ETH zürich

GIScience & Mobility

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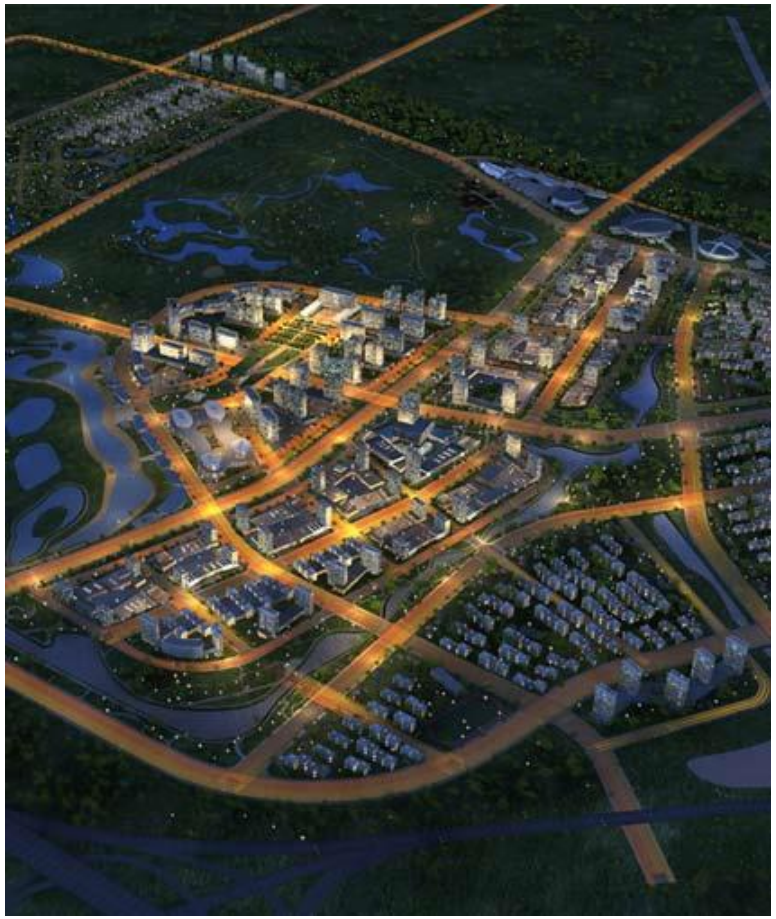
SAGEO 2013 – Brest, France



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GIScience & Mobility

- Modeling human mobility patterns
  - Where are people's activity spaces?
  - How similar are people's trajectories?
  - Where are the hotspots of an urban system?
- Explaining people's mobile behavior
  - Why do people make particular decisions?
  - Why do people commit wayfinding errors?
  - How can Location Based Services help?

What's new for GI researchers?

- Novel data sources for computational investigations of human behavior
  - Information and Communication Technologies (ICTs)
  - Georeferenced mobile phone data for geographic knowledge discovery
- Novel technologies for observing people's spatio-temporal behavior
  - Mobile eye-tracking

Overview

- Extracting human mobility patterns from mobile phone data
- Explaining human wayfinding behavior through location-aware mobile eye-tracking
- Providing gaze history for orientation on small display maps (GeoGazemarks)
- Conclusions

Human mobility patterns

Can we extract human mobility patterns & activity behavior from mobile phone data?

- Dynamic clustering of human mobility
  - Impact of temporal factors
    - Natural temporal order: morning/afternoon/evening
    - Social temporal order: weekday/weekend
- Points of interest (POI) clustering
  - Home / work locations
  - POIs and urban infrastructures

Background

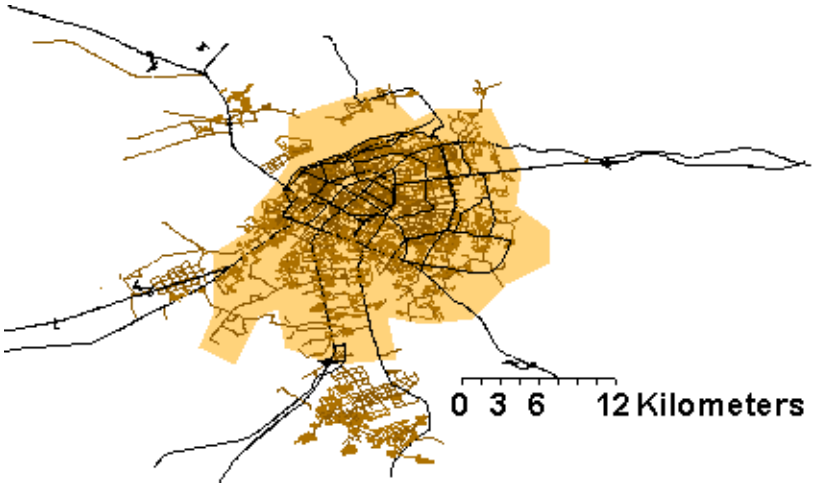
- Information & communication technologies (ICTs) => spatio-temporal data sources
- Traditional geographic knowledge discovery => limited capability to model large-scale activities, e.g., travel diaries
- Georeferenced mobile phone data
  - Large spatio-temporal scale
  - Low spatio-temporal resolution
  - Few individual attributes

