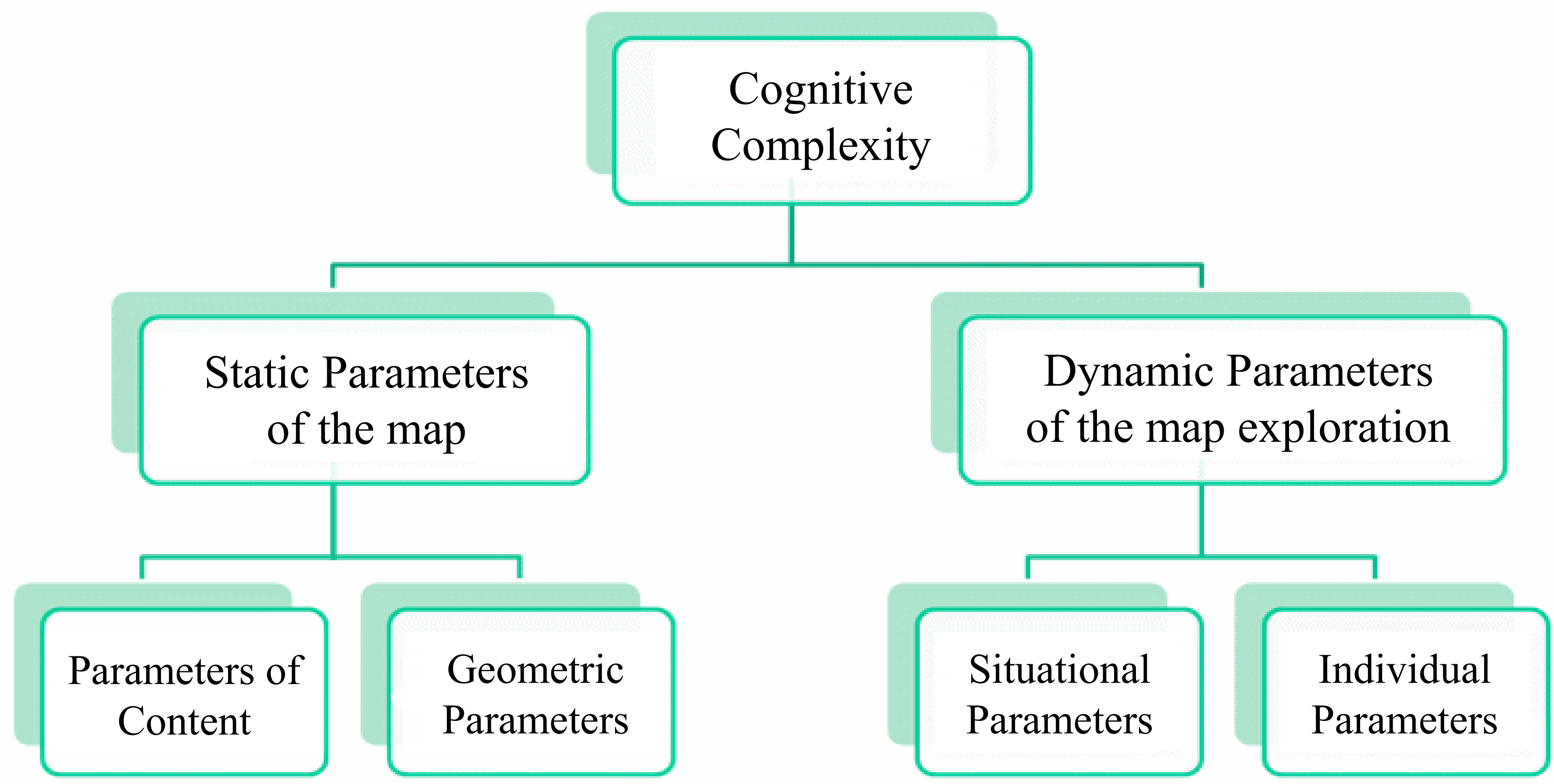
Study 1.B: Context of Use of Tact. Orient. Maps - Results

Cognitive Adequacy

Cognitive Adequate Tactile Map

- Strube, 1992: Cognitive adequacy (for expert systems)
- Tactile maps are used in a process of knowledge acquisition
- Process of knowledge acquisition should foster mental representations that are appropriate to facilitate successful problem solving
- Cognitive Adequacy is the property of some artefact or behaviour that supports human reasoning such that cognitive errors (e.g. misconceptualizations) are reduced and successful task execution supported

Proposed Model of Cognitive Complexity



Content & Geometry Related Parameters of the Map

- Static Parameters of the Map
  - Parameters of Content
    - # edges, # nodes, # regions, # landmarks per region
    - Existence of Stable Frame of References
    - Existence of Static Relations in partitioned maps
  - Geometric parameters
    - Style of lines: straight vs. curved, oblique vs. horizontal/vertical
    - Abstraction of angles: 4 vs. 8-intersection model → form of regions
    - Prominence of landmarks: “near” some edge/node vs. in region

A Selection of Parameters

- Quantitative Parameters
  - # nodes, # segments, # regions
- Qualitative Parameters:
  - Style of lines, e.g., straight vs. curved
  - Intersection model (90° vs. 45°) → types of lines and forms
  - Style of explorations: one-handed, two-handed
  - Prior knowledge

Situational Parameters of the Map Exploration

- Factors in the learning situation
  - Surrounding of the exploration, e.g. quiet vs. noisy
  - Urgency of the task, e.g. limited vs. unlimited time
  - Emotional state of the user, e.g. aroused vs. depressed (Valence-Arousal-Model by Russell, 1980)

Individual Parameters in Cognitive Processing

- Cognitive abilities of the map reader (Hirn, 2009)
  - Exploration strategies, e.g. with or without a second hands for setting a reference point
  - Ability to interpret maps
  - Knowledge of concepts used in maps
- Prior knowledge of the map reader (Schmid, 2008)

Bibliography

Graf, C. (2010). Verbally Annotated Tactile Maps: Challenges and Approaches. In Spatial Cognition VII, Lecture Notes in Computer Science (vol. 6222, pp. 303-318). Mt. Hood / Portland, Oregon: Springer.

Hirn, H. (2009, Juni 5). *Pre-Maps: An Educational Programme for Reading Tactile Maps* (Monograph). University of Helsinki, Faculty of Behavioural Sciences, Department of Applied Sciences of Education, erityispedagogiikka.

Schmid, F. (2008). Knowledge-based wayfinding maps for small display cartography. Journal of Location Based Services, 2(1), 57-83. doi:10.1080/17489720802279544

Strube, G. (1992). The role of cognitive science in knowledge engineering. In *Contemporary Knowledge Engineering and Cognition*, Lectures Notes in Computer Science (vol. 622, pp. 159-174). Berlin / Heidelberg: Springer.