

AutoCarto 2022,
Redlands, CA, Nov 02-04 Nov

Session 1 | Inclusion in Cartography and GIScience

Thematic Tactile Maps for Blind and Visually-Impaired People:
**A Conceptual Cartographic Framework for Map Creation
using Open-Source Data and LCD Printing Tech**

Y-R. Chen & S. van Gasselt*

Geomatics Group | Department of Land Economics
National Chengchi University, Taipei, Taiwan

Thematic Tactile Maps for BLV People

Background

30% of the global population suffers
from some form of vision impairment

World Health Organization, 2019

Background

30% of the global population suffers from some form of vision impairment

World Health Organization, 2019

Up to 45 million blind people globally – and growing

Potential Causes

Medical reasons

age-related macular degeneration, cataract, diabetic retinopathy, glaucoma, uncorrected refractive errors (WHO 2022)

Behavioural Causes

intense and overtime working, lack of outside activities (Holden et al., 2016)

Future

Number will continue to grow due to overaging and lifestyle (Bourne et al., 2017)

Background

Tens of millions of blind and low vision (BLV) people cannot access effective support services and assistive products

(Chiang et al., 2011; Langelaan, 2007)

Background

Tens of millions of blind and low vision (BLV) people cannot access effective support services and assistive products

(Chiang et al., 2011; Langelaan, 2007)

BLV people are often experiencing

- lower levels of educational achievement → **education inequality**
- lower rates of workforce participation → **high unemployment rate**

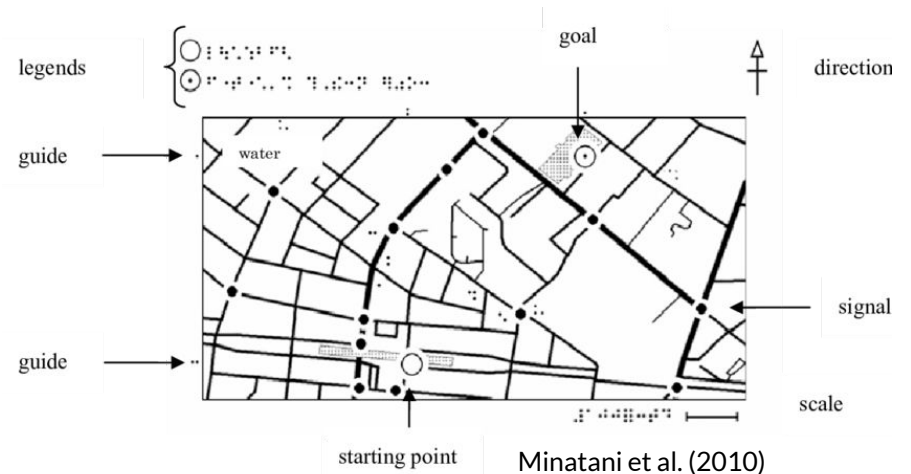
Background

People depend on visual input for stimulation and orientation.

BLV people must rely on substitutes but lack spatial context.

Advantages of tactile feedback

- better spatial decision making
- environmental knowledge
- independent travel
(Lobben & Lawrence, 2012)



Background

Developments made by sighted people is likely more technology-centric rather than human-oriented.

(Perkins, 2002)

Use of 3D printing technology has shown

to improve situation in unfamiliar urban environments

(Espinosa et al., 1998; Wabiński, 2020)

to actually help building a cognitive map by shaping spatial information through fingertips

(Maingreud et al., 2005)

Background

There is technology to make better use of spatial information (use and create).

Much work has been focussing on orientation maps, including real time navigation, not so much on educational thematic maps.