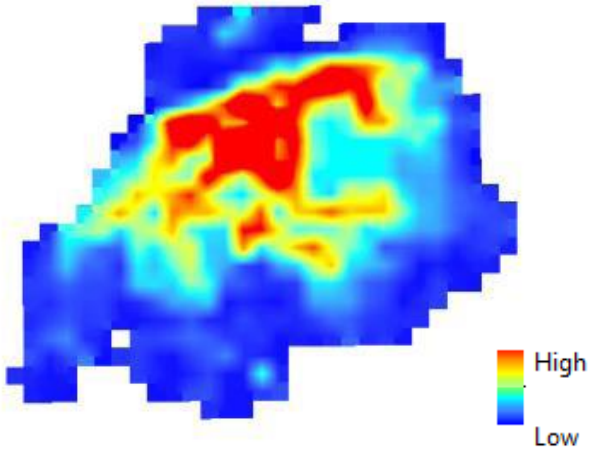
Dataset

Mobile phone connection records in Harbin City.

- Time, duration, and location of mobile phone connections.
- Age and gender attributes of the users.

[Yuan, Raubal, Liu 2012]



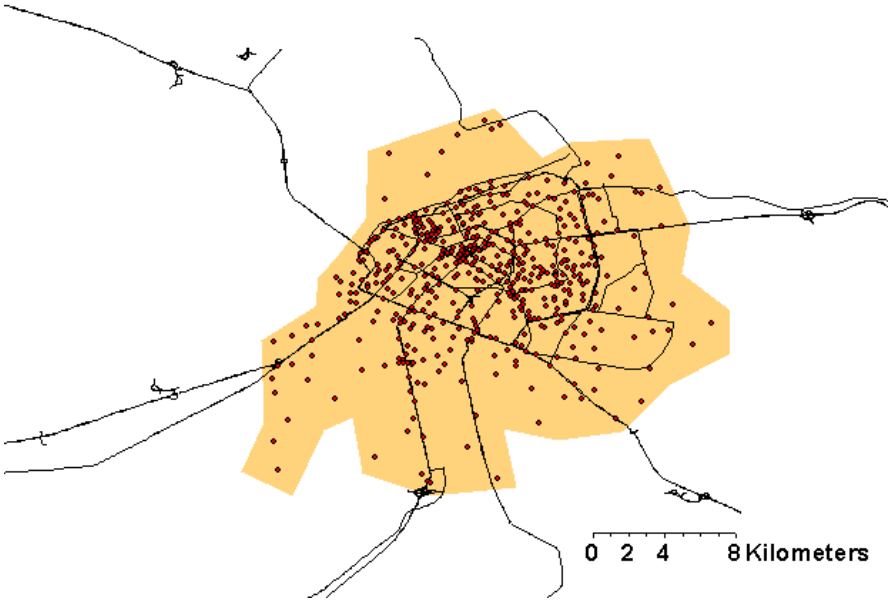


Phone number	Longitude	Latitude	Time	Duration
1350*******	126.*****	45.*****	14:36:24	12mins
1350*******	126.*****	45.*****	15:21:43	44mins
1350*******	126.*****	45.*****	15:47:04	22mins

