Map Making, Geovisualization, and User Experience

Cartographic Visualization in GIS 2025 Tue 20.5.2025

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in the National Land Survey of Finland

Maps and me

- Orienteering in all forms from 4-year old
- Minor in Cartography at Helsinki University of Technology in the Geomatics program
- Cartographic and geoinformatic research at the FGI-GEOINFO, Paris Déscartes, UCSB since 2007
- Commission chair and vice-chair in the International Cartographic Association since 2011
  - Maps and the Internet
  - Cognitive Issues in Geographic Information Visualisation
- Doctoral dissertation on wayfinding landmarks and geopictures in 2014
- Designing of NLS maps (Taustakartta, Selkokartta, Maastokartta)
- Research manager since 2018
  - group Geospatial representation and interaction (GeoRI)
- Active in Finnish Cartographic Society and ProGIS ry

Task for post-discussion

- Write down topics that you want to elaborate.

Contents

I Cartography

"Map"

- "A symbolised representation of a geographical reality, representing selected features and characteristics, resulting from the creative effort of its author's execution of choices, that is designed for use when spatial relationships are of primary relevance." (*International Cartographic Association*, 2003)

- "Downscaled and generalized image of an [geographical] area with explicated symbols and complementing information." (*Niemelä*, 2004; orig. Finnish)

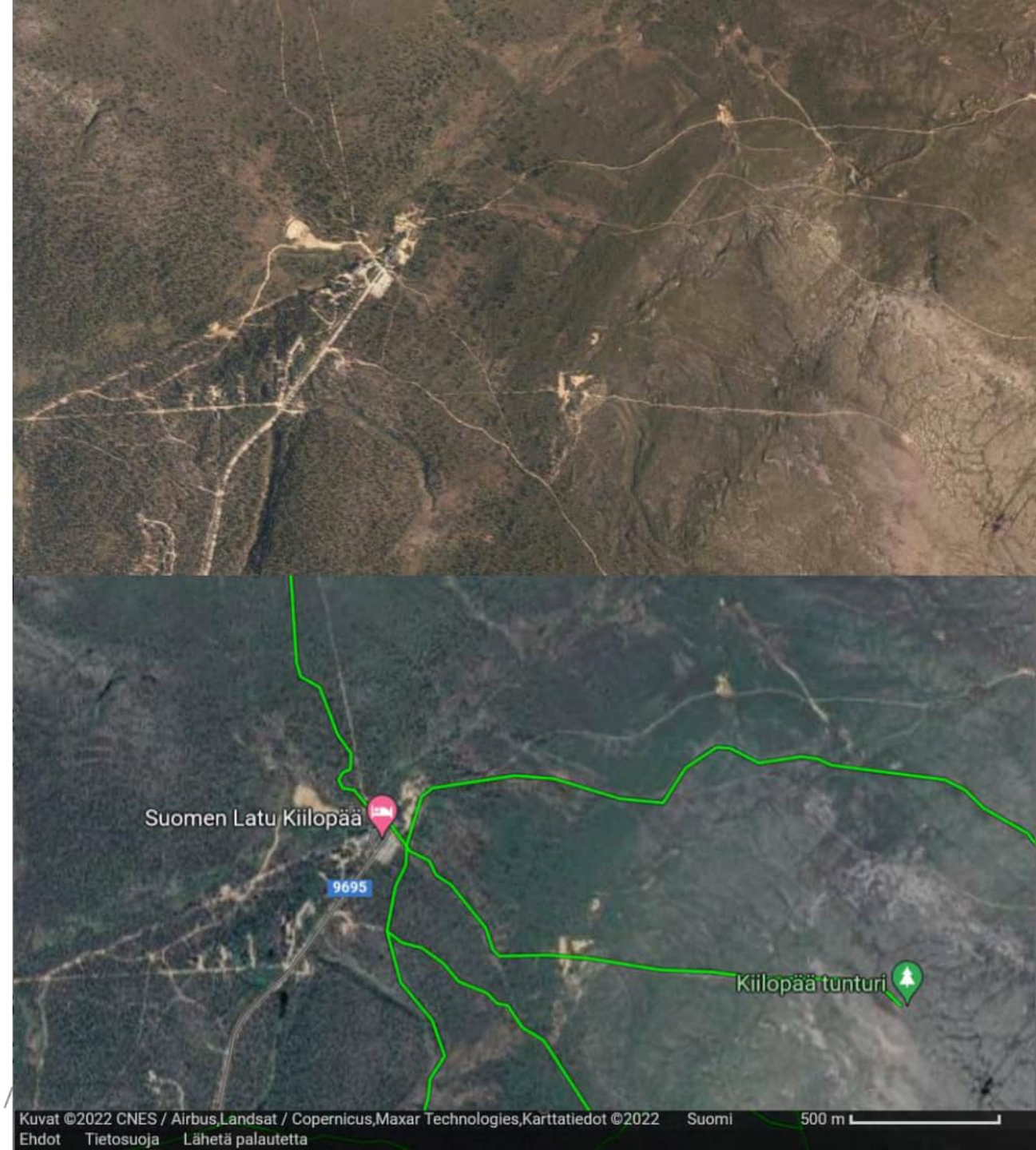
- "Conventional geometric representation of relational locations of concrete or abstract locatable phenomena in space." (*SEIGN*, 2008; orig. French)

- "An abstracted and authored (often) visual representation of geographic phenomena or processes." (*Kraak et al.*, 2020)

What would *not* be a "map"?

- Direct remote sensing data
  - aerial and satellite images
  - point clouds
- Raw vector data
- …

- …but refining and enriching these, the definition of a map gets closer…



"Cartography"

- "A unique facility for the creation and manipulation of visual or virtual representations of geospace – maps – to permit the exploration, analysis, understanding and communication of information about that space. (*International Cartographic Association*, 2003)
- "Representation means, map production and use as well as teaching." (*Niemelä*, 2004; orig. Finnish)
- "Entity of scientific, artistic and technical research and actions, which concers developing, compiling and usage of maps and other forms of expression, originating from direct observation or existing documentation." (*SEIGN*, 2008; orig. French)
- "The art, science, and technology of making and using maps." (*Kraak et al.*, 2020)

My formulations from previous definitions

MAP

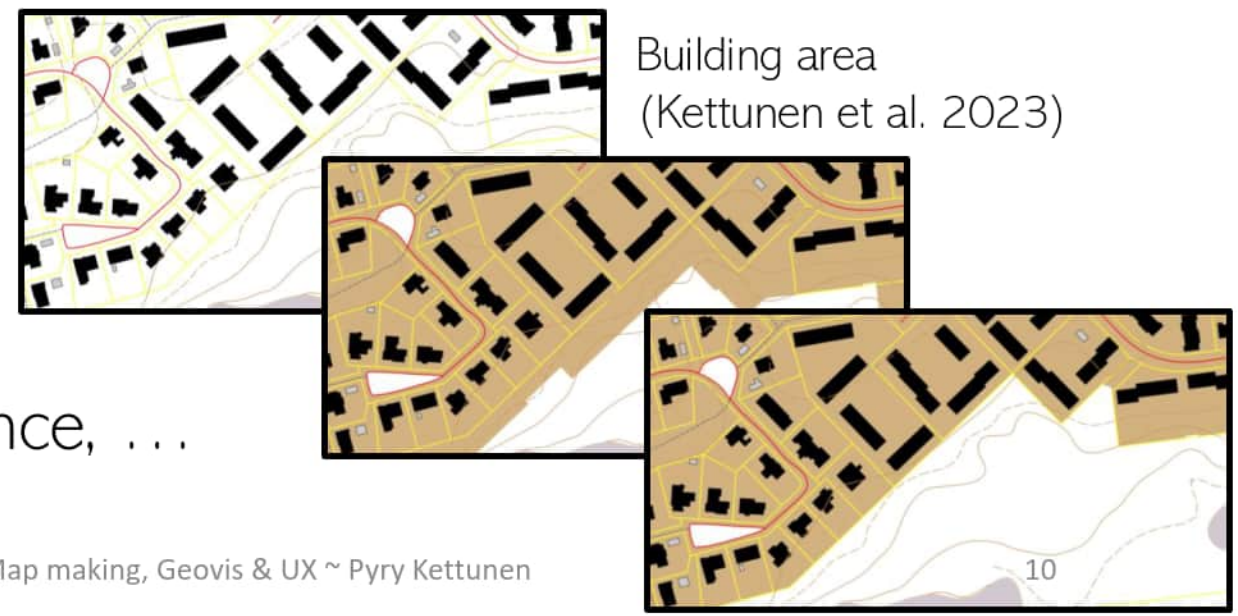
Purpose-driven, refined and generalized, pictorial representation of features in space and time.

CARTOGRAPHY

Art, science, research, and technical development concentrating on carefully constructed maps.

Cartographic generalisation

- The core process of all map-making.
- Maps always represent intended aspects of the "real world" or "ground truth"
  - the intended representation is constructed through *cartographic generalisation*.
- Generalisation operators
  - selection: select, displace, …
  - geometry: simplify, merge, …
  - symbolisation: resymbolize, enhance, …

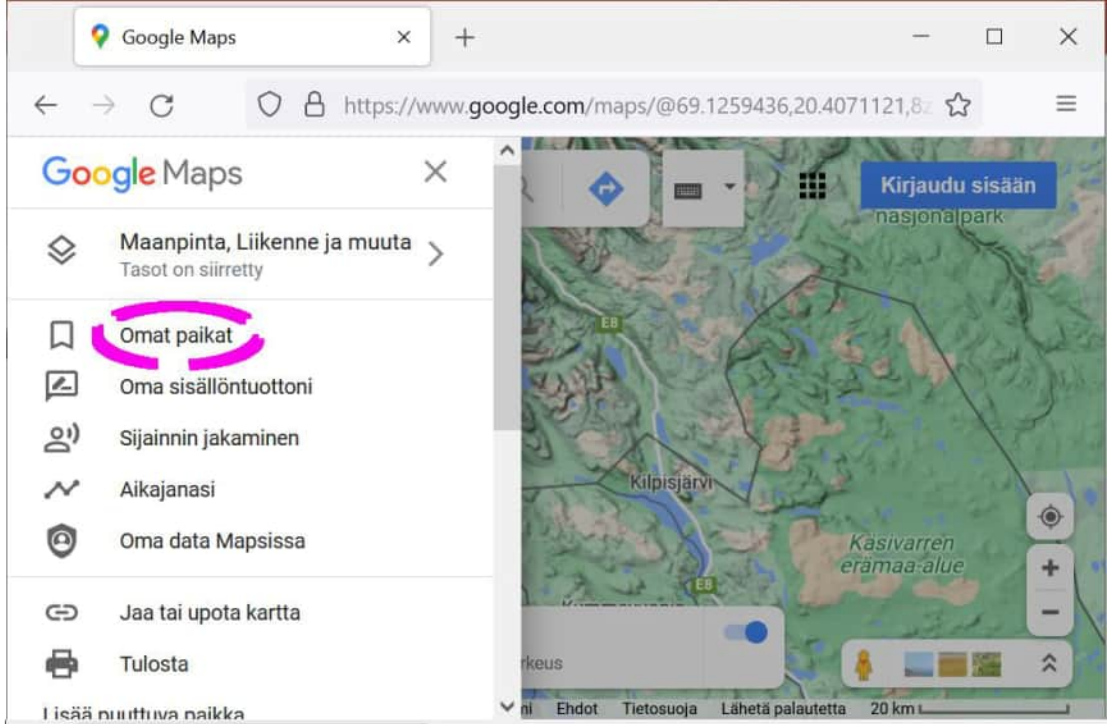


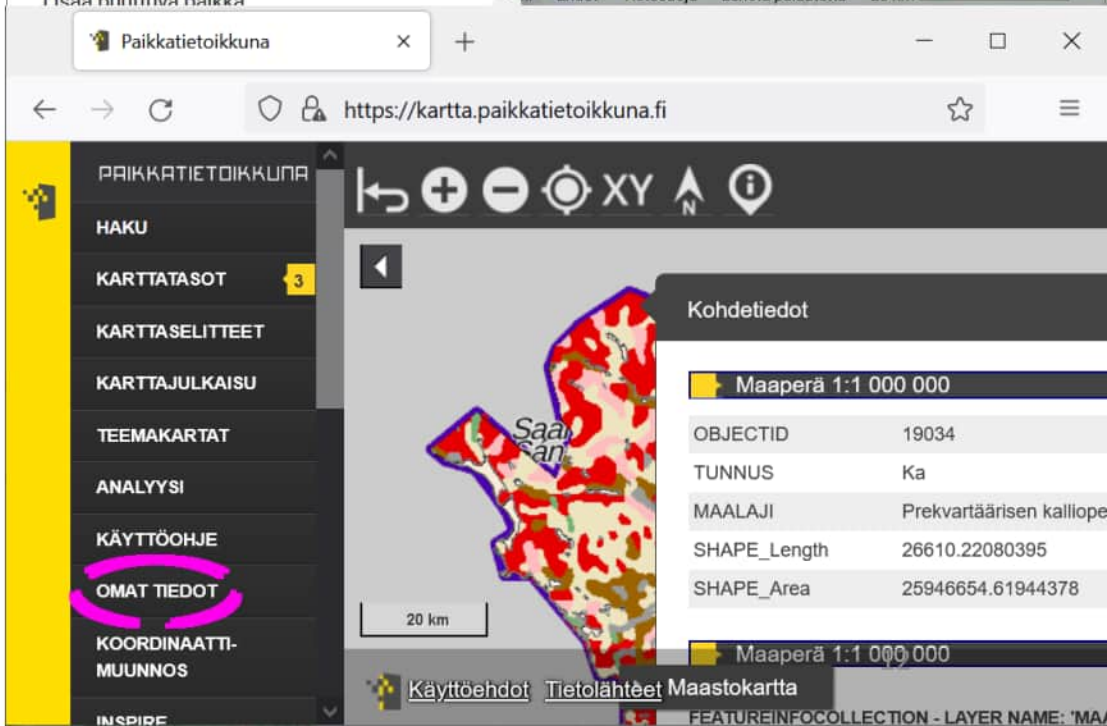
Building area
(Kettunen et al. 2023)

II Modern tools of map-making

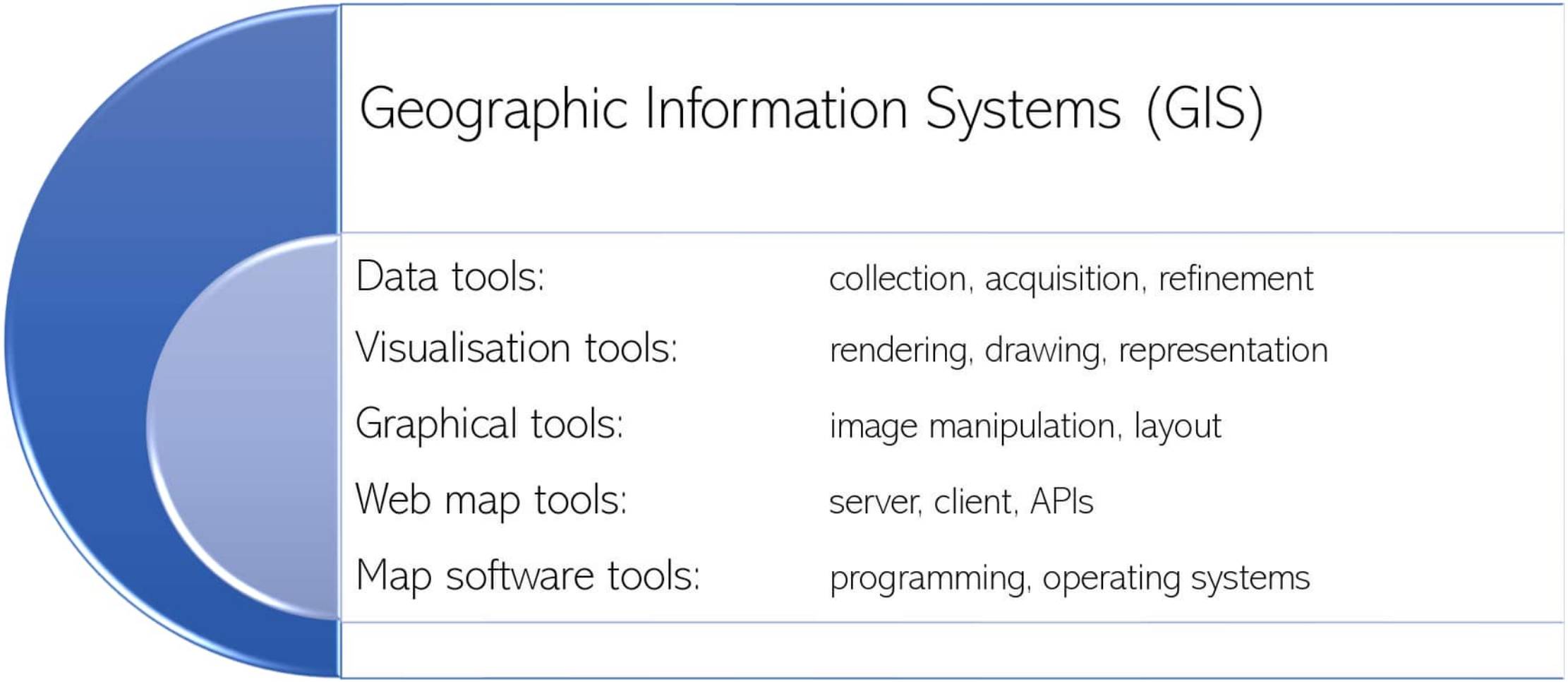
Everyone's map tools

- Digitalisation and particularly opened data has allowed map-making not only for cartography experts but also for wide crowds.
- Big Tech platforms
  - Google, Bing, Apple etc.
- Public map and data platforms
  - in Finland: Paikkatietoikkuna (kartta.paikkatietoikkuna.fi, oskari.org)