It might be the right time to look into improving educational material

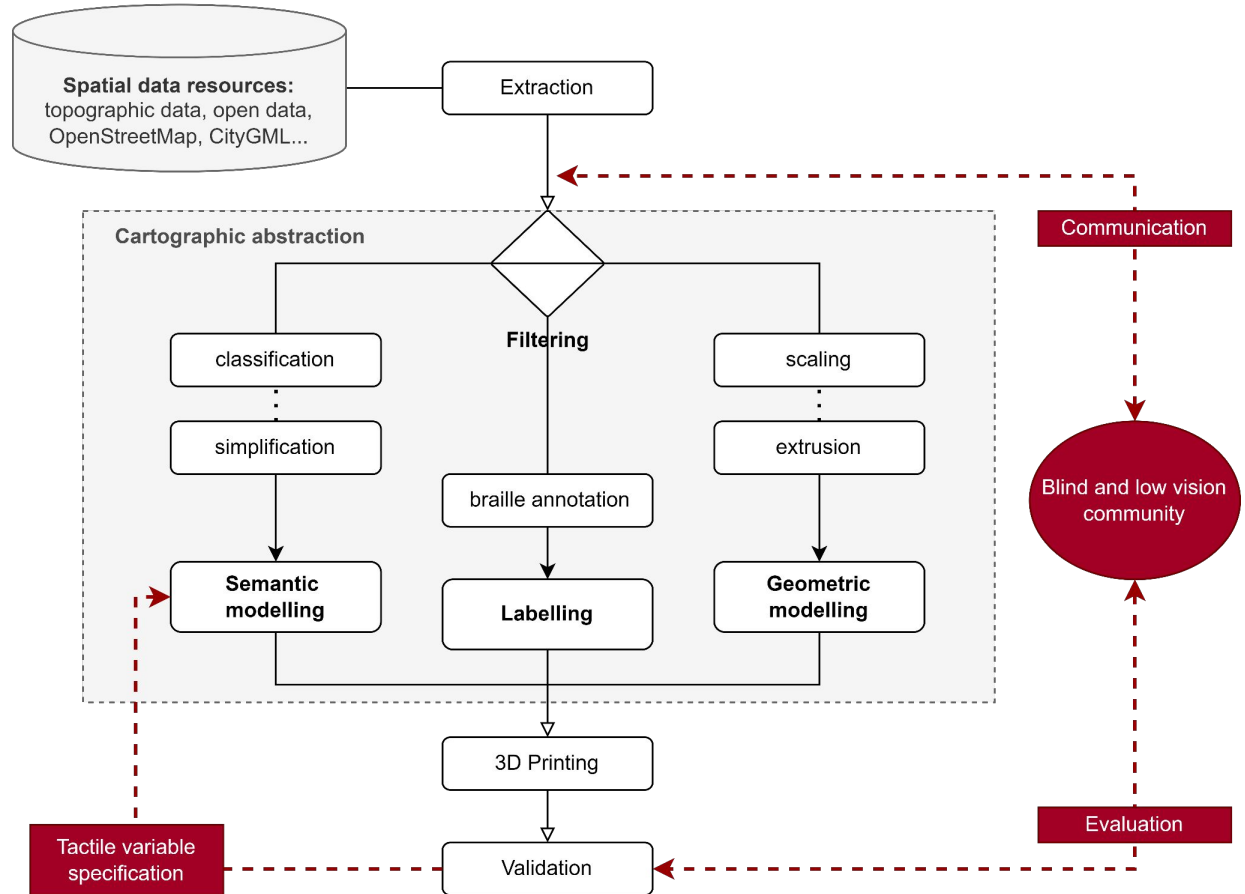


Objectives and Requirements

Objectives

Build a workflow using a map-printing device that allows to generate and print thematic 3D maps with data extracted from openly accessible sources, and which can be used as potential educational resource.