Phone number	Gender	Age
1350*******	Male	45

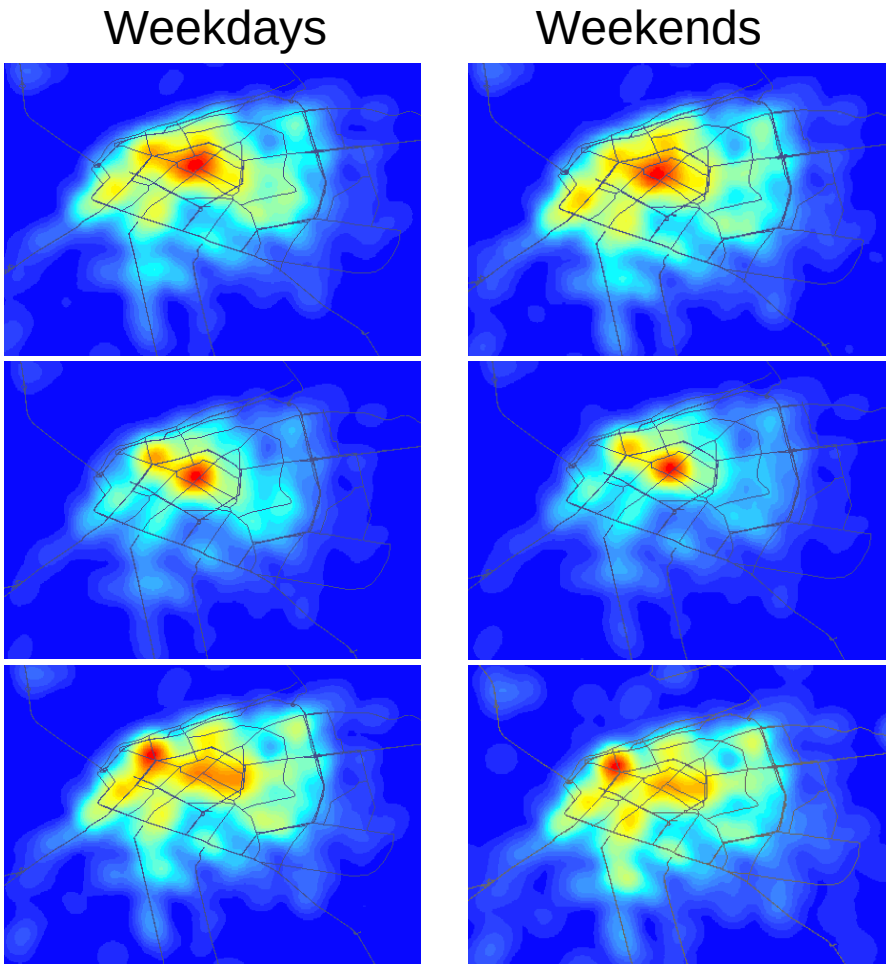
Dynamic clustering

- Hourly aggregated data for each cell phone tower



- Kernel density estimation

Dynamic clustering



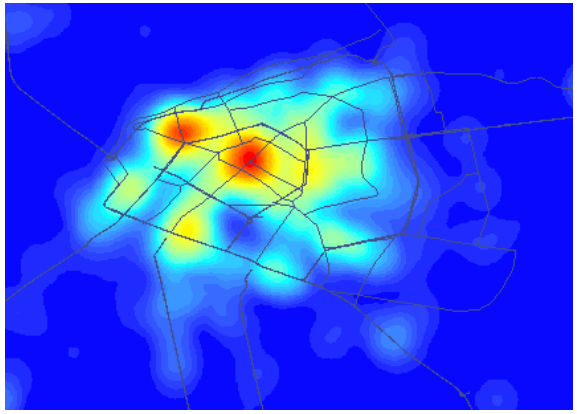
- Weekdays – weekends => high similarity
- Clusters in city center (T_1,T_2) *vs.* spread pattern (T_3).

Dynamic clustering

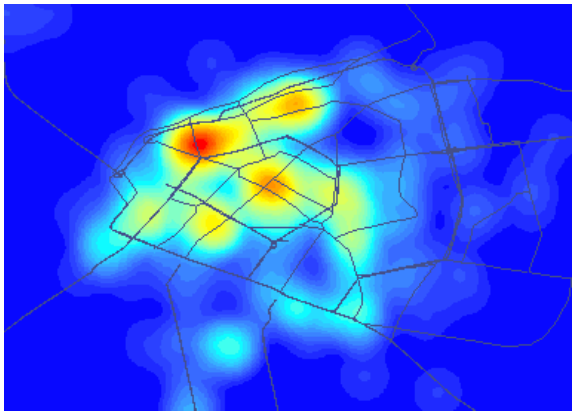
Mobility patterns of different population groups.

Example: Weekday 2pm-3pm

Age: 12-17



Age: > 60

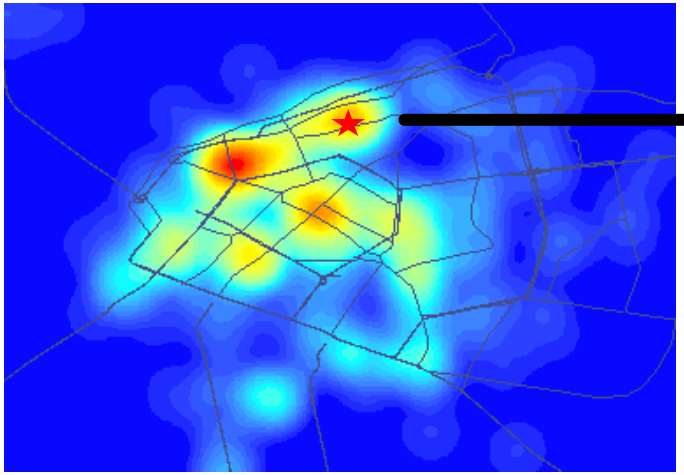


Dynamic clustering

Provide input for urban infrastructure planning

Example: Are public facilities where people are?