Cartographer's professional tools



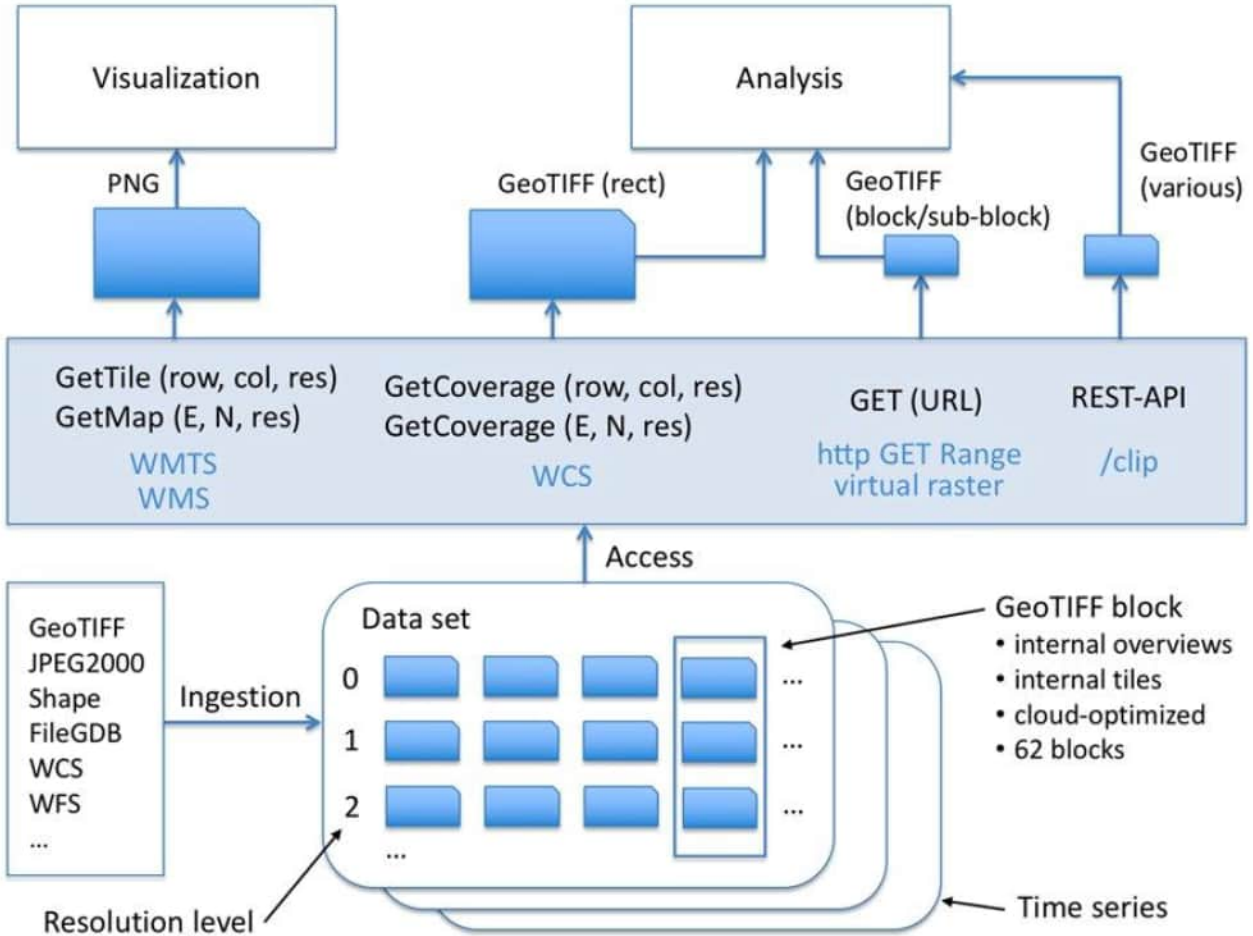
Free and open software

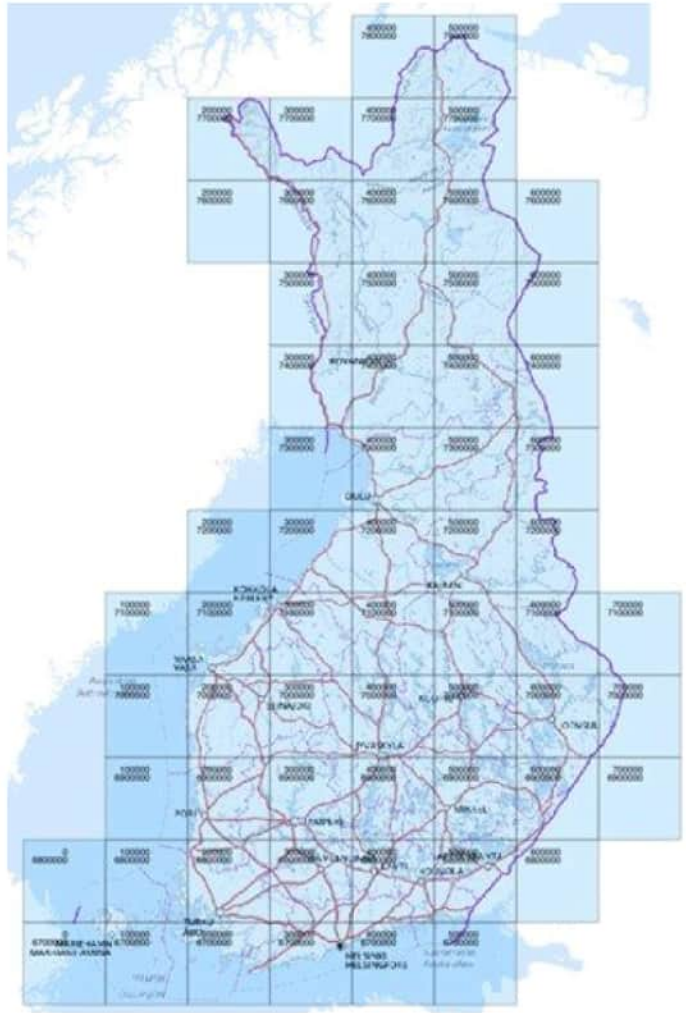
- Free (and Libre) Open Source Software (F(L)OSS).
- Become increasingly common and serviceable also in GIS
  - FOSS4GIS
- Particularly fit for studies, reseach and development due to their malleability.
- Counterforce to the traditionally weak transparency and market locks of the proprietary commercial software.

Geoinformatic APIs

- Application Programming Interface (API)
- Internet interfaces for tying together geoinformatic data and services
- Open Geospatial Consortium
  - open standard APIs, such as Web Map Service (WMS), Web Feature Service (WFS), Web Processing service (WPS), …
- Vector tiles
- Data cubes
- Data lakes
- Data spaces

Geocubes Finland





Lehto et al. 2000s

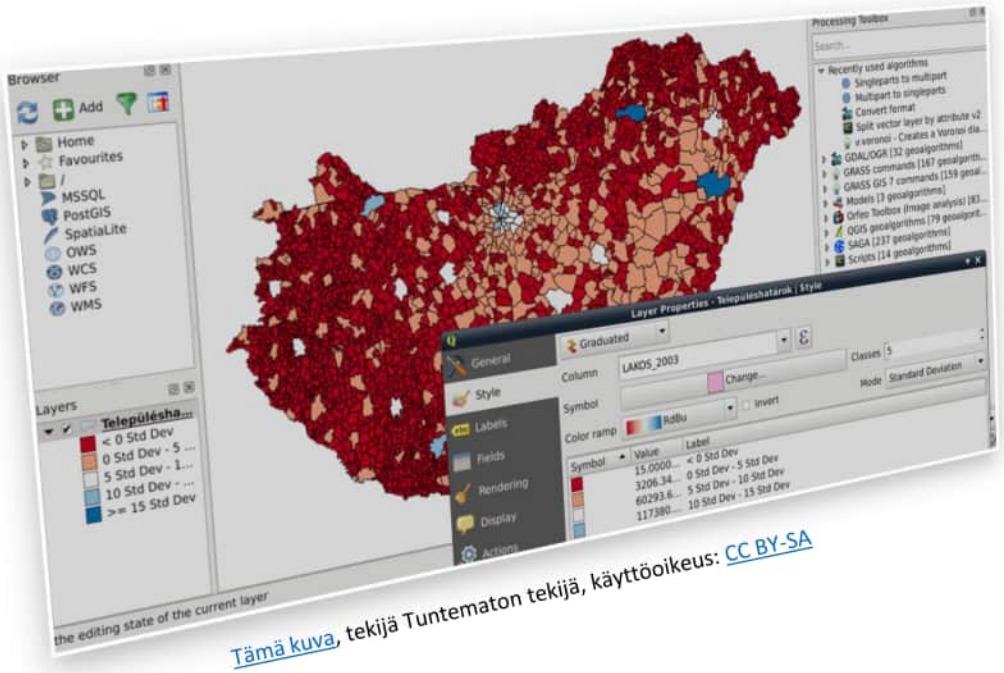
Map scripting

Interactive geoinformatic operating with graphical user interfaces

- \+ ready functionalities for small and large tasks
- – human forgetting of complex workflows
- – inflexible instructions on model workflows

→ Agile scripting

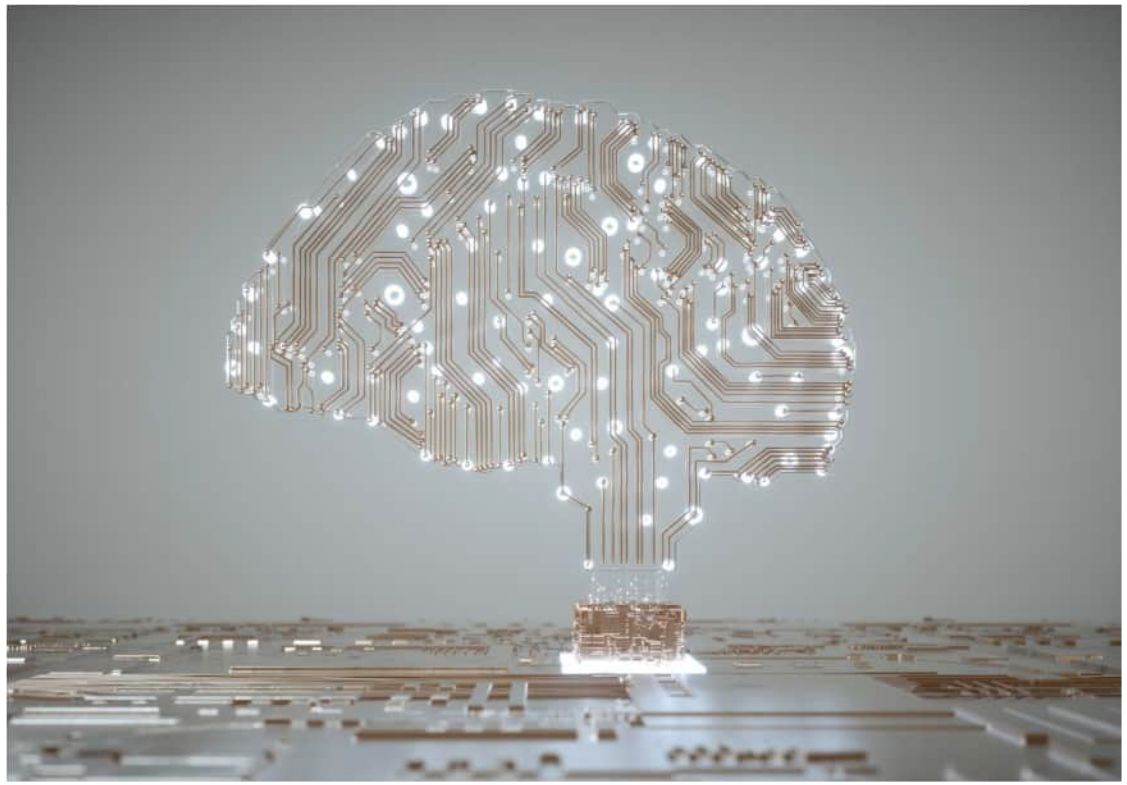
- \+ high-level programming languages: Python, JavaScript, terminal scripts
- \+ preservation of workflows in scripts
- \+ easy modification of scripts for new purposes
- – small threshold as for programming



Artificial intelligence in map-making

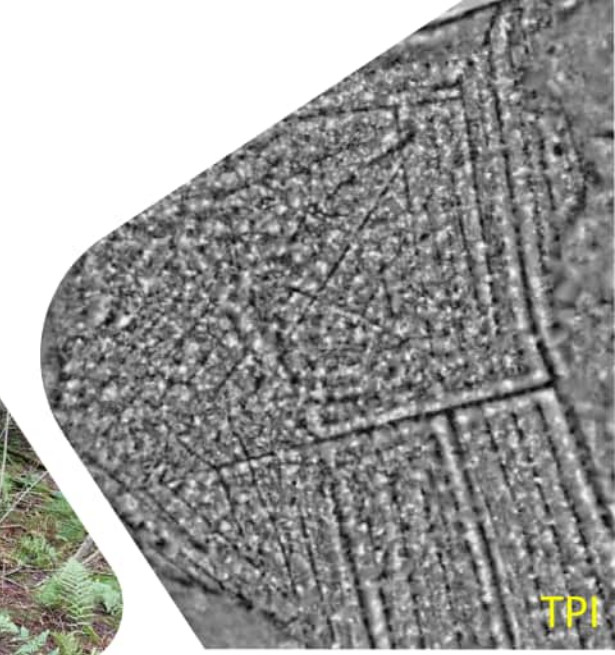
- Image interpretation.
- Feature extraction.
- Clustering.
- Quality of data is highlighted.
- Striving for homogeneity in GIS analyses requiring human expertise.
- Human must understand how AI has operated on and analysed the geoinformatic data.

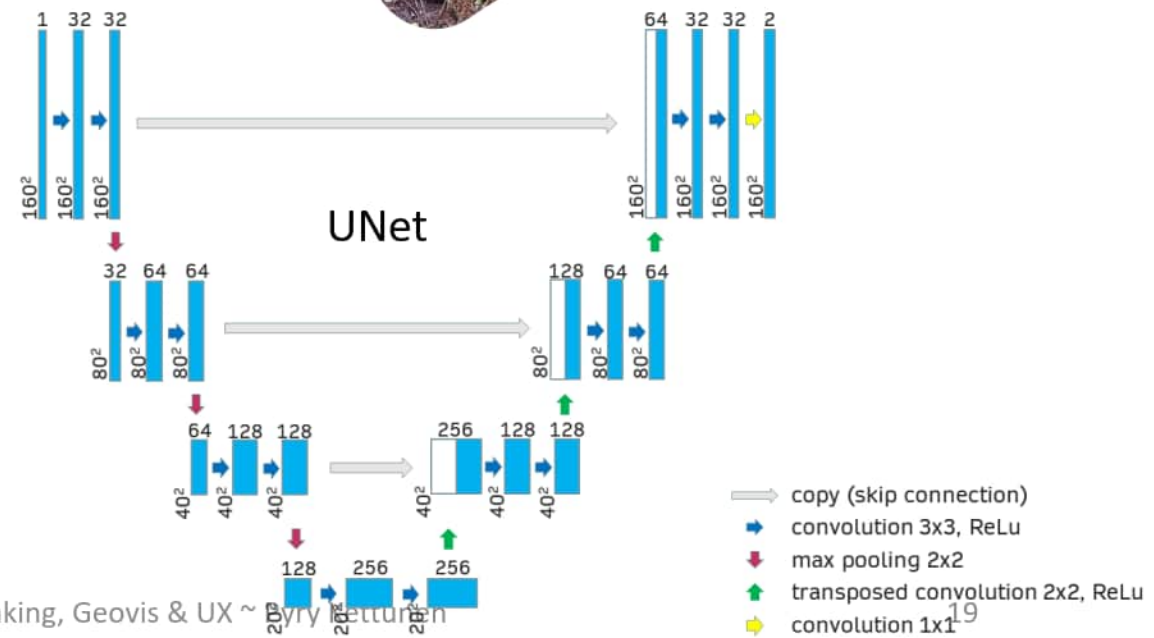
- Spatial knowledge is so elementary for human action.
- Human does not necessarily want to outsource understanding their environment.



Case: Machine vision mapping of ditches and watercourses

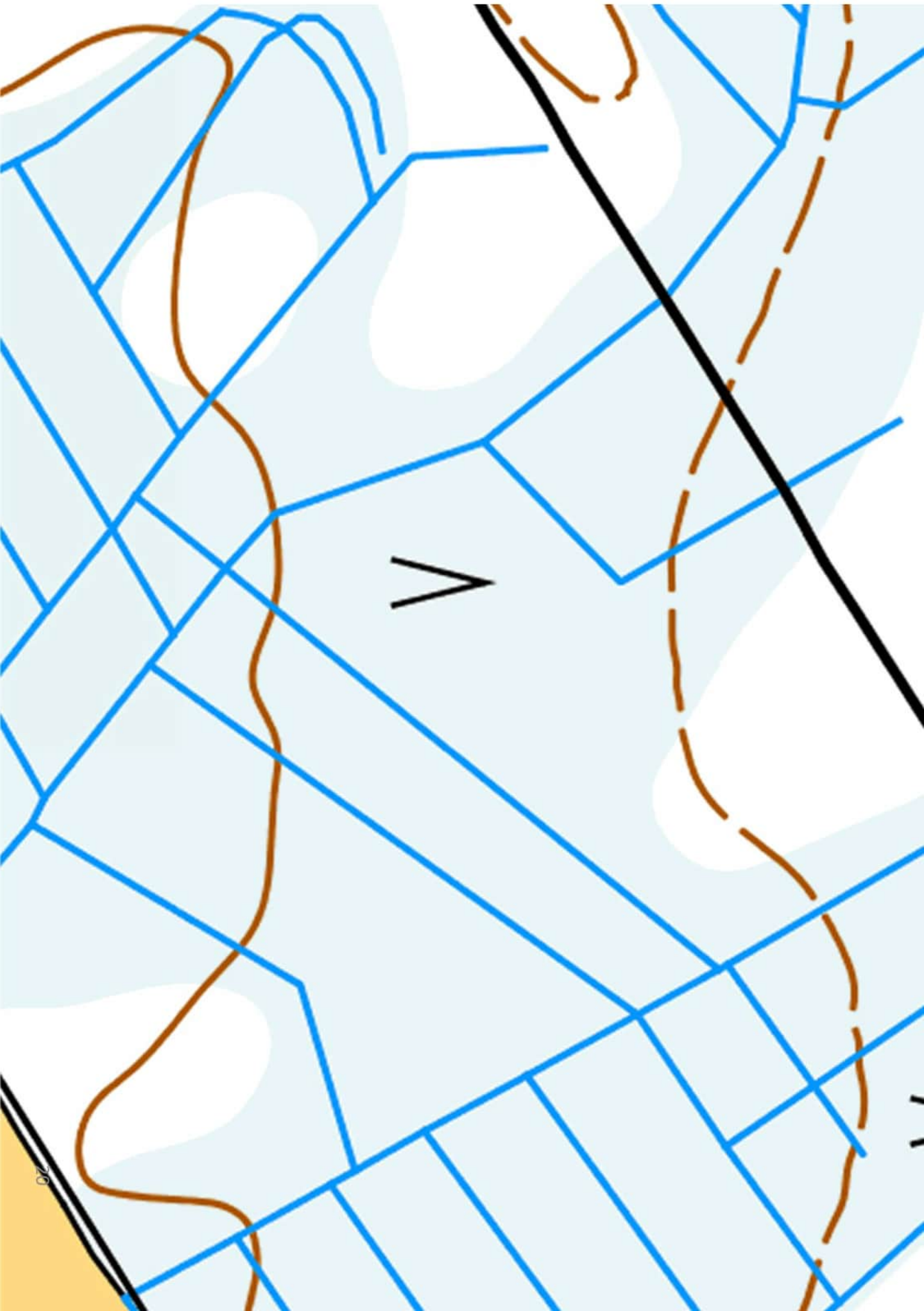
- Vast quantities to be mapped throughout the country and the situation changes continuously.
- Neural networks for machine vision are very fit to recognise watercourses, particularly ditches that are relatively regularly shaped.
- However, variation in the shapes of ditches causes challenges.