Realisation



Expected Challenges

Data ex- and imports

Getting data out of somewhere is easy, getting it into a consistent format for printing not so much

Merging different data sources

Transfer of cartographic variables

Usability of standards and consistency

Information density with limitations of map scales and extents

Some undefined issues with the printer or the slicer

Thematic Tactile Maps for BLV People

Expected Challenges

- Limitations of Print-Sizes

- Limitations of Perceivable Detail

- Limitation of Variable Overloading



Limitation of Perceivable Information Depth and Map Complexity

Expected Challenges

■ Limitations of Print-Sizes

■ Limitations of
Perceivable Detail

■ Limitation of
Variable Overloading



Solution

Tiling scheme with printed plug connectors

Limitation of Perceivable
Information Depth and Map Complexity

Expected Challenges

■ Limitations of Print-Sizes

■ Limitations of Perceivable Detail

■ Limitation of Variable Overloading



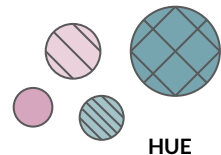
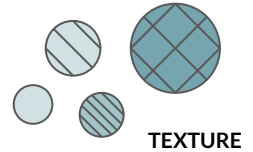
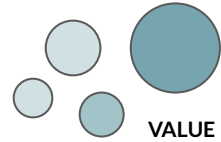
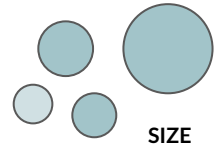
Solution

Tiling scheme with printed plug connectors

Limitation of Perceivable Information Depth and Map Complexity

No Solution

Physiological limits which can also not be solved by better printers.



Expected Challenges

■ Limitations of Print-Sizes

■ Limitations of Perceivable Detail

■ Limitation of Variable Overloading



NOTE

Tools might not be optimum but they are not the limitation.

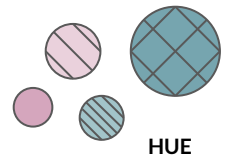
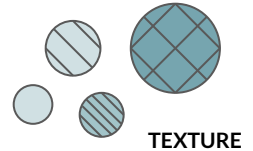
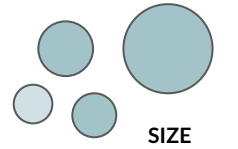
Solution

Tiling scheme with printed plug connectors

Limitation of Perceivable Information Depth and Map Complexity

No Solution

Physiological limits which can also not be solved by better printers.



Concepts and Developments

Thematic Tactile Maps for BLV People

Underlying Principles

Sighted people read the entire map at once.

BLV people read and memorize the map in fragments

(Olczyk, 2014)

We would have to communicate an idea or information,
not to merely reproduce a visual depiction

(American Printing House for the Blind [APH], 2008; Rosenblum & Herzberg, 2015)

Development Cartographic Concept

Spatial dimension and geometry




Levels of measurement

nominal, ordinal, interval, and ratio data

Visual variables

size, (hue, value), texture, orientation, and shape

When the dimension is extended to 3D, the freedom of height variations is also added

tactile variable(3D) visual variable(2D)	level of measurement			
	nominal	ordinal	interval	ratio
Size		○	○	○
Texture		○	○	
Value 		○	○	
Hue 	○			
Orientation	○			
Shape	○			
*Height 	○	○	○	○

Thematic Tactile Maps for BLV People

Development Data Sources

OpenStreetMap (OSM)

Open Government Data (open government data platform)

National Land Surveying and Mapping Center (NLSC)

Taiwan Geospatial One Stop (TGOS)



https://www.tgos.tw/tgos/web/tgos_home.aspx




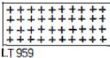


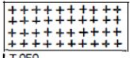

<https://maps.nlsc.gov.tw/>

Develop Map Symbology

Symbol guidelines from Australian standard due to similarity in map topic w/ detailed specifications on map design

The NSW Tactual and Bold Print Mapping Committee (2006): A Guide for the Production of Tactual and Bold Print Maps (3rd ed.)