Age: > 60



park

POI Clustering

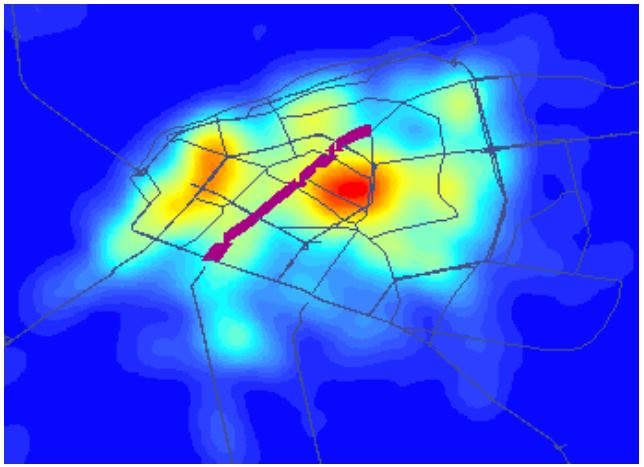
Home/Work locations estimation:

- Extracting stops [Phithakkitnukoon *et al.* 2010]
  - $R = \{(p_1, t_1) \rightarrow (p_2, t_2) \rightarrow .... \rightarrow (p_n, t_n)\}$
  - Home location: the most frequent *stop* during the night hours (7pm-7am)
  - Work location: the most frequent stop during day hours on weekdays

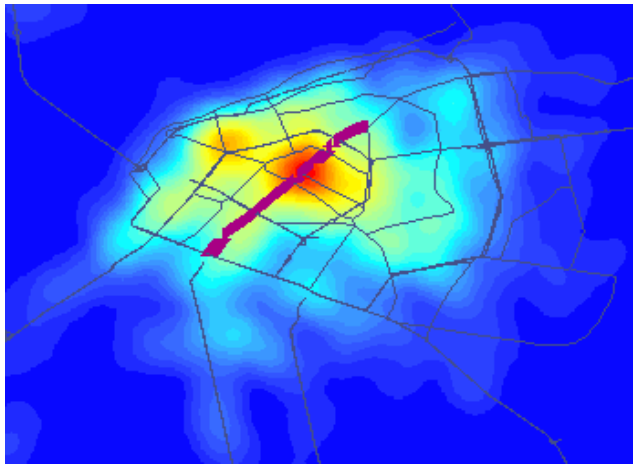
POI clustering

- Spatial clustering of POIs

Home Locations



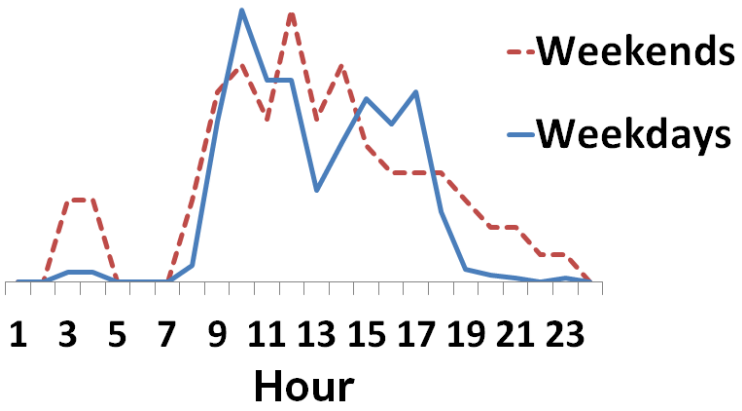
Work Locations



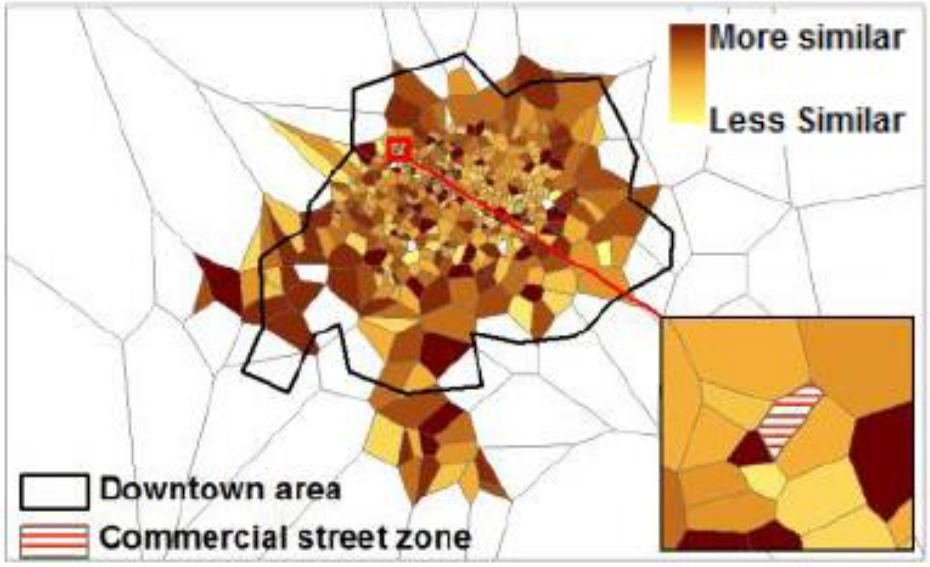
- Both clustered at city center
  - Home locations: south-east side of main street
  - Work locations: both sides of main street