20.5.2025

NLS Topographic map



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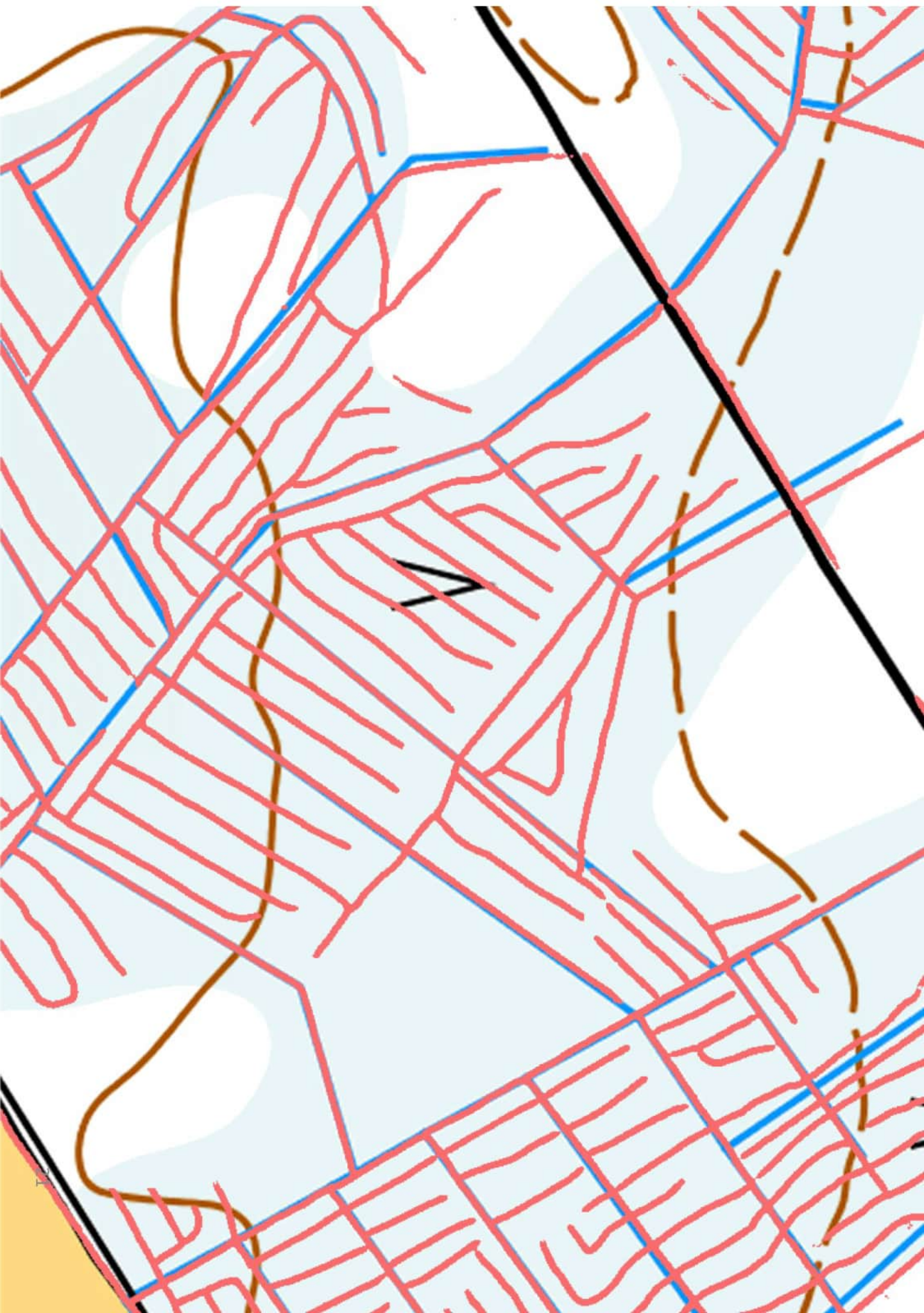
Recognised ditches from the supervised neural network

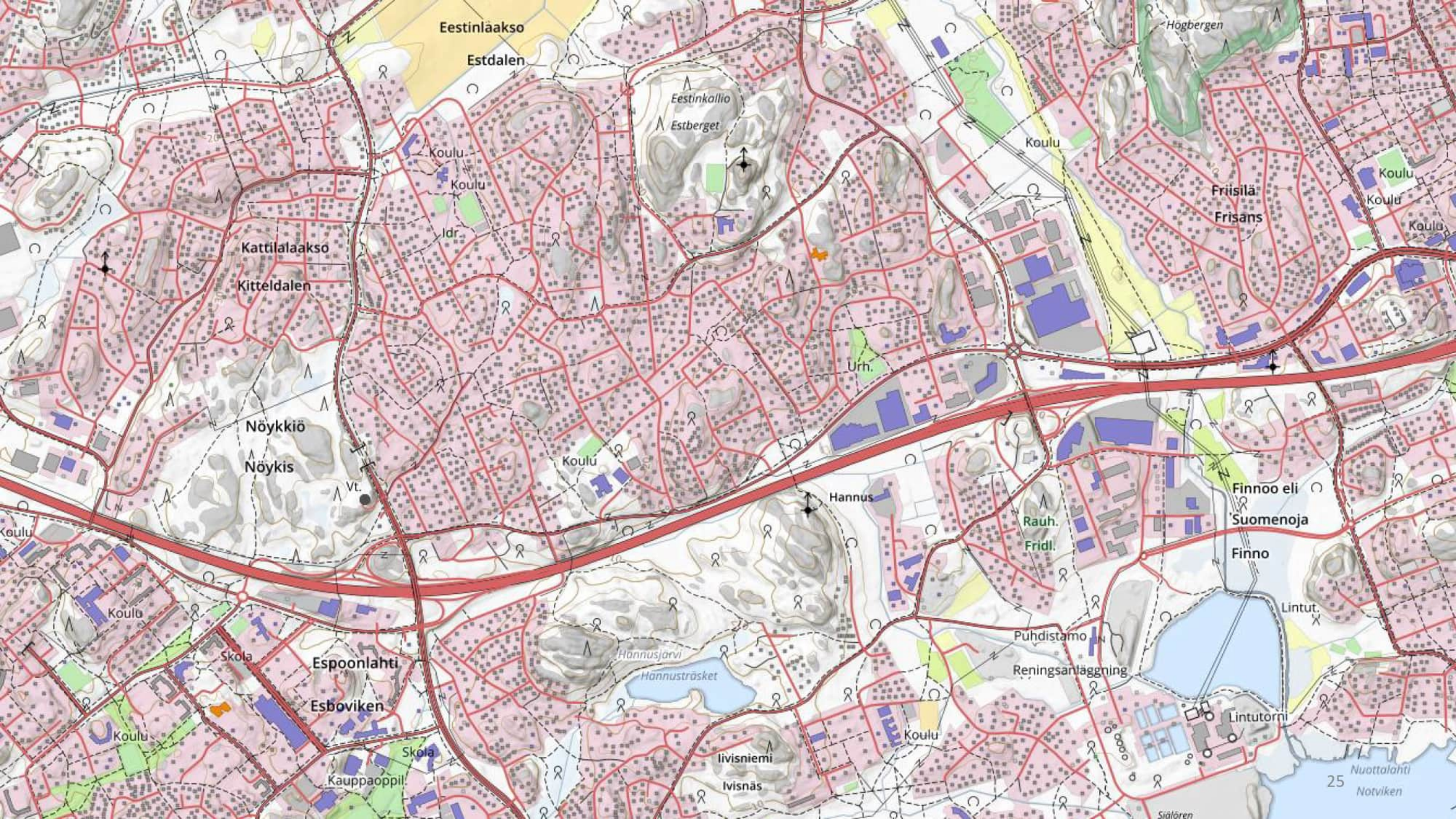


III Map design

Drivers of map design

- User and purpose of the map in the core of the design:
  - Why is the map made?
  - Who does the map serve?
  - How will the map be used?

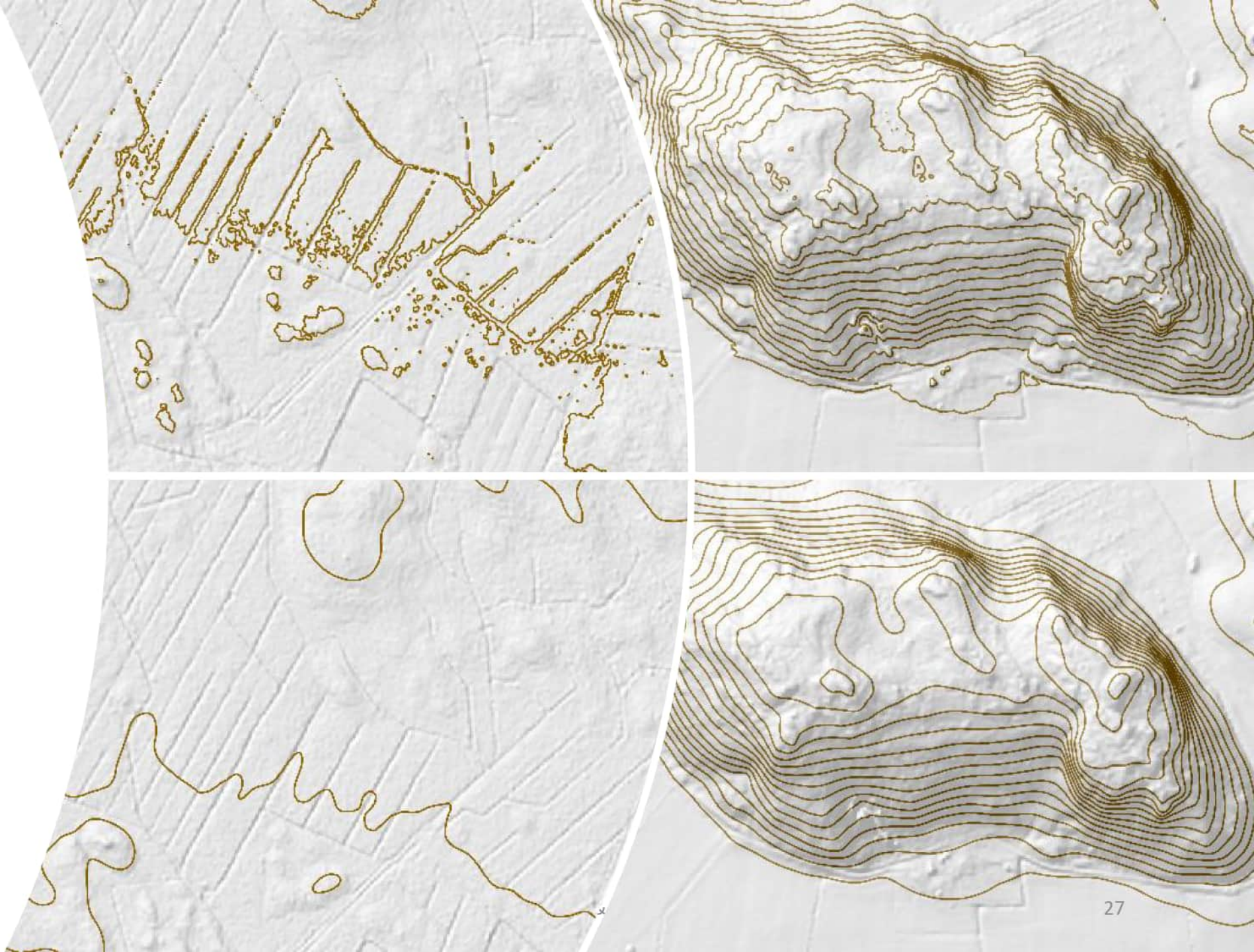

Ollila
Tervalampi
Saarijärvi
Luukki
Keimola
Seutula
Korso
Nikinmäki
VANTAA
Tikkurila
Kuninkaanmäki
Siikajärvi
Nuuksio
Veikkola
Myyrmäki
Bodominjärvi
Nupuri
Malmi
Hakunila
Itäsalmi
KAUNIAINEN
Haaga
Viikki
Kauklahti
ESPOO
Munkkiniemi
Tapiola
Humaljärvi
Nöykkiö
Matinkylä
Masala
Lauttasaari
HELSINKI
Villinki
Soukka
Suomenlinna
Santahamina
Melkki
Tanskarla
Suvisaaristo


Eestinlaakso
Estdalen
Eestinkallio
Estberget
Koulu
Idr.
Kattilalaakso
Kitteldalen
Nöykkiö
Nöykis
Vt.
Hannus
Urh.
Hogbergen
Friisilä
Frisans
Finnoo eli
Suomenoja
Finno
Rauh.
Fridl.
Lintut.
Puhdistamo
Reningsanläggning
Lintutorni
Hannusjärvi
Hannusträsket
Espoonlahti
Esboviken
Skola
Kauppaoppil.
Ivisniemi
Ivisnäs
Nuottalahti
Notviken
25


Pikku-Malla
Šilismalla dahjege
Gilbbesmalla
Siilaskoski
Maantielahti
Ahkioniemi
Viikinvainio
Siilastupa
Saunaniemi
Kaakkurilantto
Čáhppesláttu
Gáhkkorjávrráš
Mallanniemi
Mallanjárga
Porosaari
Boazosuolu
Kalottireitti
Kalohttamáđi
Skirhasjohka
Skirhasgaska
Skirhasvággi
Kilpisjärvi
Gilbbesjávri
Rajavartioasema
Retkeilymaja
Venesatama
Saana
Sáná

Elevation contours

- Representation known since 16th century.
- Automatic extraction from the digital elevation model makes contours too meandering for the map reader (upper pictures).
- Our developed adaptive DEM smoothing creates more readable representation (down pictures).
- Research article read in the internet 9000+ times, algorithm widely implemented in global software (Kettunen et al. 2018).

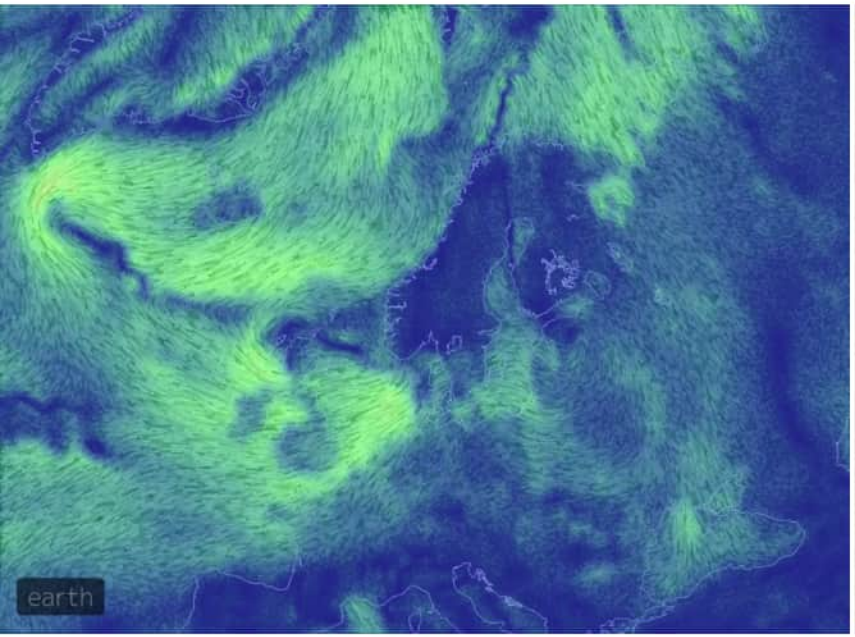


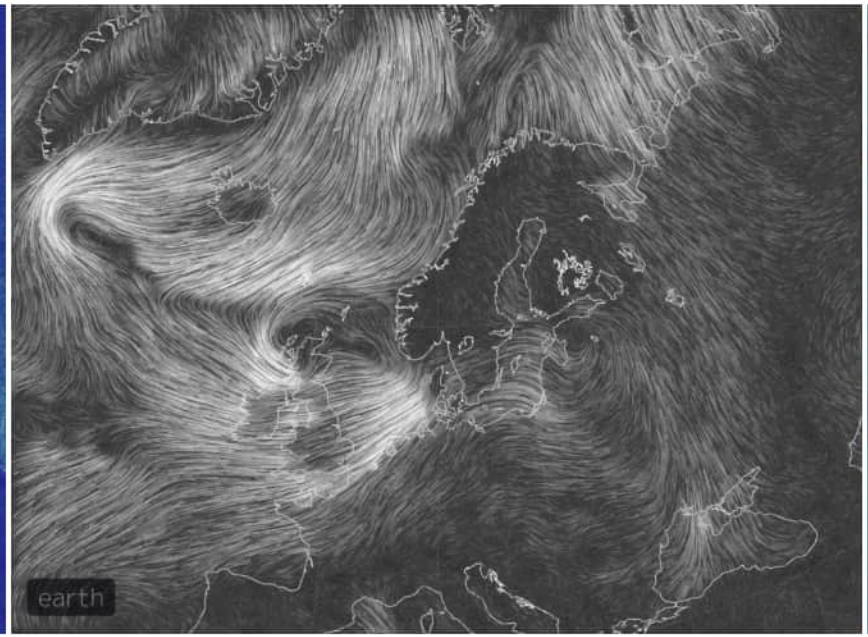
Animated maps

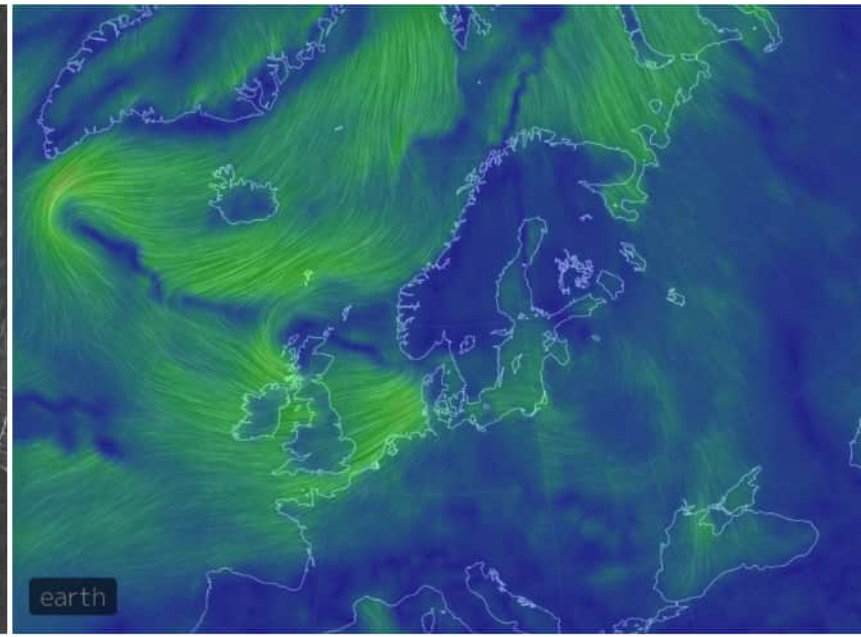
1. Animation of time
   - real-world time shown in condensed map time.
2. Time-independent animation
   - animation of momentary data for impressive illustration.
   - facilitating the understanding of map by consequent visualisation of map features.