Land Use Map Layers

Feature type	Layer name	Height criteria	Texture criteria	
polygon	Residential area	+1 mm		
	Commercial area	+2.8 mm		
	Water area	-3 mm		
	Facility area	+3 mm		
	School area	+3 mm		
	Green area	+0.5mm		
	Conservation area	+0.5mm		
Feature type	Layer name	Width criteria	Height criteria	Texture criteria
Line	Secondary road	4 mm		
	Tertiary road	2 mm		
	Residential road	1 mm	+0.8 mm	
	Service road	0.5 mm		
	River	8 mm	-3 mm	
Point	Bus stop	r=1 mm	+4 mm	
polygon	School		+2 mm	
	Green area		+0.5mm	

Thematic Tactile Maps for BLV People

Development Device Selection

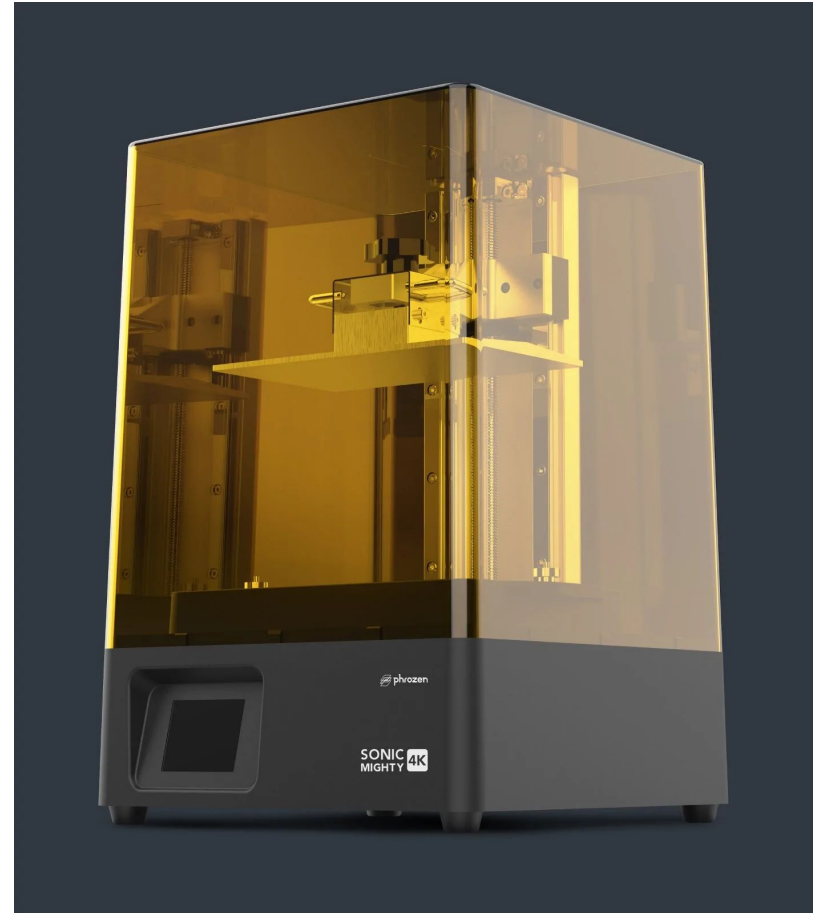
Liquid-Crystal Display (LCD) 3D Printing using Vat Photo-Polymerization (VP)

Affordable equipment, un-skilled operation process, and satisfying
printing resolution

Phrozen Sonic Mighty 4K LCD Printer

low-cost, user feedback, precision

XY Resolution	0.052 mm
Layer Thickness	0.01-0.30 mm
Print Speed	80 mm/hr
Price	~550 USD (2021)