Time series patterns

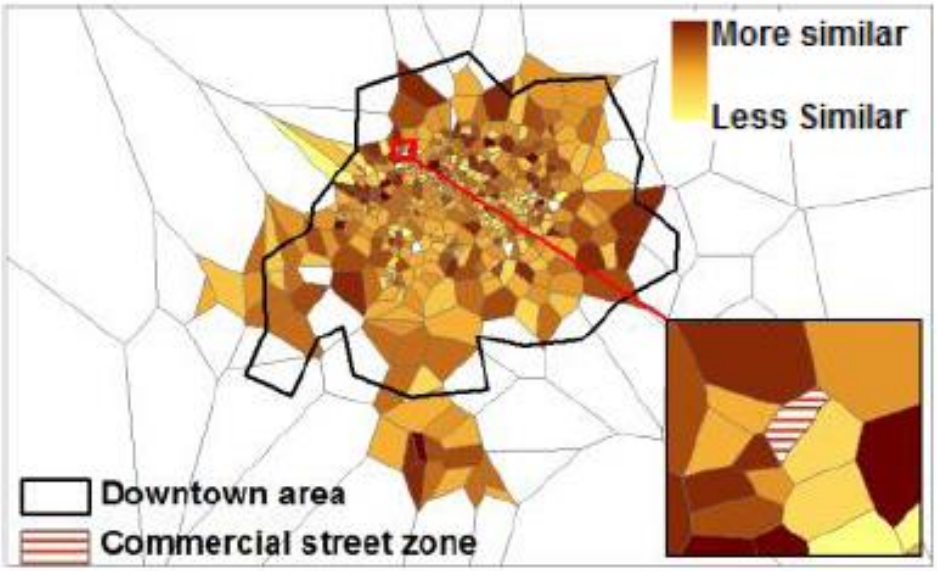
- Hourly time series to represent dynamic mobility patterns in different urban areas.
- Dynamic Time Warping (DTW) to measure similarity between time series => classify urban areas based on mobility patterns.
- Outlier urban areas identified through abnormal mobility patterns.



Dynamic mobility patterns



Weekdays



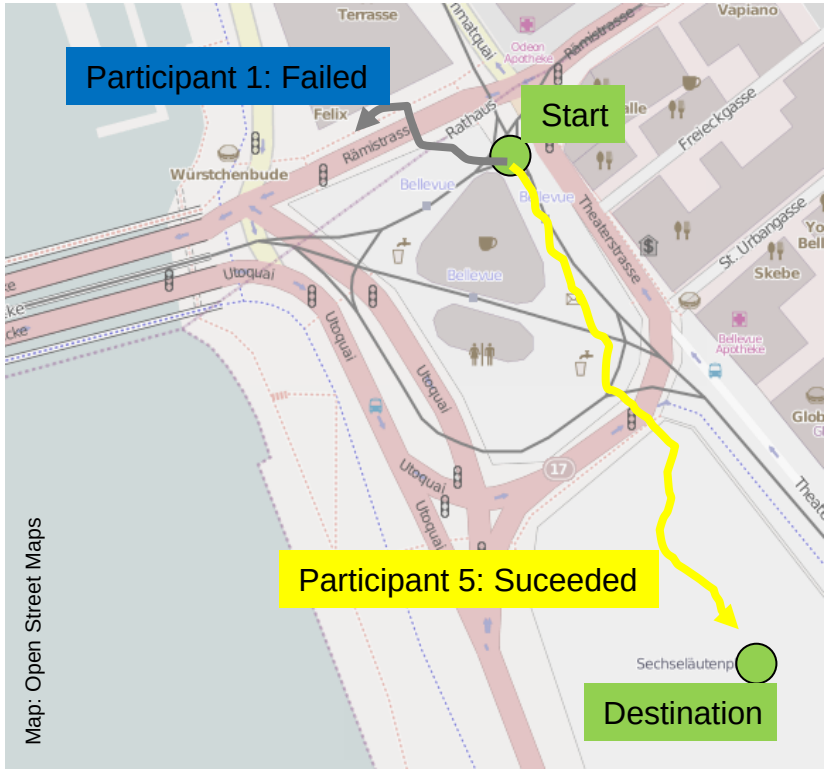
Weekends

- Mobility patterns more similar on weekdays.
- Surrounding polygons more similar on weekends.

[Yuan & Raubal 2012]

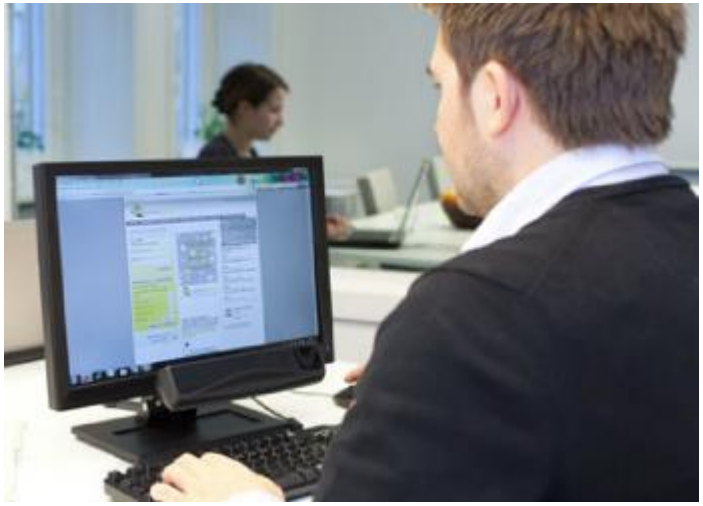
Human wayfinding behavior

- Where and why do people get lost?
  - Ambiguity, complexity, instructions, map design, etc.
  - Typical approaches: questionnaires, interviews, behavior observation
- Can we get better answers to the ‘why’ question?