VUOSI / ÅR / YEAR: -5000
Kiiminki
Hailuoto
OULU
Oulunsalo
Kempele
Puolanka
Lumijoki
Liminka
Muhos
Tyrnävä
Utajärvi
RAAHE
Ruukki
Vaala
Pyhäjoki
Vihanti
Paltamo
Merijärvi
OULAINEN
Pulkkila
KAJAANI
Alavieska
HAAPAVESI
YLIVIESKA
Fyhäntä
Copyright © 2012 Juha Oksanen ja Geodeettinen laitos
Korkeusmalli: Copyright © 2012 Maanmittauslaitos, lupa 165/MML/12

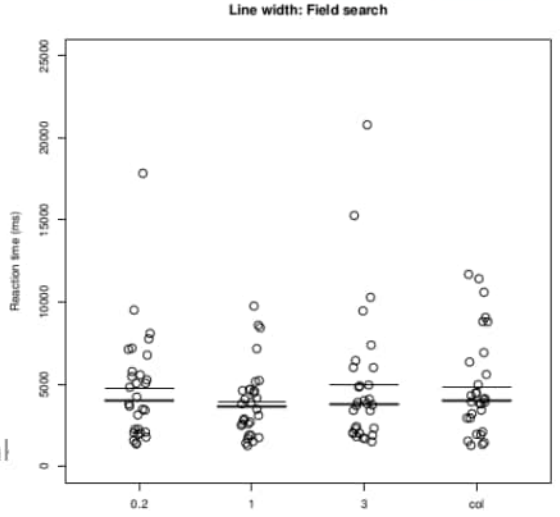
Usability of map animation

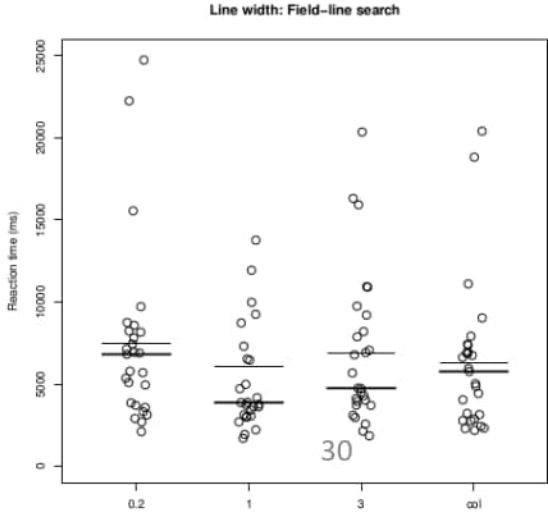






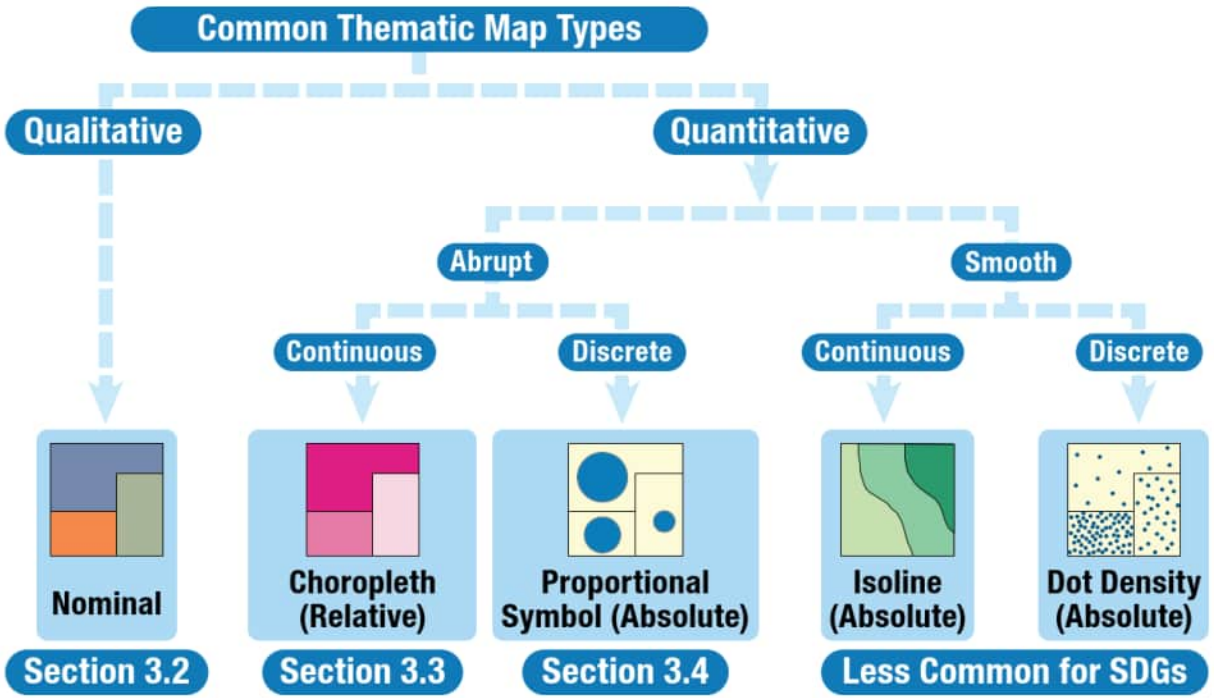
- Graphical parameters of the animation can be modified surprisingly freely without affecting its readability and interpretation.
- Similar performance level in the laboratory and over the Internet.
- Research articles Kettunen and Oksanen (2019):
  https://doi.org/10.1080/15230406.2018.1553113
  https://doi.org/10.4230/LIPIcs.GVIZ.2018.7

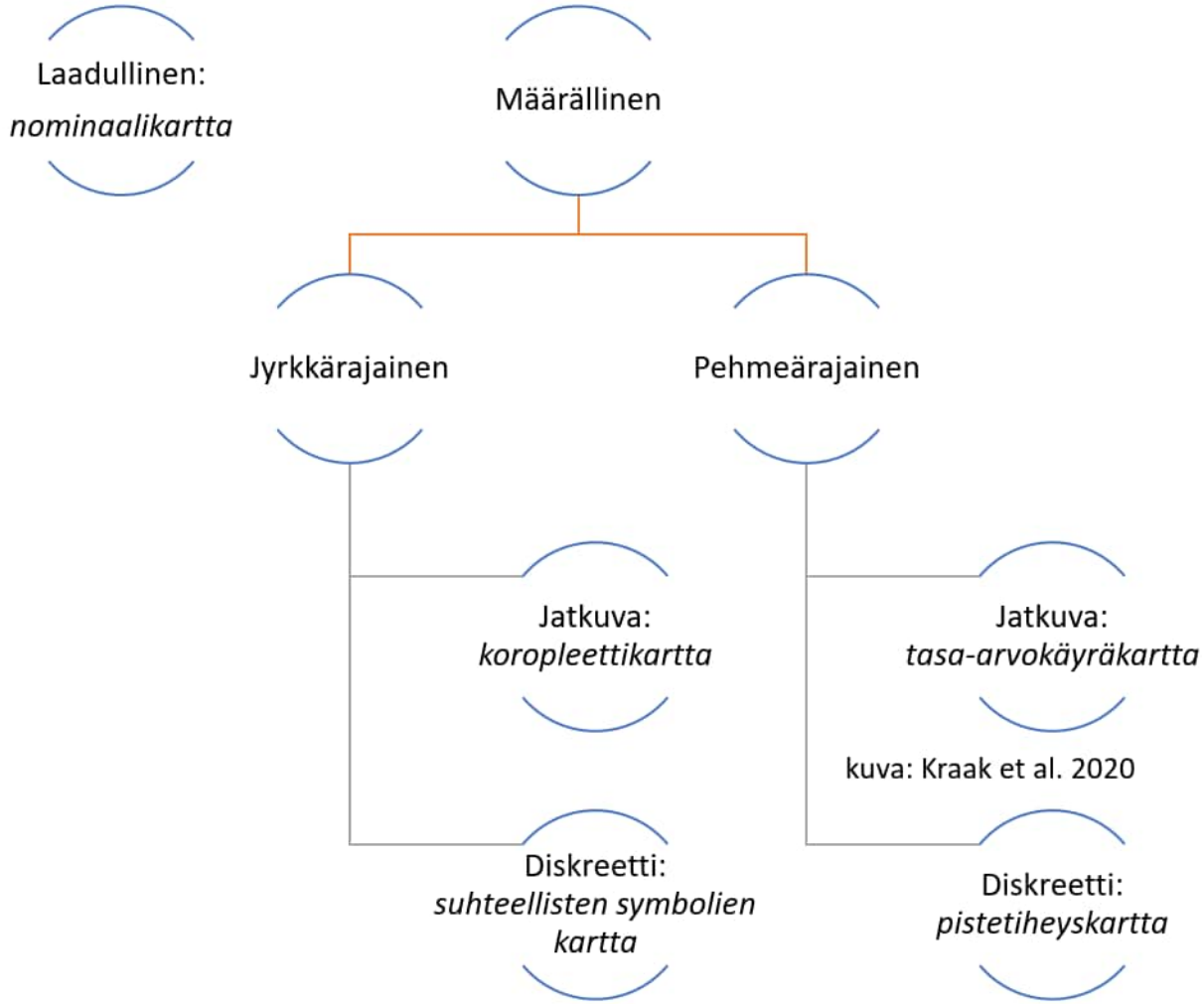




Thematic maps

- Thematic map combines attributes and locations of geospatial features.





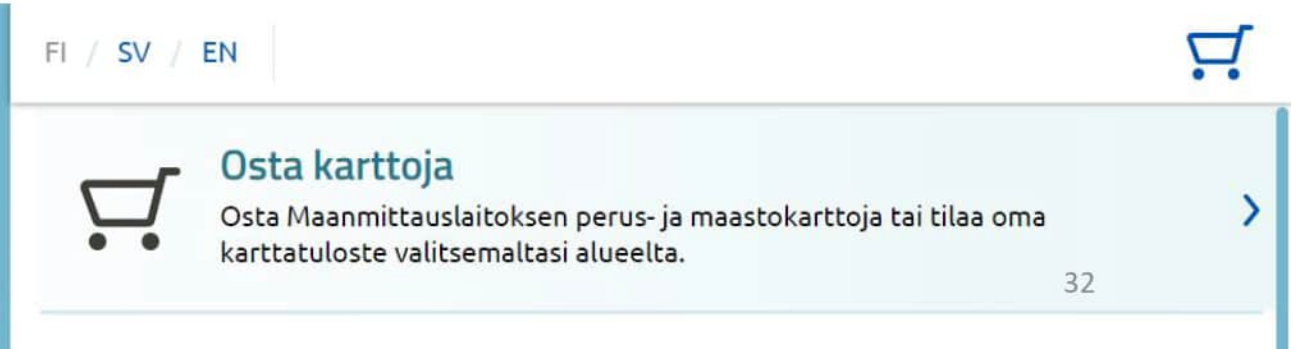
kuva: Kraak et al. 2020

Paper and printed maps

- Viewing the map both from a close and far distance.
- Purposeful to include more feature classes than on digital interactive maps.
- Choice of paper.

- Graphical finishing in emphasis:
  - image manipulation and layout.

- *NLS Karttapaikka (Map Place) allows variety of printing materials (incl. tissue)*
  - https://asiointi.maanmittauslaitos.fi/karttapaikka/



“Kartalle pääseminen” selkokartasta oli haastavaa

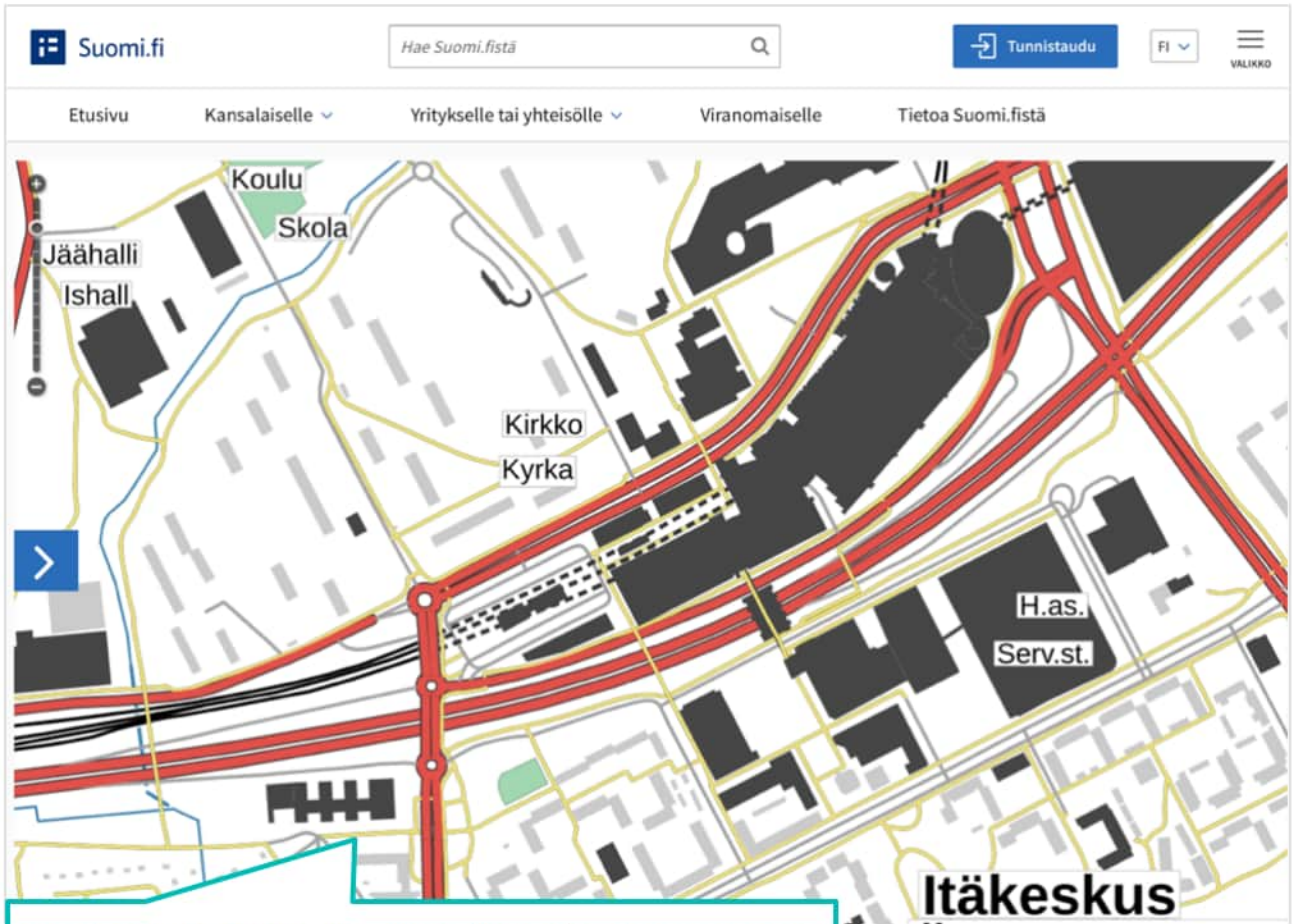
Keltaiset kevyen liikenteen väylät tunnistettiin hyvin ja niiden erillistä väriä pidettiin hyvänä.

Tien nimiä (ainakin pääteiden osalta) haluttiin näkyviin jo paljon aikaisemmilla zoomaustasoilla – etenkin kun kaikki eivät ymmärtäneet zoomata ollenkaan tai riittävästi.

Tunnettujen maamerkkien osalta hämäsi se, ettei aina näytetty nimeä lainkaan. Vrt. kuvan kartalla Itis-kauppakeskus ja Iiris-keskus, joista jälkimmäinen jopa tuttuna kohteena tunnistettiin usein vasta pidemmän ajan jälkeen lähinnä rakennuksen muodosta.

Osa hämääntyi myös siitä, että teksti Itäkeskus ei ollut kauppakeskuksen ja metroaseman yhteydessä, joiksi Itäkeskus usein enemmän miellettiin. Ei välttämättä heti ajateltu, että se voisi tarkoittaa myös laajempaa aluetta.

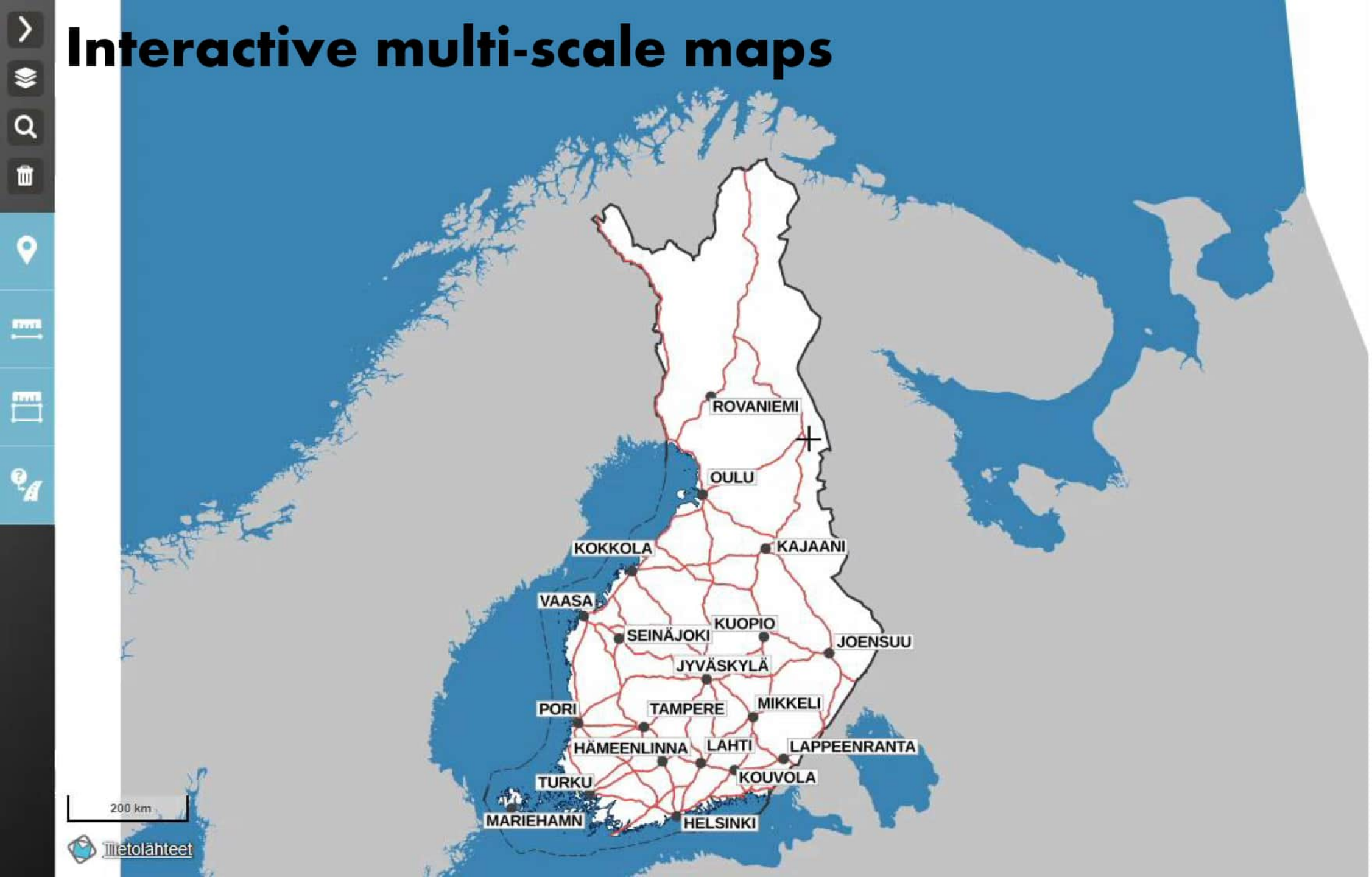
Kaksikielisyyden asemesta yksi käyttäjistä suositteli kieliasetuksen vaihtamista näyttämään jompaa kumpaa, suomea tai ruotsia. Nykyinen ratkaisu syö tilaa kartalla ja joissain tilanteissa aiheuttaa sen, että vain toinen teksteistä on oikean rakennuksen päällä ja toinen täysin väärässä paikassa.



Osa kehui rakennusten ja muiden kohteiden, kuten rantojen tunnistettavia muotoja. Joku löysi myös pitkospuut kartalta – niiden merkitseminen koettiin positiivisena.