Results and Conclusions

Development Map Layout

Print size limitations

W 12.5 cm x L 20.0 cm x H 22.0 cm

Model size

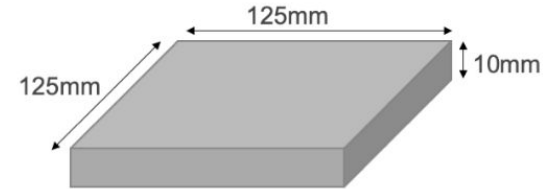
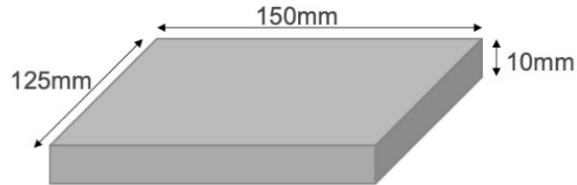
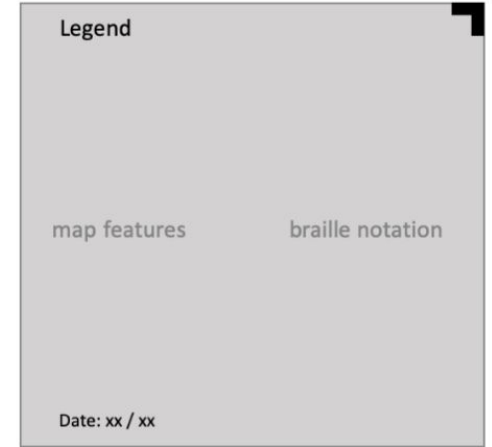
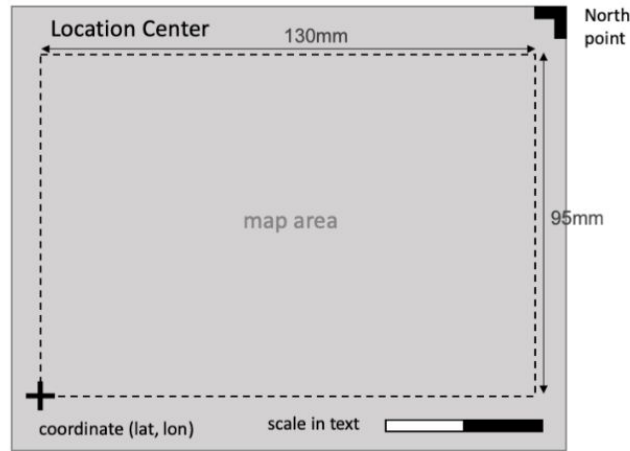
W 12.5 cm x L 15.0 cm x H 1.0 cm

Mapped area

W 712.5 m x L 975.0 m

Map Scale

1 : 7 500



Development

OSM Data Simplification



Extracted OSM data as Feature Classes in ArcGIS using the Overpass API



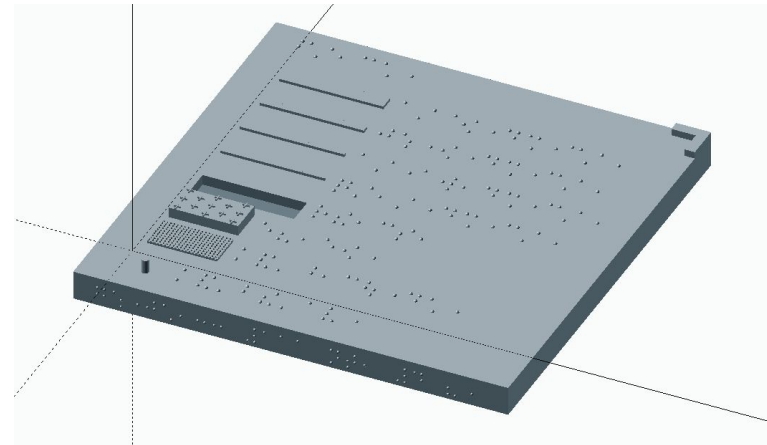
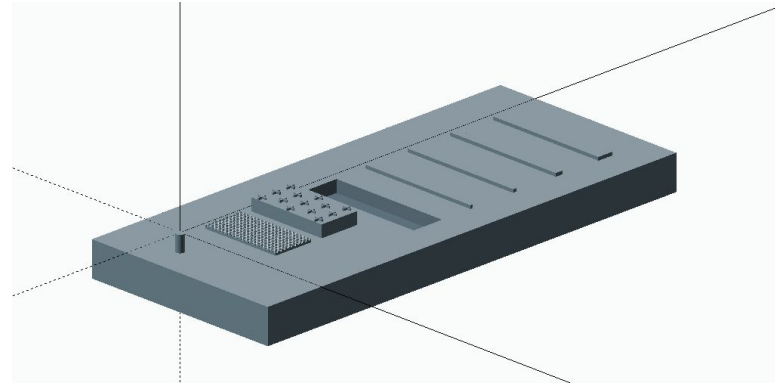
Simplified OSM data as Feature Classes in ArcGIS