Eye tracking

- Gaze recording
  - Where is a person looking at?
  - Attention tracking
- Technologies
  - Infrared reflection
  - Pupil detection
- Data analysis
  - Fixations, saccades



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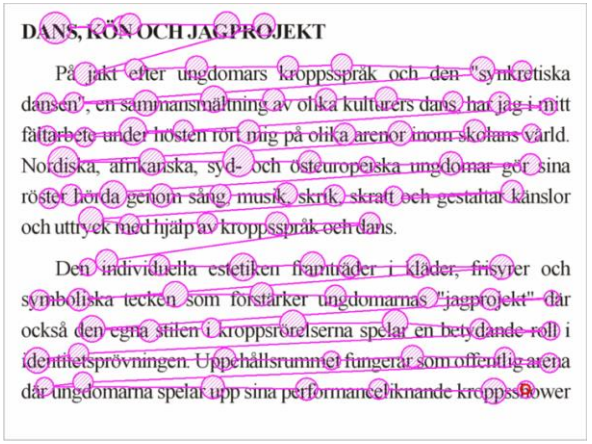
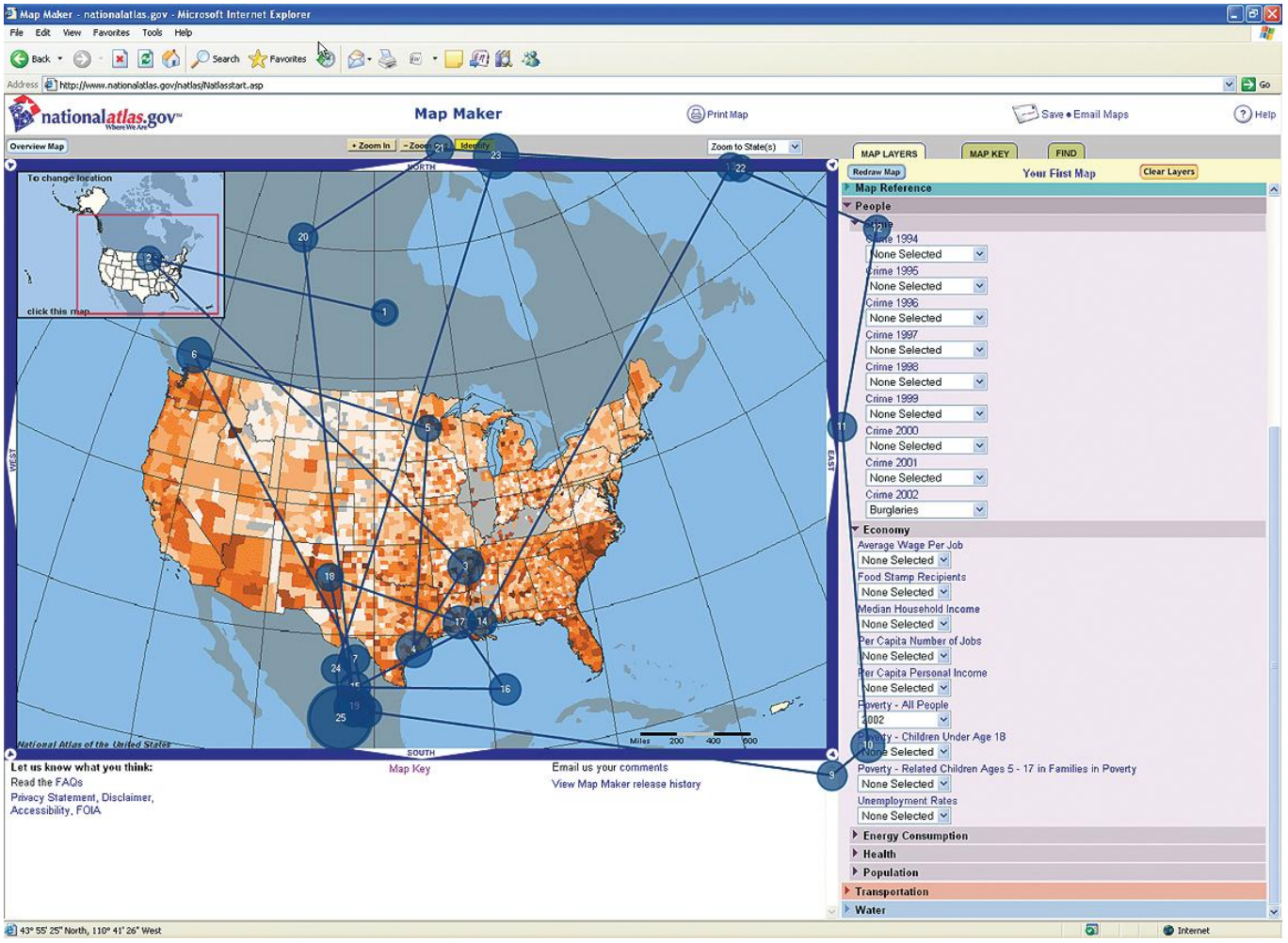


