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

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Background

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

World Health Organization, 2019
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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)
Tens of millions of blind and low vision (BLV) people cannot access effective support services and assistive products

(Chiang et al., 2011; Langelaan, 2007)
Thematic Tactile Maps for BLV People

**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 $\rightarrow$ education inequality
- lower rates of workforce participation $\rightarrow$ 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 (Maingreaud 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.
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Realisation

Spatial data resources: topographic data, open data, OpenStreetMap, CityGML...

Extraction

Cartographic abstraction

- classification
- simplification

Semantic modelling

- braille annotation

Labelling

- Geometric modelling

- scaling
- extrusion

3D Printing

Tactile variable specification

Validation

Communication

Blind and low vision community

Evaluation
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
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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
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**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.
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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.

**NOTE**
Tools might not be optimum but they are not the limitation.
Concepts and Developments
**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.
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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/
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Development
Cartographic Labels

Based on national implementations.
Taiwanese braille has adapted Mandarin Phonetic Symbols (Institute for the Blind of Taiwan, 2021).

<table>
<thead>
<tr>
<th>Braille (國立政治大學) modelled in OpenSCAD</th>
<th>愛盲點字對照表</th>
</tr>
</thead>
<tbody>
<tr>
<td>Braille model</td>
<td>愛盲點字對照表</td>
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台湾盲文已经适应了 Mandarin Phonetic Symbols (Institute for the Blind of Taiwan, 2021).
Develop Map Symbology

Symbol guidelines from Australian standard due to similarity in map topic with 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

<table>
<thead>
<tr>
<th>Feature type</th>
<th>Layer name</th>
<th>Height criteria</th>
<th>Texture criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>polygon</td>
<td>Residential area</td>
<td>+1 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Commercial area</td>
<td>+2.8 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Water area</td>
<td>-3 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Facility area</td>
<td>+3 mm</td>
<td></td>
</tr>
<tr>
<td>polygon</td>
<td>School area</td>
<td>+3 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Green area</td>
<td>+0.5mm</td>
<td>(LT907)</td>
</tr>
<tr>
<td></td>
<td>Conservation area</td>
<td>+0.5mm</td>
<td></td>
</tr>
</tbody>
</table>

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<tr>
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<th>Layer name</th>
<th>Width criteria</th>
<th>Height criteria</th>
<th>Texture criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line</td>
<td>Secondary road</td>
<td>4 mm</td>
<td>+0.8 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tertiary road</td>
<td>2 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Residential road</td>
<td>1 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Service road</td>
<td>0.5 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>River</td>
<td>8 mm</td>
<td>-3 mm</td>
<td></td>
</tr>
<tr>
<td>Point</td>
<td>Bus stop</td>
<td>r=1 mm</td>
<td>+4 mm</td>
<td></td>
</tr>
<tr>
<td>polygon</td>
<td>School</td>
<td></td>
<td>+2 mm</td>
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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

<table>
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<th>Specification</th>
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<tr>
<td>XY Resolution</td>
<td>0.052 mm</td>
</tr>
<tr>
<td>Layer Thickness</td>
<td>0.01-0.30 mm</td>
</tr>
<tr>
<td>Print Speed</td>
<td>80 mm/hr</td>
</tr>
<tr>
<td>Price</td>
<td>~550 USD (2021)</td>
</tr>
</tbody>
</table>
Results and Conclusions
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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
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Development
OSM Data Simplification

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

Simplified OSM data as Feature Classes in ArcGIS
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Develop
Map Symbology

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

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Results

OSM Map

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Results

OSM Map
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Results
Land-Use Map
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**Results**

**Map Tiling**

Four adjacent areas as map tiles.
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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
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Validation

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

<table>
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<tr>
<th>Map feature</th>
<th>School area</th>
<th>Facility area</th>
<th>Green area</th>
<th>Conservation area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correctness rate</td>
<td>66%</td>
<td>50%</td>
<td>30%</td>
<td>100%</td>
</tr>
</tbody>
</table>

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

Points identification was clear.
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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
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**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.
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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.