Thematic Tactile Maps for BLV People

Develop Map Symbology

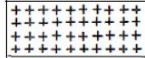

Symbol guidelines from Australian standard
due to similarity in map topic w/ detailed
specifications on map design

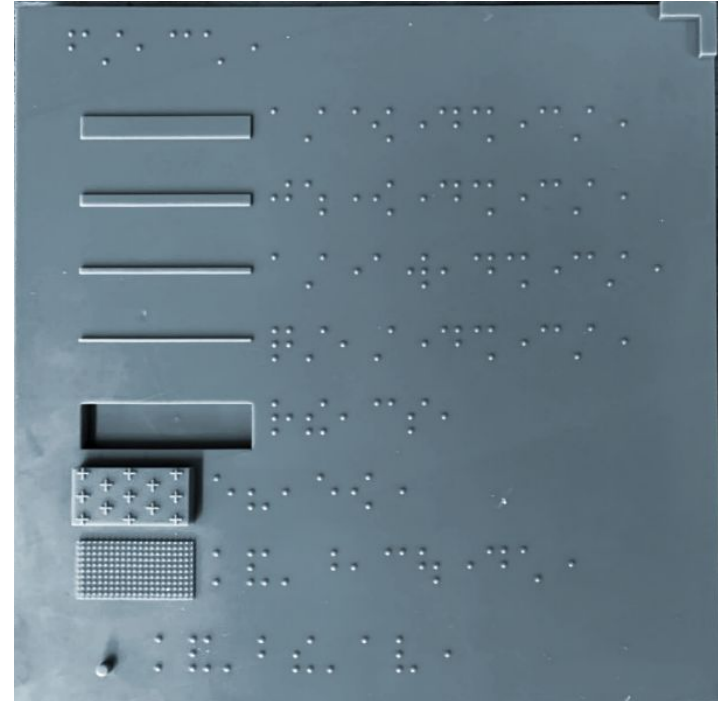
The NSW Tactual and Bold Print Mapping Committee (2006): A
Guide for the Production of Tactual and Bold Print Maps (3rd ed.)



Results

OSM Map

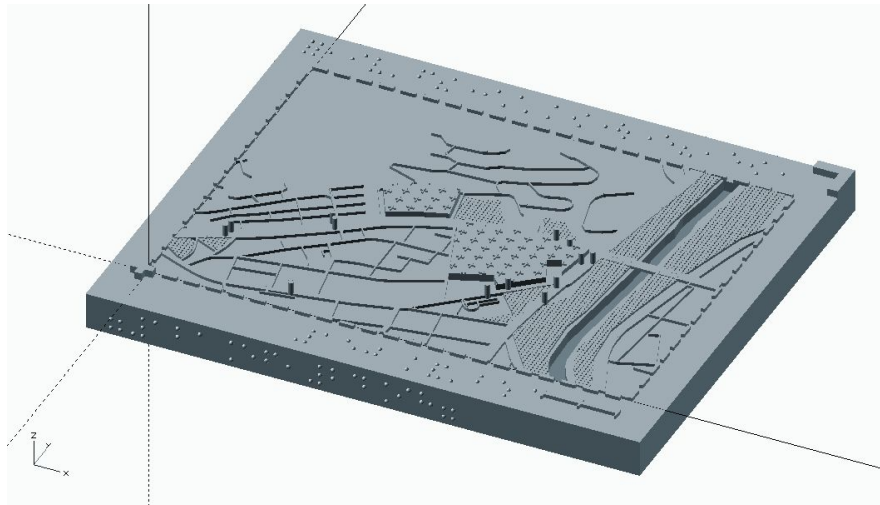
Feature type	Layer name	Width criteria	Height criteria	Texture criteria
Line	Secondary road	4 mm		
	Tertiary road	2 mm	+0.8 mm	
	Residential road	1 mm		
	Service road	0.5 mm		
	River	8 mm	-3 mm	
Point	Bus stop	r=1 mm	+4 mm	
polygon	School		+2 mm	 LT 959
	Green area		+0.5mm	 (LT907)