DANS, KÖN OCH JAGPROJEKT

På jakt efter ungdomars kroppsspråk och den "synkretiska dansen", en sammansmältning av olika kulturers dans, har jag i mitt fältarbete under hösten rört mig på olika arenor inom skolans värld. Nordiska, afrikanska, syd- och östeuropeiska ungdomar gör sina röster hörda genom sång, musik, skrik, skratt och gestaltar känslor och uttryck med hjälp av kroppsspråk och dans.

Den individuella estetiken framträder i kläder, frisyrer och symboliska tecken som förstärker ungdomarnas "jagprojekt" där också den egna stilen i kroppsrörelserna spelar en betydande roll i identitetsprövningen. Uppehållsrummet fungerar som offentlig arena där ungdomarna spelar upp sina performanceliknande kroppsshower

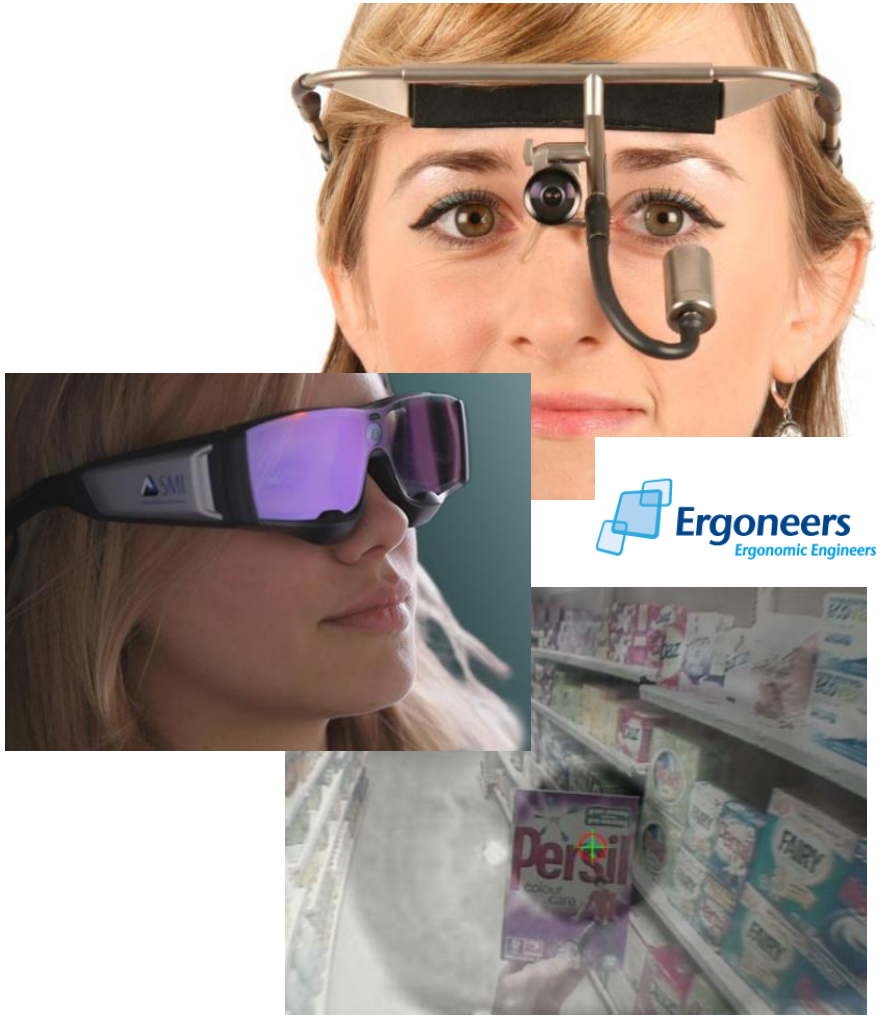
Map interface design



[Çöltekin et al. 2009]

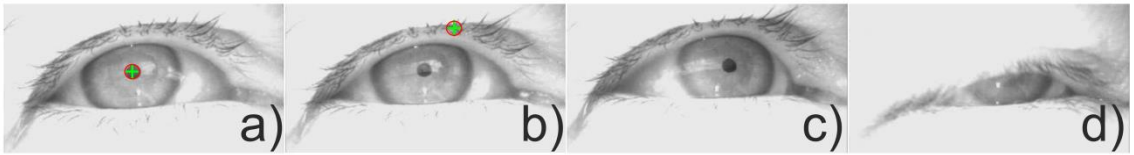
Mobile Eye tracking

- Head-mounted device
  - Increased mobility
  - Realistic conditions
  - Sunlight & infrared?
- Gaze-overlay video
  - Frame coordinates
  - Visual markers define world-coordinate-system