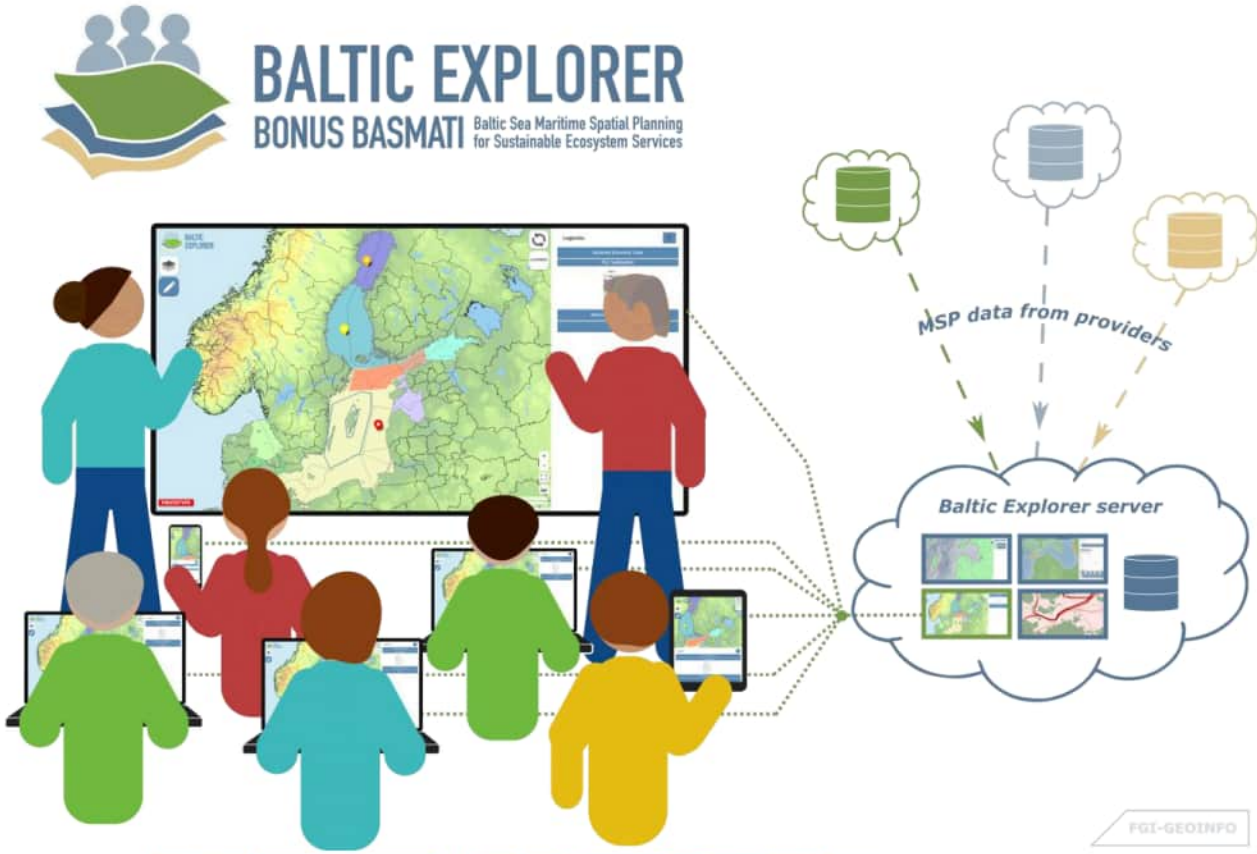
IV Map user interfaces

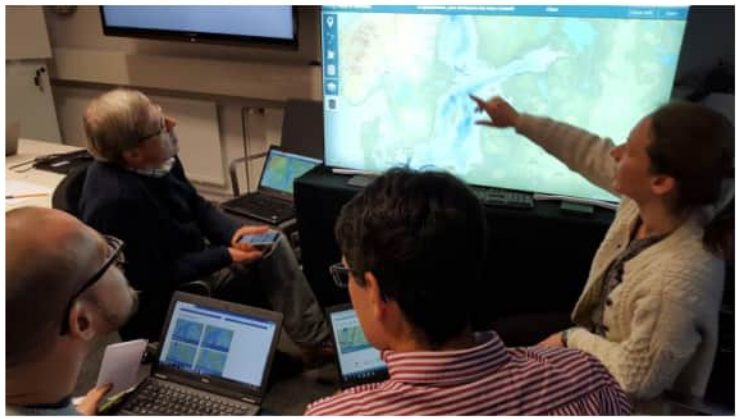
Interactive multi-scale maps



Collaborative geographic information systems

- Multi-purpose and multi-device interactive web map platform.
- Particularly for palm-size and large displays.
- Purpose: planning of activities employing stakeholder participation.
- Published as free and open software.
- https://balticexplorer.eu
- Research articles Koski, Rönneberg, Jussila, Kettunen et al. since 2020.





BALTIC EXPLORER

WEB MAP APPLICATION

FOR COLLABORATIVE

MARITIME SPATIAL PLANNING

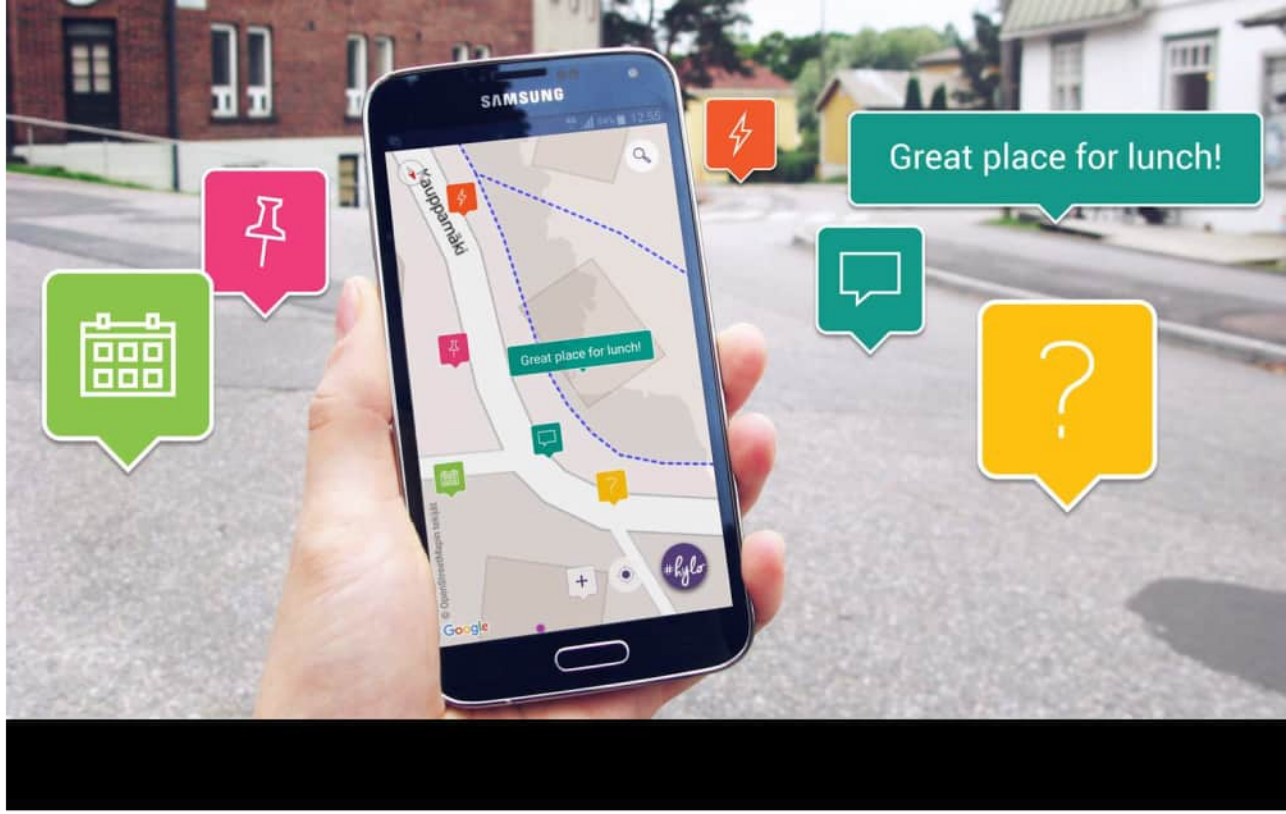
https://balticexplorer.eu

Video:

Geosocial networks

- Geospatial platforms for sharing and crowdsourcing geoinformation
  - communities
  - sharing
  - commenting
  - evaluation.

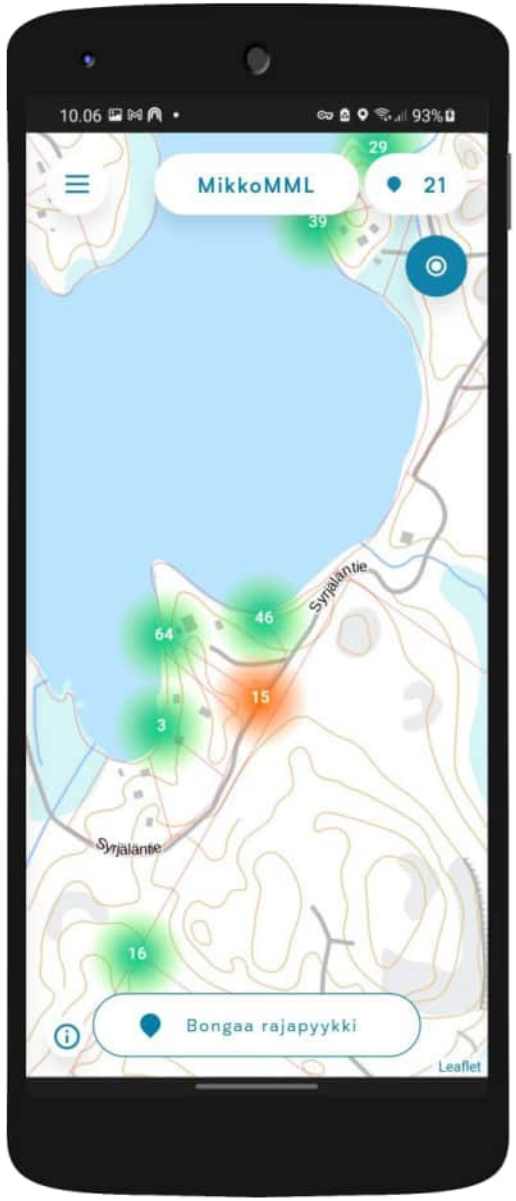
Video:

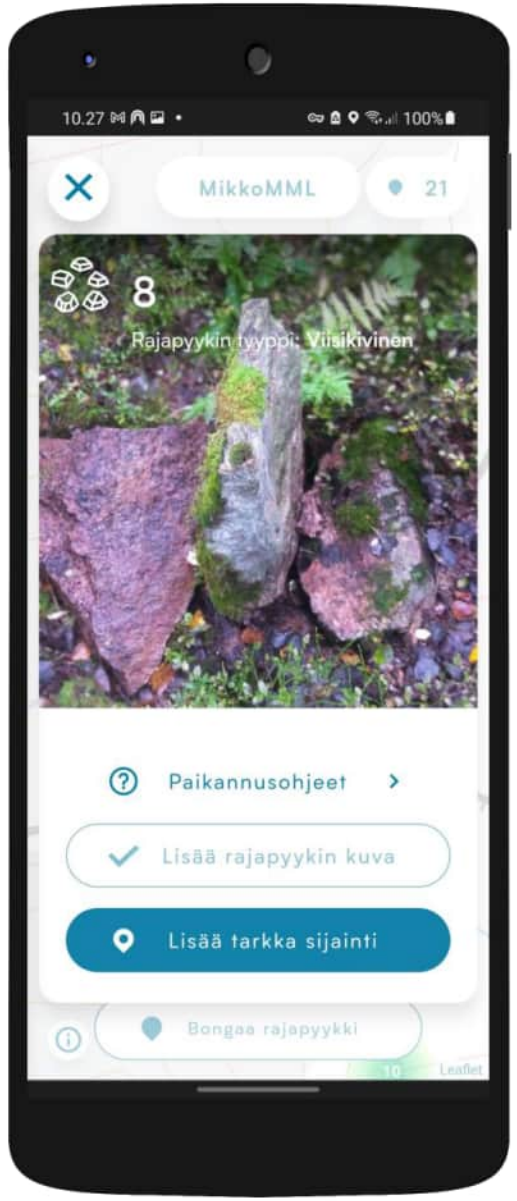


What's going on in your favorite places?

Crowdsourcing map-making: case Marker Quest (Pyykkijahti)

- Game for enhancing location accuracy of border markes in the Finnish cadastral index map by crowsourcing.
- Players measure inaccurate markers in the terrain *or* mark them missing.
- June 2021 – September 2022
  - 4 500+ users.
  - 30 000+ contributions.
  - 82% considered Pyykkijahti pleasant or very pleasant experience (n=402).





V Scientific research of map use

About scientific history of cartography

- Skills- and arts-based science since human learned to draw
  - map master – map student
  - slow step-wise development of map-making principles
- Applied always perceptual fysiology and communication sciences, e.g. psychology since its emergence in the end of the 19th century
  - e.g. Wertheimer, 1923. Laws of Organization in Perceptual Forms. *A Sourcebook of Gestalt Psychology*.
  - *spatial cognition*
- Big cartography textbooks
  - Eduard Imhof, 1965. *Kartographische Geländedarstellung.*
  - Jacques Bertin, 1967. *Sémiologie graphique : les diagrammes, les réseaux, les cartes.*
- Empirical cartography since 1970s
  - new wave 2000-10s

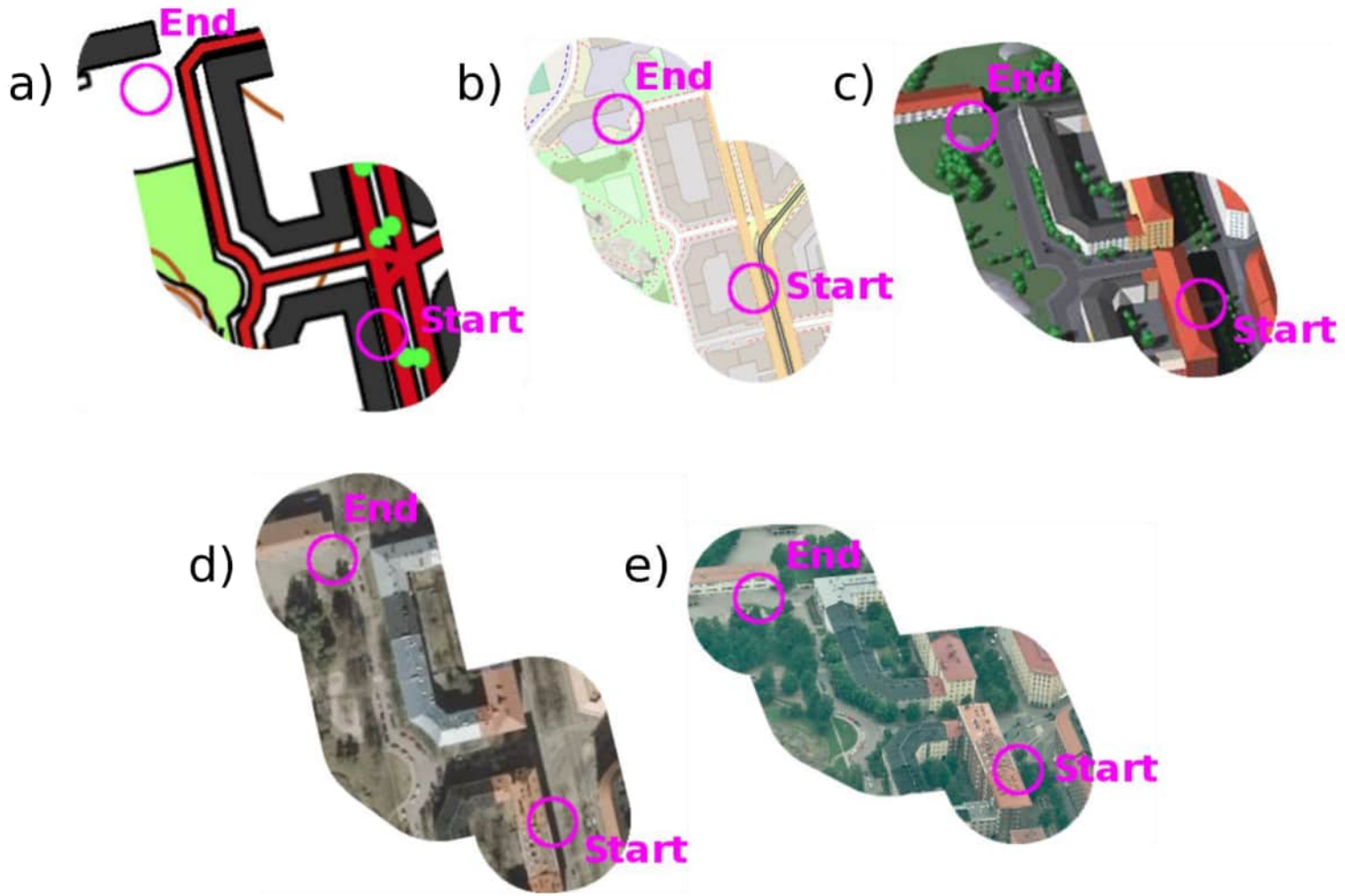
Spatial cognition

- Understanding human thinking lying under the use of geospatial representations.

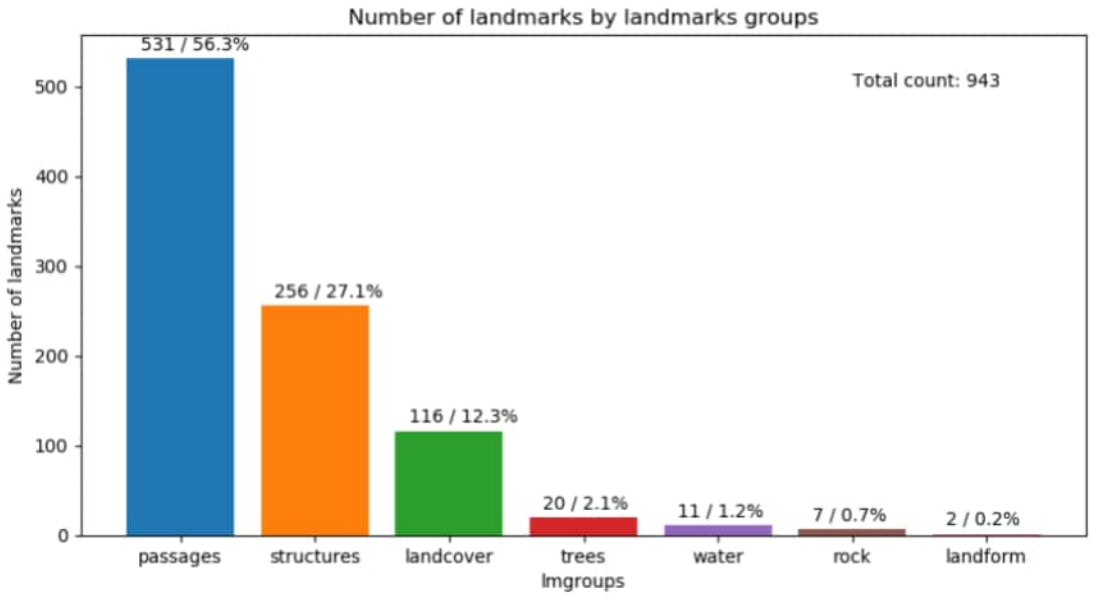
- Landmarks.
- Wayfinding.
- Map reading.