Thematic Tactile Maps for BLV People

Results

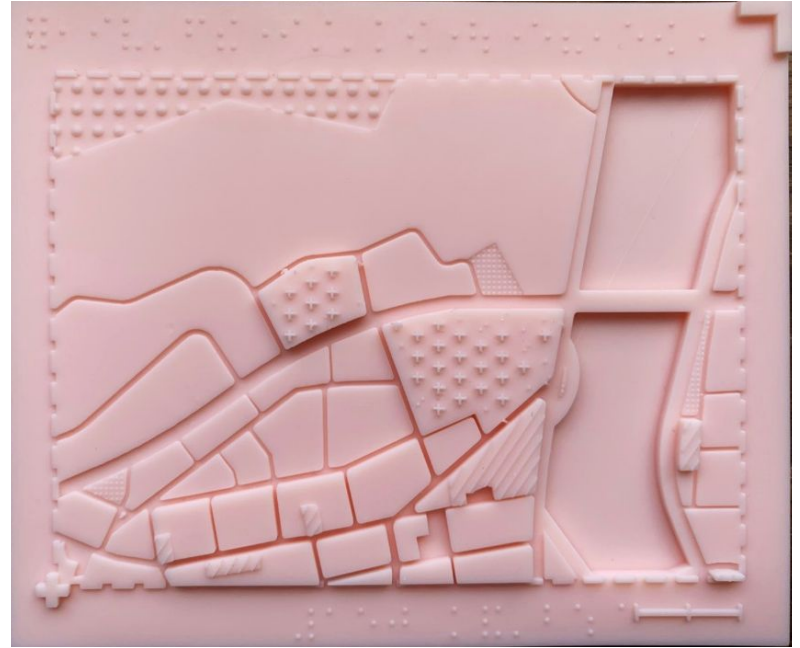
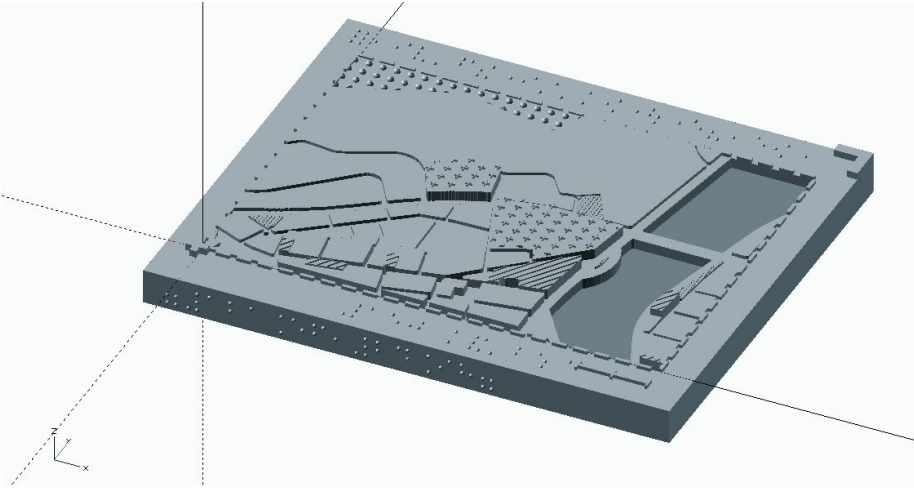
OSM Map