- Empirical research.

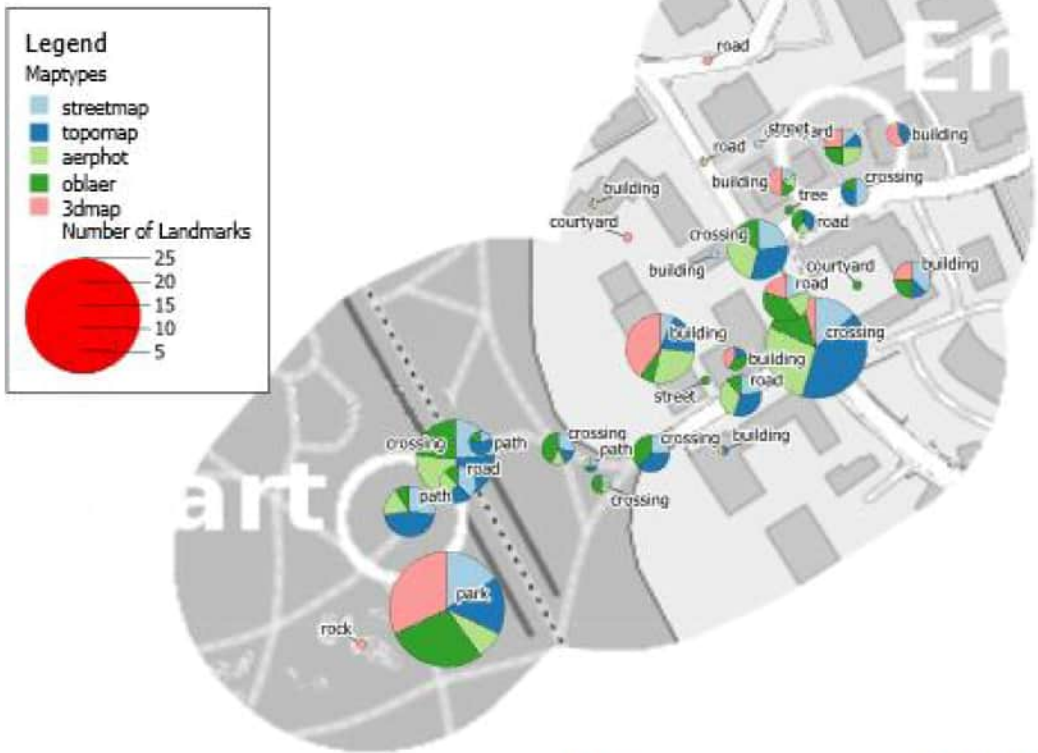
- See my dissertation https://aaltodoc.aalto.fi/handle/123456789/14049

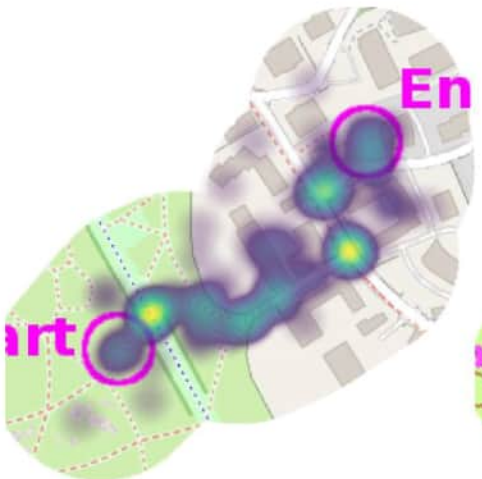


Route planning experiment
(Kettunen et al. 2018)

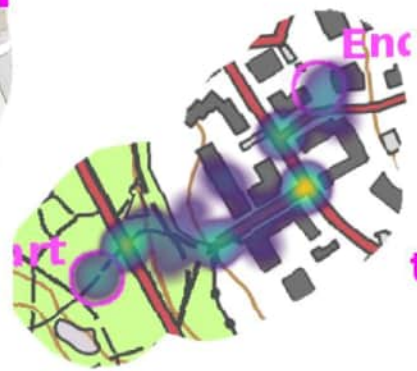


Repartition of the selected landmarks: all maptypes



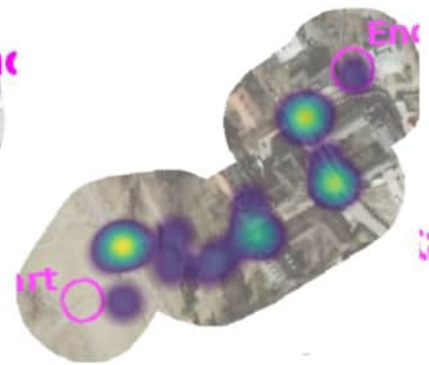


All geopicture types

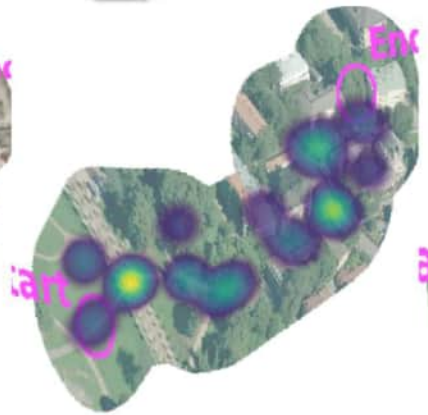


Topographic map

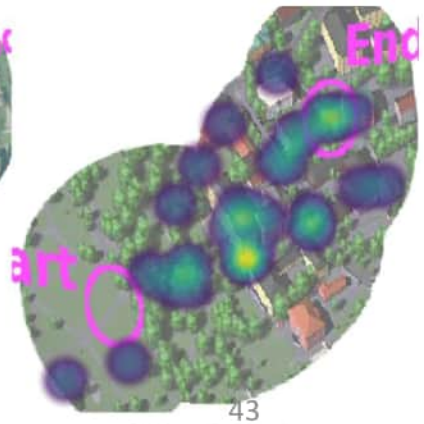
Streetmap



Aerial orthophoto



Oblique aerial photo



Oblique 3D drawing

Short history of spatial cognition research

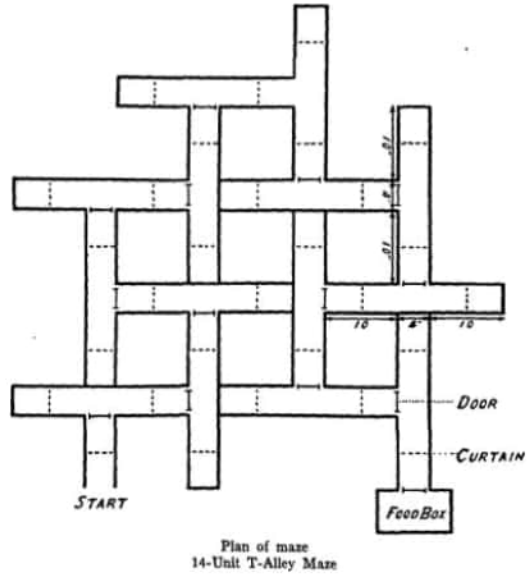
Armchair experiments of early psychology 1900–
- "imaginary maps" of Trowbridge (1913)

Behavioral experiments on animals (rats) 1920–
- inspired by Ivan Pavlov and his dogs

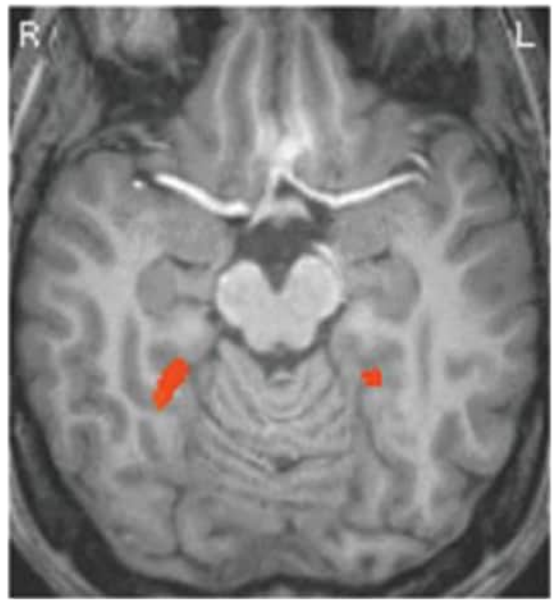
Cognitive map of Edward Tolman (1948)
- rats searching for food in a maze
- adaptation to the changes of the maze
- ability to take shortcuts

Model of spatial knowledge (Siegel and White 1975)
- landmark, route and configuration knowledge

Neuroimaging CAT, EEG, PET, MRI, fMRI 1970–
- search for the spatial neurons (Nobel prize 2014 O'Keefe, Moser and Moser)



Elliot (1928)



Janzen and van Turennout (2004)

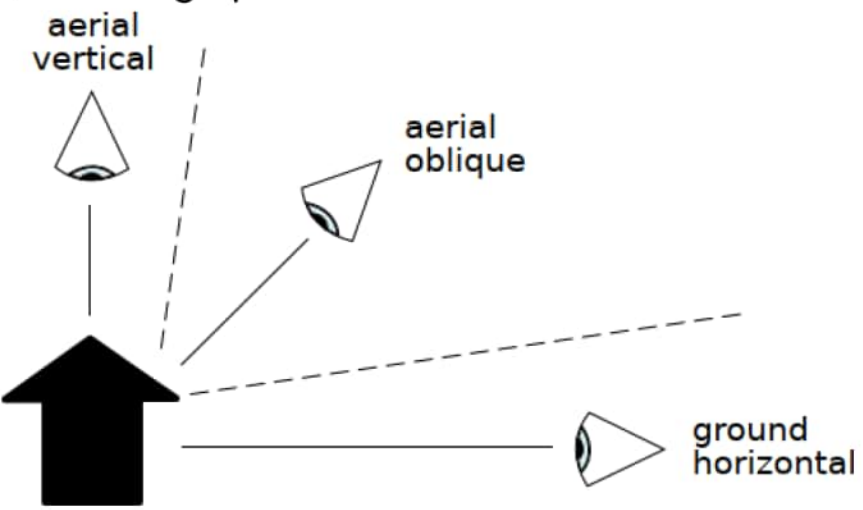
Spatial knowledge acquisition

Model established by Siegel and White (1975), refined by Ishikawa and Montello (2006):

1. **Landmark knowledge**
   - information for identifying landmark features
2. **Route knowledge**
   - sequential information about itineraries and surrounding landmarks
3. **Configurational knowledge**
   - structured information about features and their locations in the environment

Evaluation framework for spatial knowledge acquisition from geopictures (Kettunen et al., 2012)

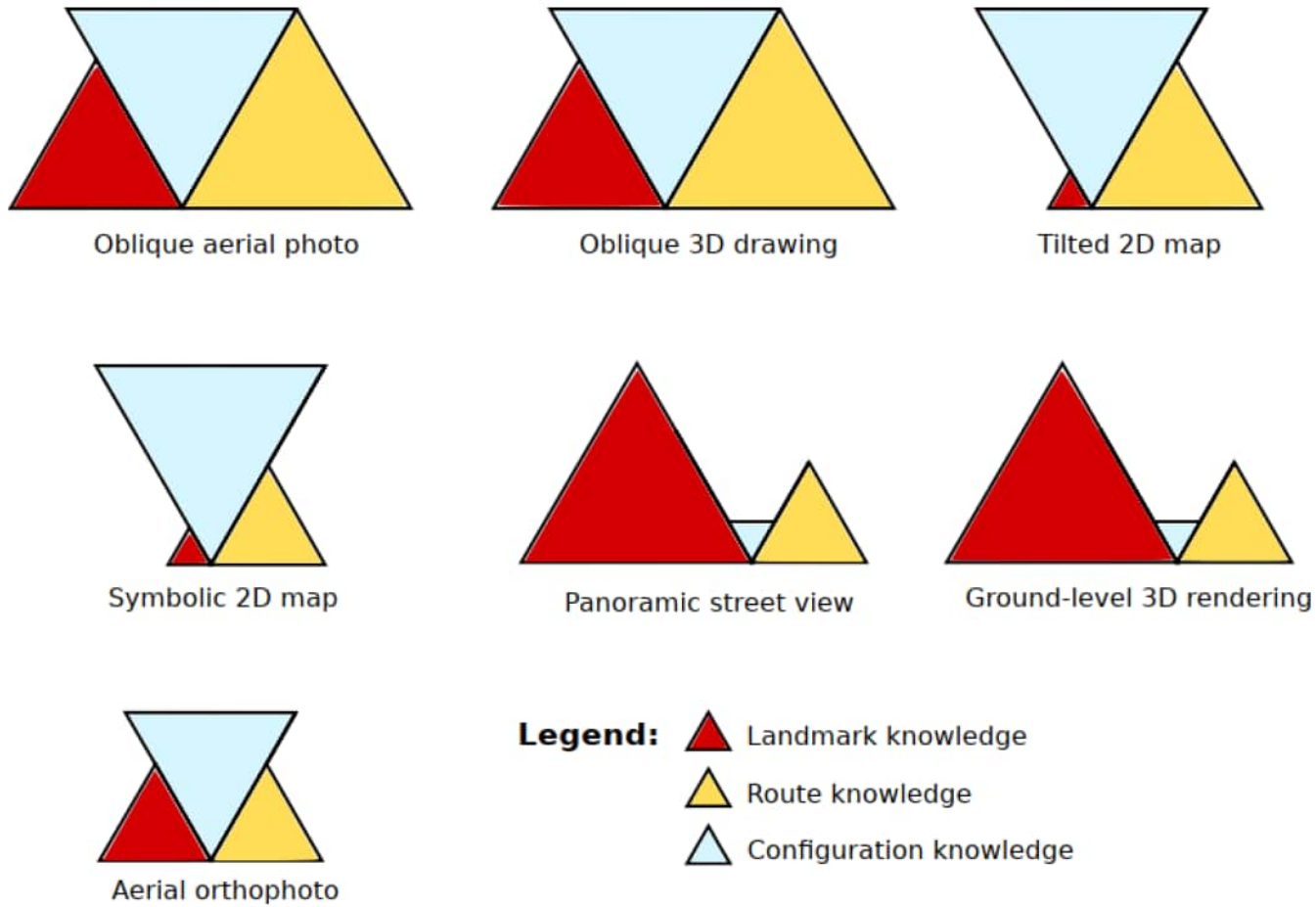
1. Vantage point



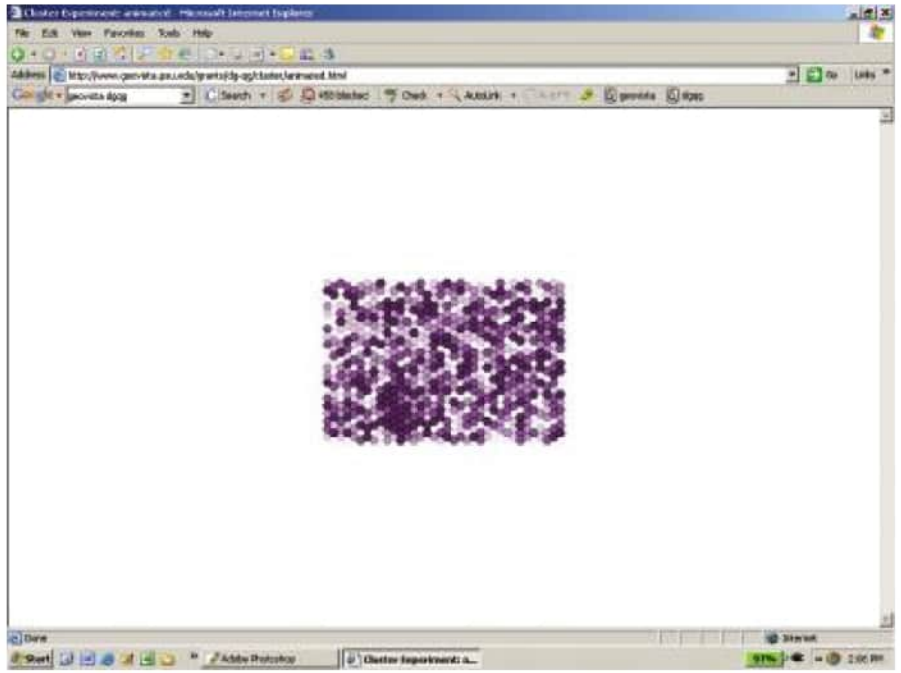
2. Visibility of vertical features

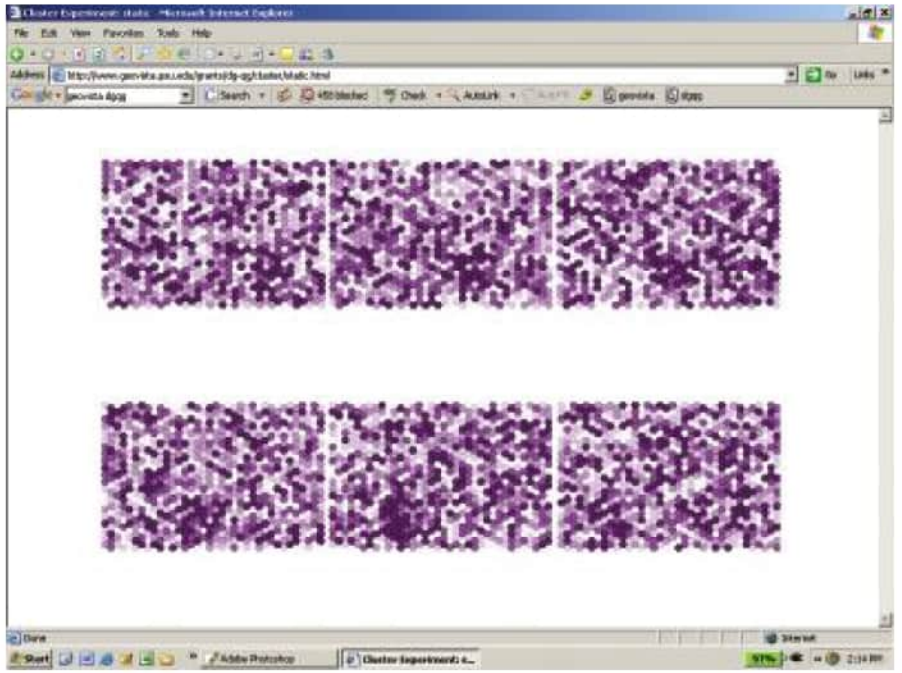
3. Visual realism

Spatial knowledge from common map types
(Kettunen et al. 2012)

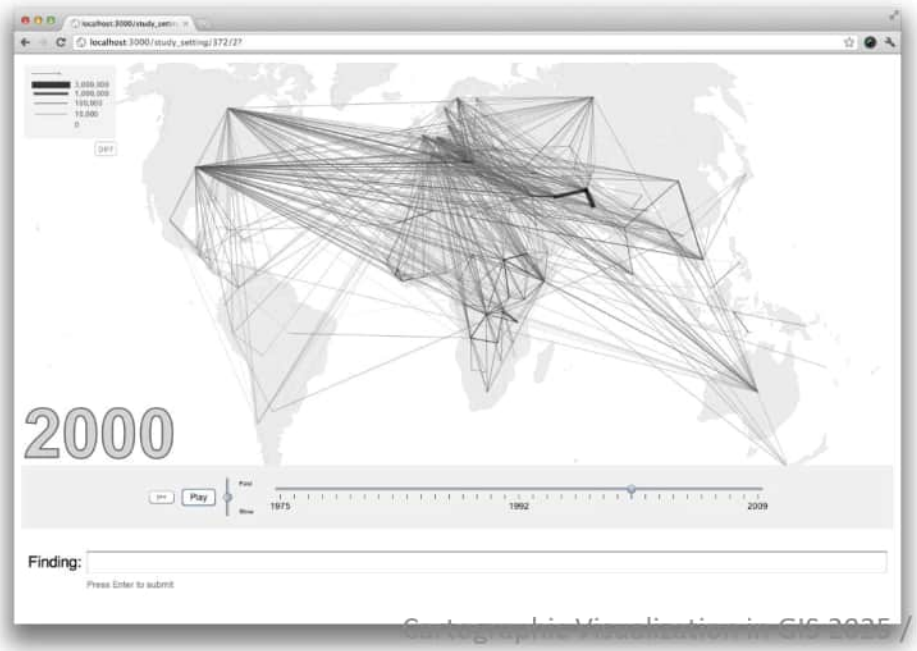


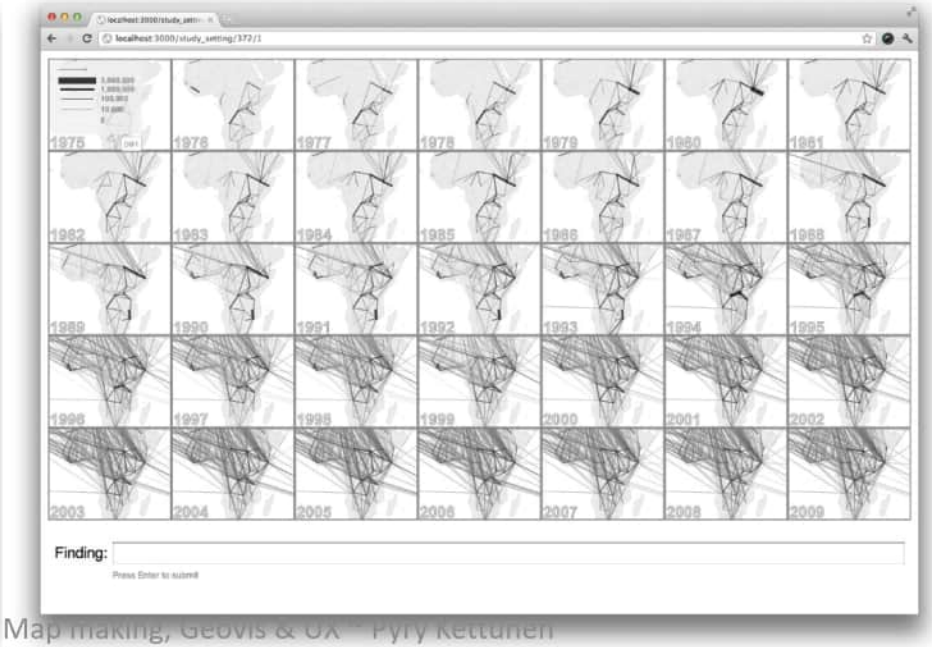
Empirical cartography





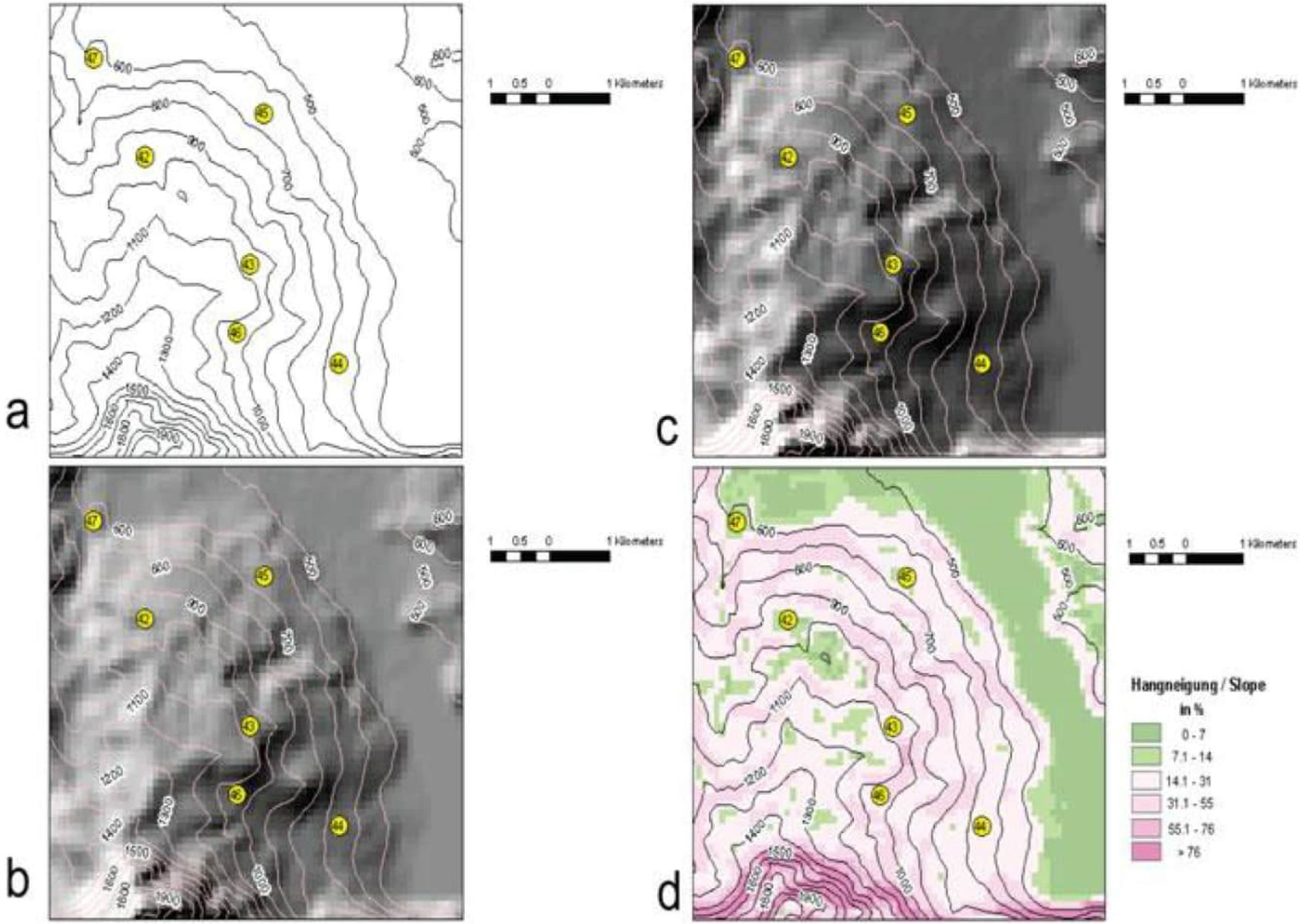
Griffin et al. (2006)





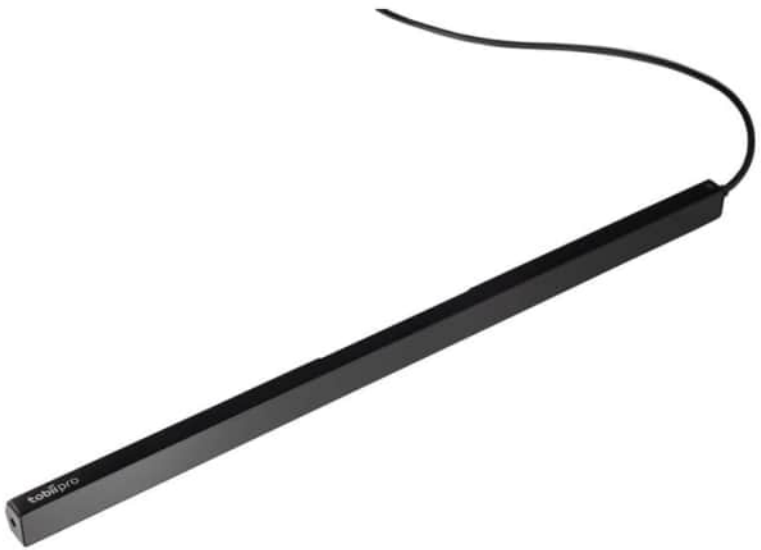
Boyandin et al. (2012)

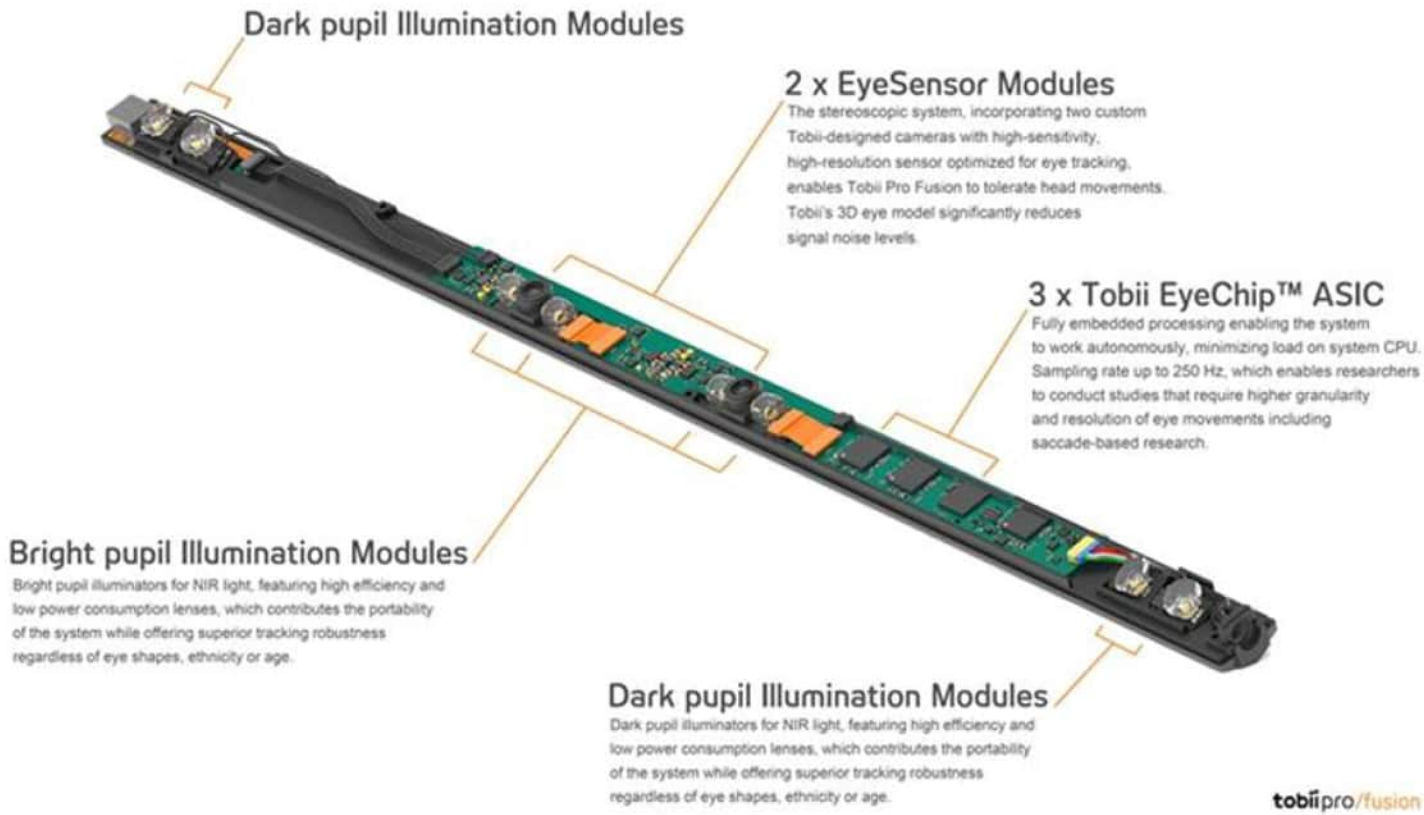
Empirical cartography



Wilkening and Fabrikant (2011)

Eye-tracking camera 250 Hz





Basics of eye-tracking

Target of measurement	Point of gaze on the screen: location (x, y) and time (t).
Metrics	Gathered from points of gaze: Fixations, saccades, drifts, strolls, …
Stimuli	Paper, screen, virtual reality, real environment, …
Analysis	Qualitative, e.g. visuaalinen Quantitative, e.g. statistics

Time	Type	Trial	L POR X [px]	L POR Y [px]
15256356851	SMP	1	589,64	590,82
15256365267	SMP	1	586,6	587,1
15256373592	SMP	1	824,04	396,63
15256390210	SMP	1	589,08	584,7
15256398588	SMP	1	592,91	580,93
15256406933	SMP	1	588,32	578,83
15256423568	SMP	1	594,35	580,26
15256431942	SMP	1	594,57	579,7
15256440305	SMP	1	598,26	575,05
15256448557	SMP	1	598,33	571,11
15256456954	SMP	1	597,96	569,4
15256465310	SMP	1	597,92	571,55
15256481930	SMP	1	600,35	570,2
15256490314	SMP	1	601,55	571,8
15256498681	SMP	1	603,14	568,78

Eye-tracking metrics

Fixation

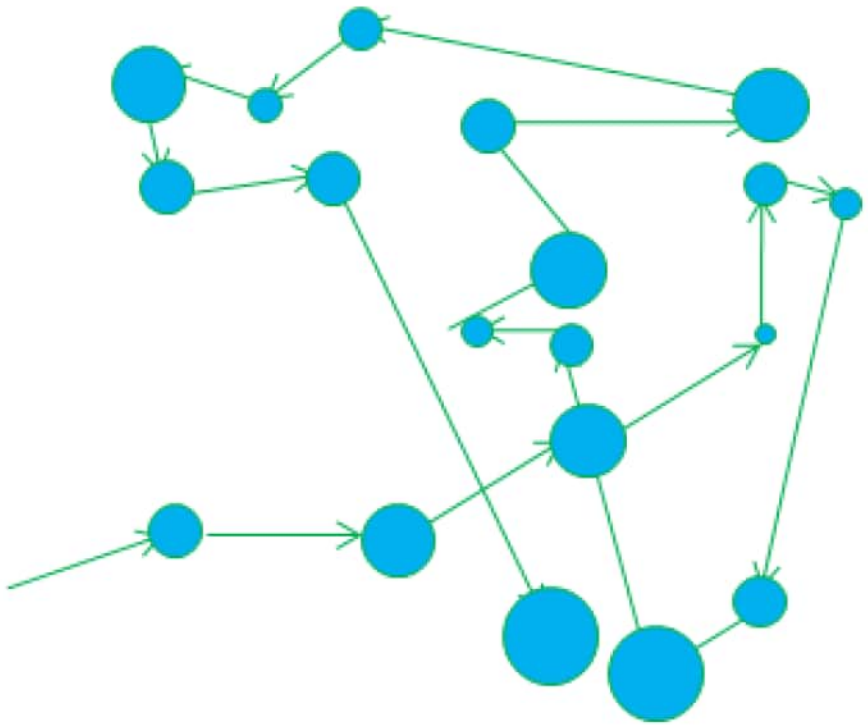
- Stopping of pupil (~200–300 ms).
- During fixations, visual content enters consciousness.

Saccade

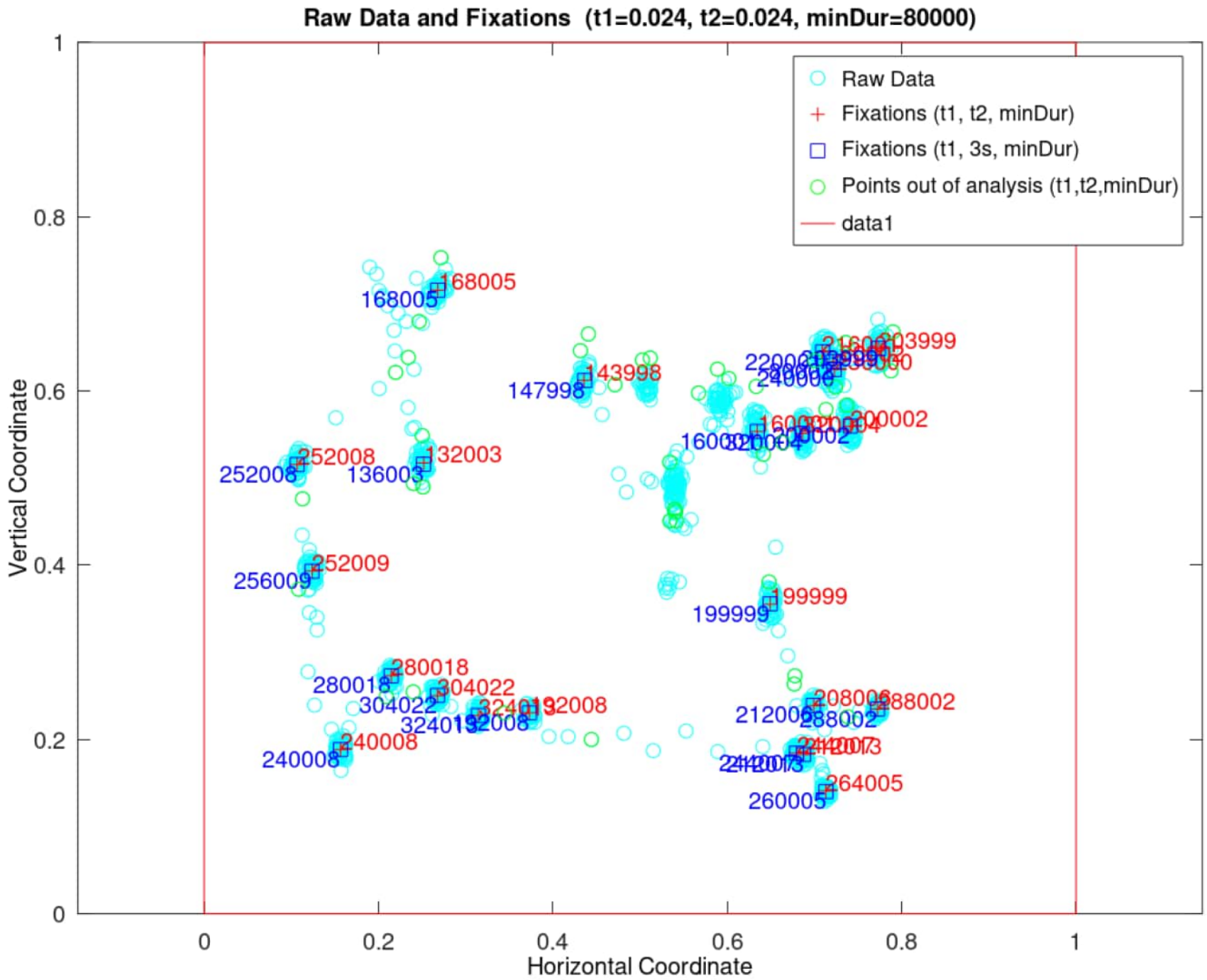
- Very rapid movement of pupil between fixations (~30–80 ms).
- During saccades, visual content does not enter consciousness.

Pupil

- Size and dilation of pupil.
- Tells about cognitive load, for instance.