Thematic Tactile Maps for BLV People

Results

Land-Use Map

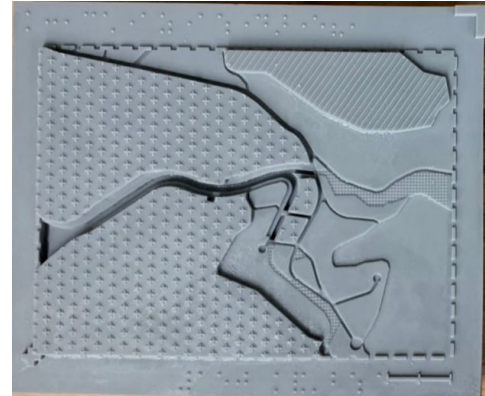


Thematic Tactile Maps for BLV People

Results

Map Tiling

Four adjacent areas as map tiles.



Validation

Visually impaired people were invited during the later project stages.

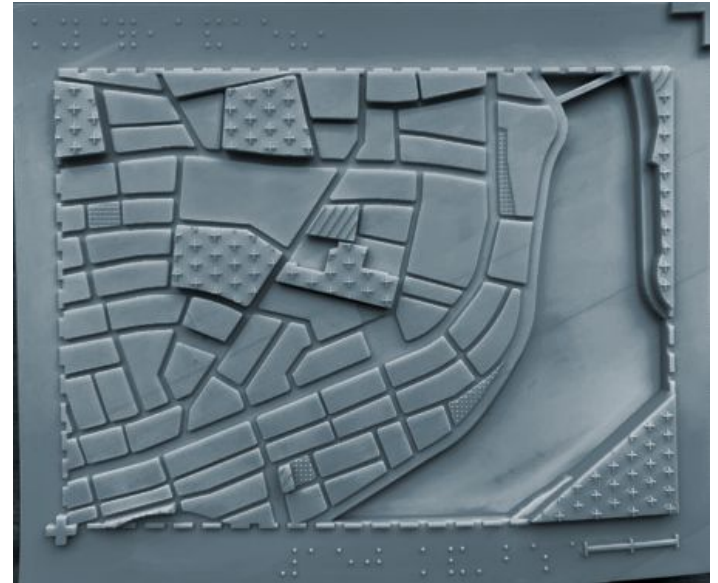
Some were familiar with thermoforming tactile maps.

Legend-Reading Tasks

- (1) differentiate the properties of each legend
- (2) read the braille annotation

Map Tasks

- (1) orientation tasks
- (2) recognition tasks



Validation

- Height difference (residential & commercial) is not an effective variable.
The smaller the land parcel, the harder for participants to differentiate the texture.

Map feature	School area	Facility area	Green area	Conservation area
Correctness rate	66%	50%	30%	100%

- Width (4 road levels) is not an effective variable.

- Points identification was clear.

Community Feedback

- 3D printed map has better (“sturdier”) texture than traditional tactile map
→ better haptic feedback
- Not familiar with height variation on the map
→ recommendation unclear
- Lack of freedom of different zoom level and amount of information
- Improvement regarding map size and scale
→ create sets of map models

Unexpected **Challenges** (sort of) and Operational Limitations

- Bending and deformation due to differential hardening/curing.
- Solid slab models produce sticky surface.
- Printer adjustments are possible but process seems very sensitive to temperature environment.
- Regular examination and calibration are required.
- Standard 3D printing resin is not safe before curing, and we lack information about abrasion.



Conclusions

- LCD 3D printing technology works well for tactile maps as it combines sturdy/long-lasting/washable characteristics with tactile use, and still allows for more delicate map textures.
- 1:7,500 prototypes seem to be too small for thematic maps.
- Visually impaired people are more familiar with texture than with height or width variations, some counterintuitive observations.
- Process automatization is far from being perfect.

Outlook

- More BLV community work needed.
- ICC 2023 @Cape Town, South Africa, 14–18 Aug. (community)
- We need to develop more insights into properties of tactile variables and their perception by BLV people.
- For our next funding period we would like to go for a second round and realise a demonstrator atlas and test it in a community.