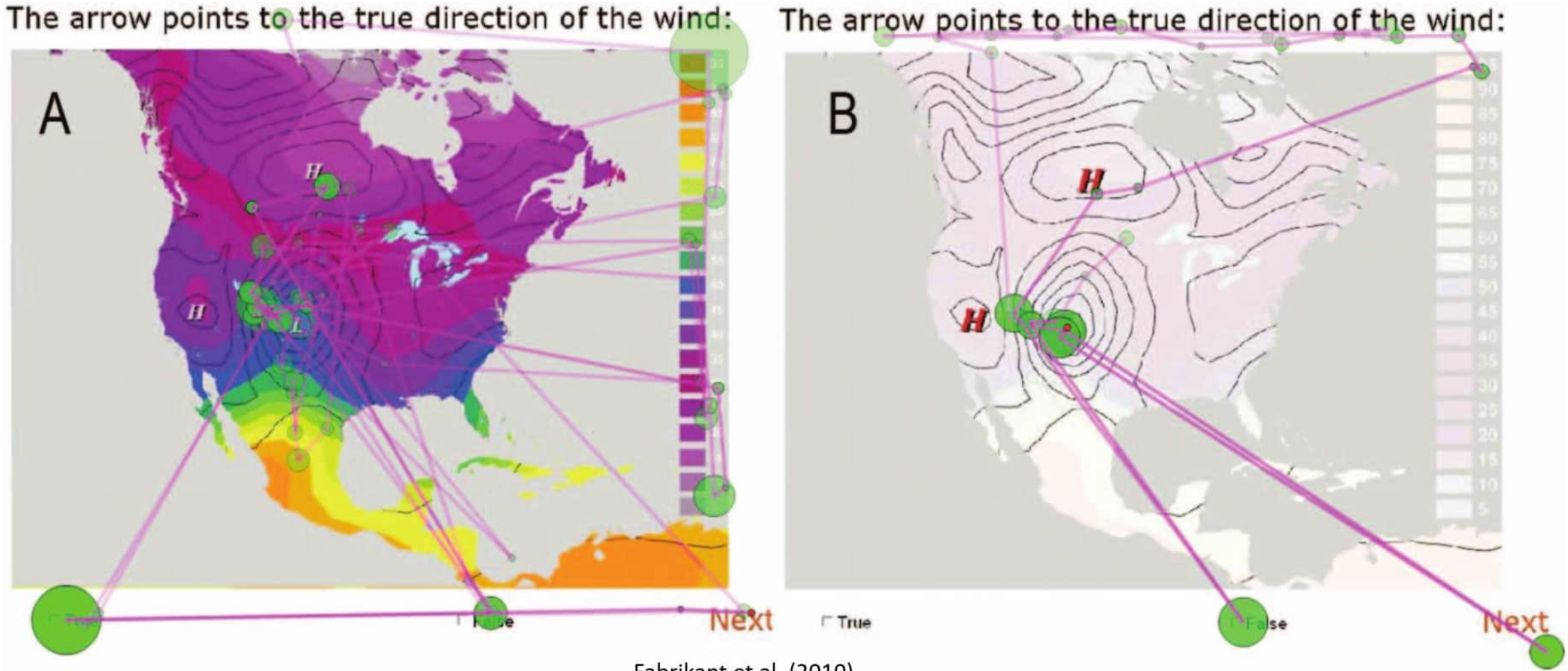
Eye-tracking data



attention

forest has

Eye-tracking studies



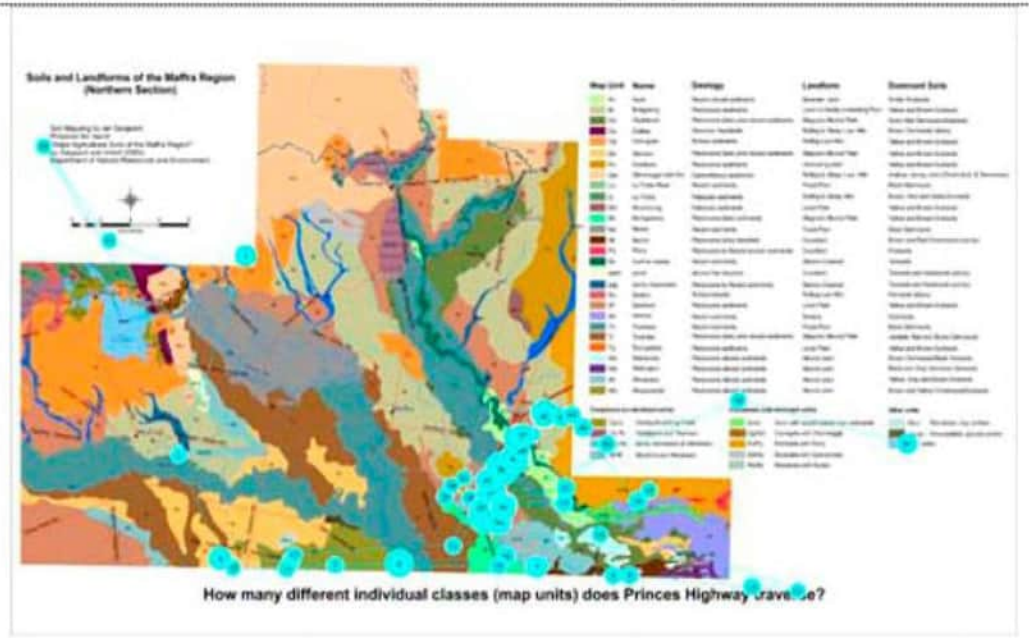
Fabrikant et al. (2010)

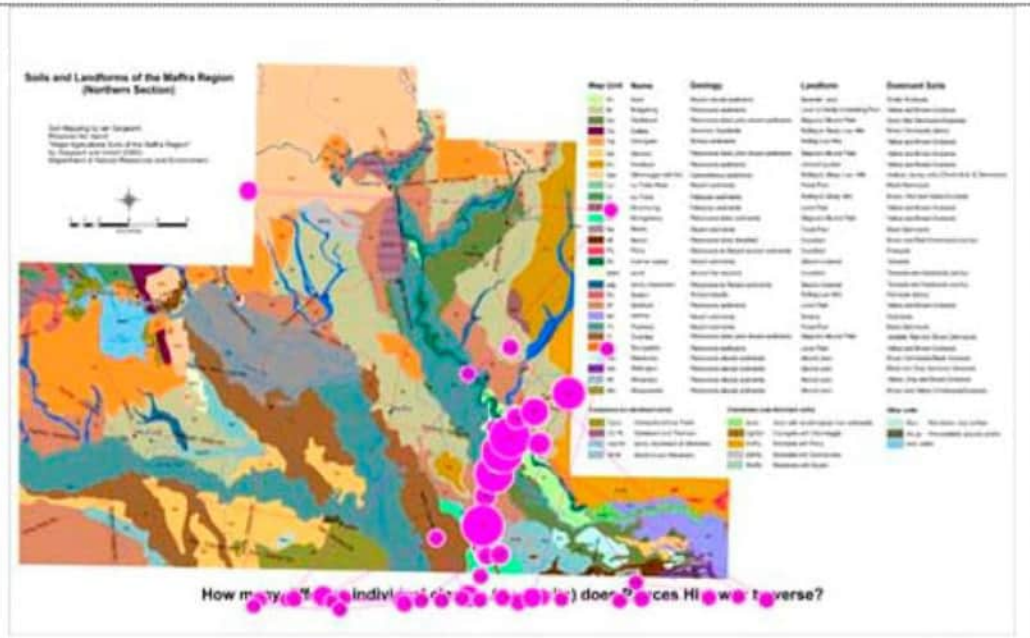
Eye-tracking studies

Çöltekin et al. (2016)

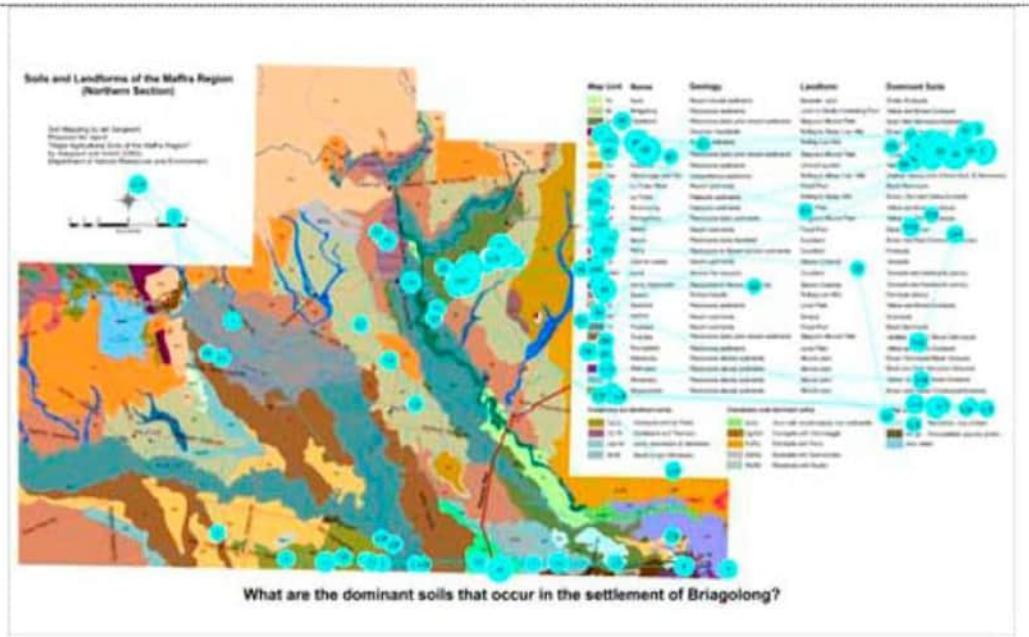
Best performer (BP)

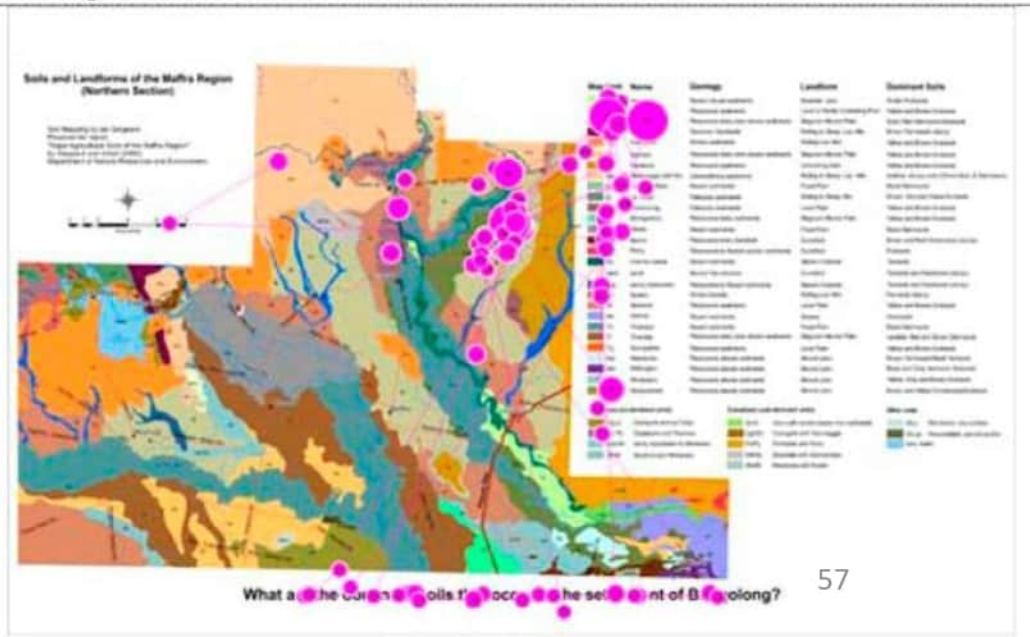
Worst performer (WP)



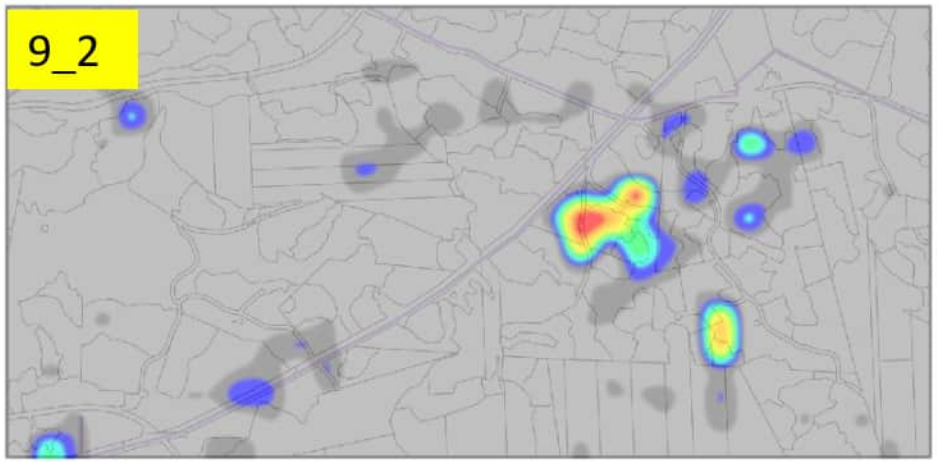


Q1: The BP followed the road without hesitation, counted the colors crossing the road. The WP took longer to read the instruction, and went back to one of the categories twice to ensure it is there





Our TUGEVA project: highlighting map features



Heat maps

Red, yellow, green and blue colors represent in descending order the amount of gaze points that were directed towards parts of the image.

Heat maps visualize which elements attract more attention than others and help understand how people view a stimulus.

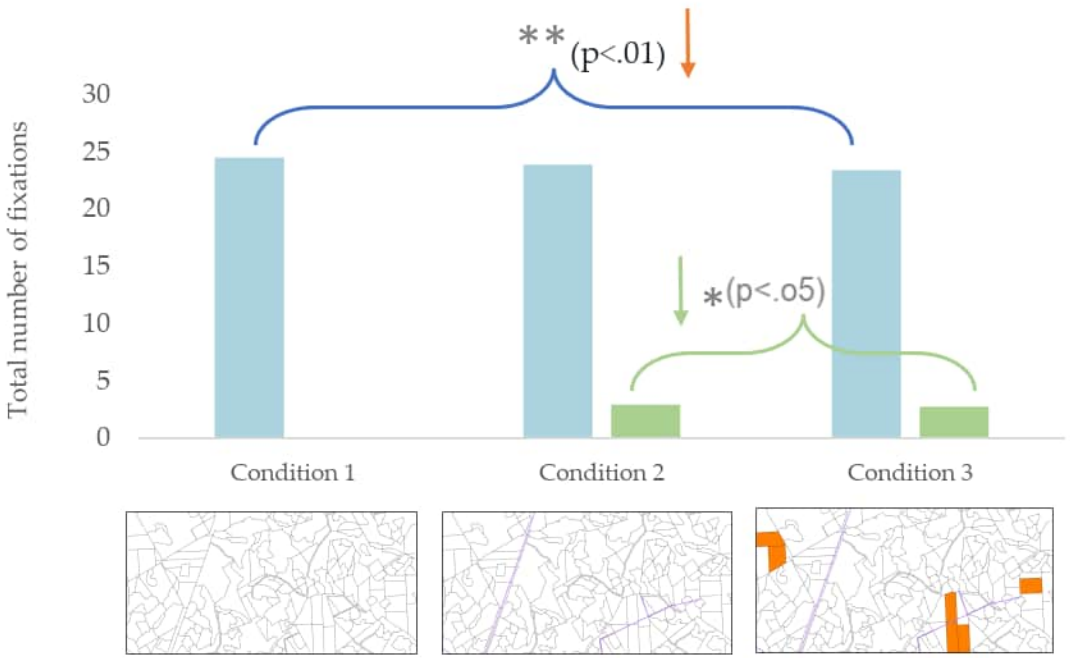
Heat maps show that different areas caught the participant's attention in each map image.

Inclusion of linear and polygon features shifted the participants' attention not necessarily towards some of these newly added features, but their surroundings and other areas (*see 9_2, 9_3*).

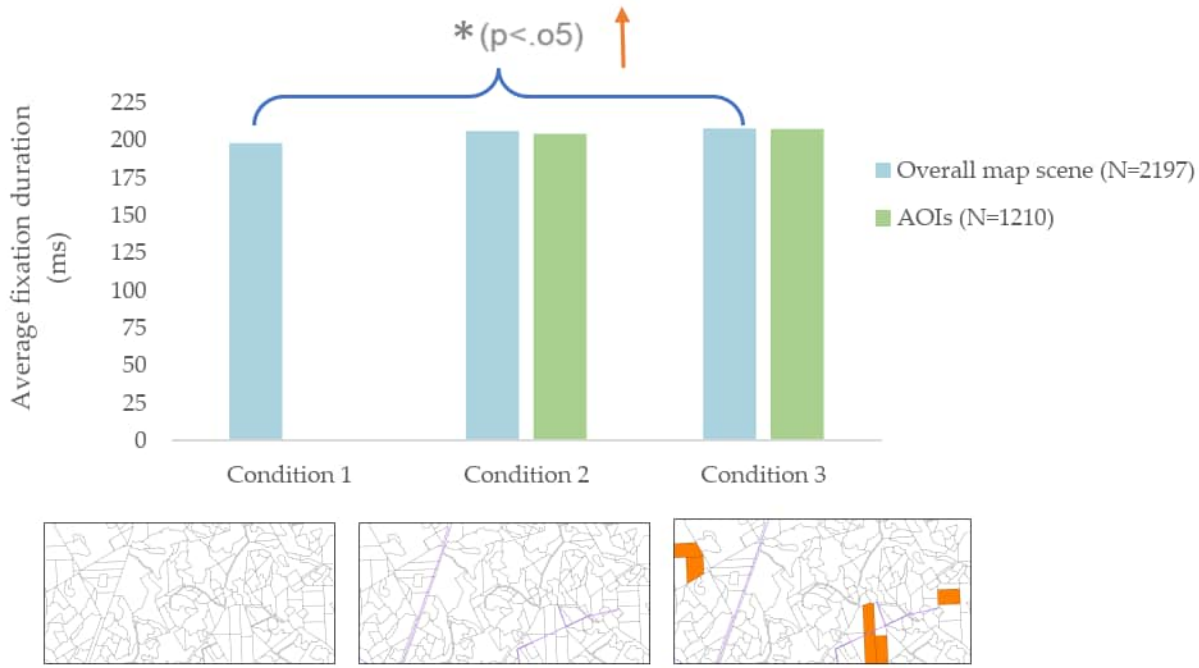
**The eye tracking data used to calculate these heatmaps is from 9 participants.*

From non-highlighted map image to highlighted map features

Higher **fixation amount** indicates higher attention on the visual target.



Longer **fixation duration** indicates stronger devotion to the task.



The strongest devotion to the task was observed when both linear and areal features were highlighted (C3).

ANOVA pairwise comparisons: significantly lower amount and longer duration of fixations in C3 compared to C1.

Take part in a short user experiment!

Booking for Kumpula

https://calendly.com/anna-saarinen/eye-tracking-experiment-at-kumpula

Booking for Otaniemi

https://calendly.com/anna-saarinen/eye-tracking-experiment-at-otaniemi

- Your input is invaluable to research in cartography and GIS

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+358 50 320 5690

Finnish communities of geoinformation and cartography

- GeoForum ry
- GeoPortti web service
- ProGIS ry
- Suomen Kartografinen Seura SKS (Finnish Cartography Society)

Post-discussion

- Small groups:
  - Discuss the topics you wrote down and what you wander about them.
  - Crystallise questions you want to know more about.
- All together:
  - Try the lecturer Q&A!

Thank you for your attention!

Feedback →