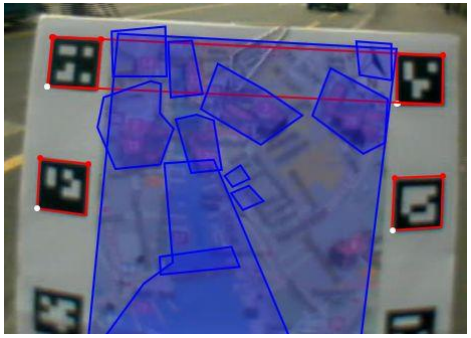
Technological Challenges (1)

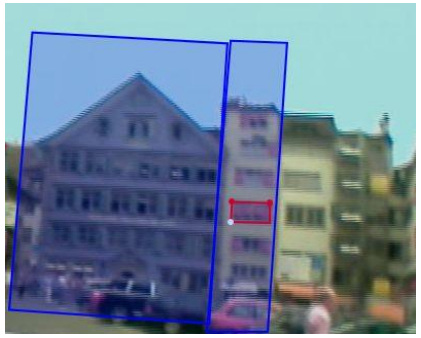
- Sunlight
  - ... interferes with infrared
  - Dikablis
    - Saves two videos, manual post-processing frame-by-frame
    - Labor-intensive!
  - SMI Glasses
    - Sunshades

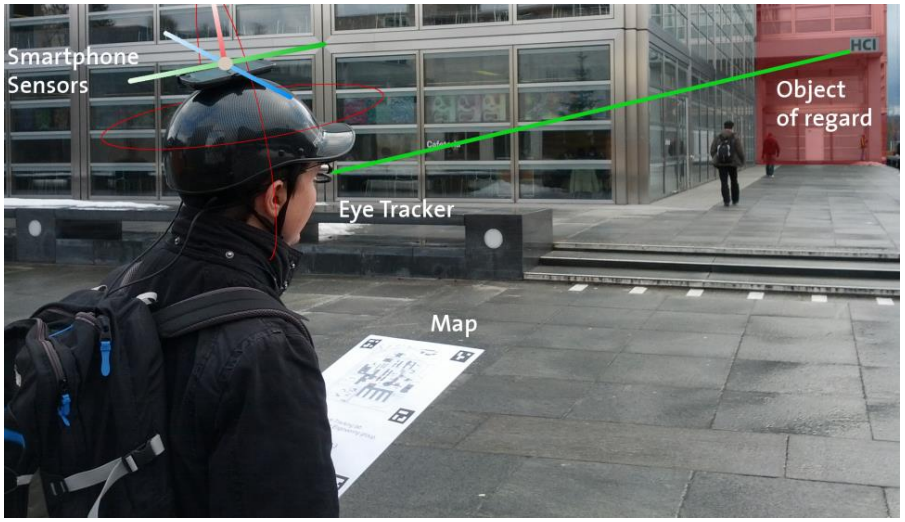


Technological Challenges (2)

- Determining Object of Interest
  - (3D fixation point)
  - Dikablis
    - Marker-based solution
    - Labor-intensive!
  - MSc thesis [Mosimann]
    - Simple head-tracking helmet
    - 3D city model

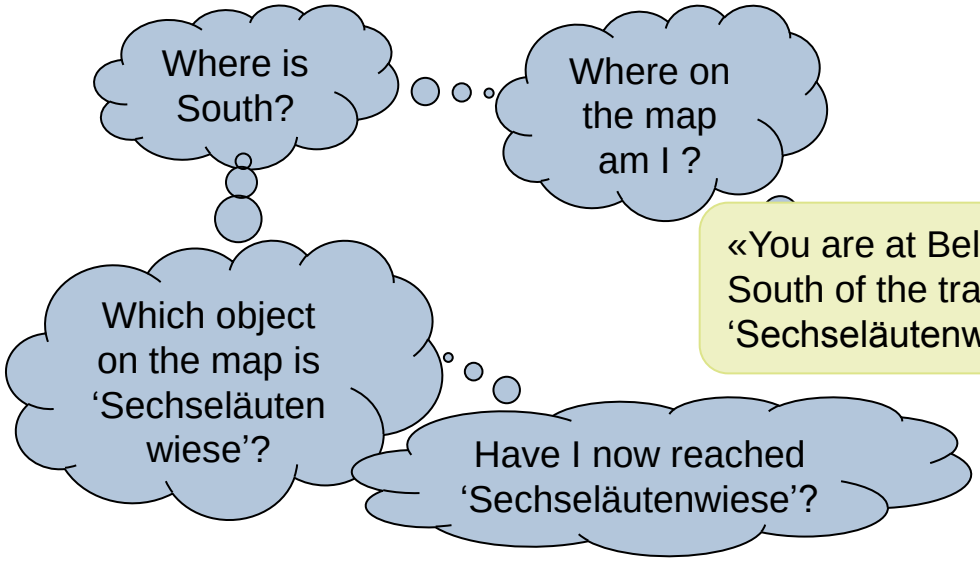




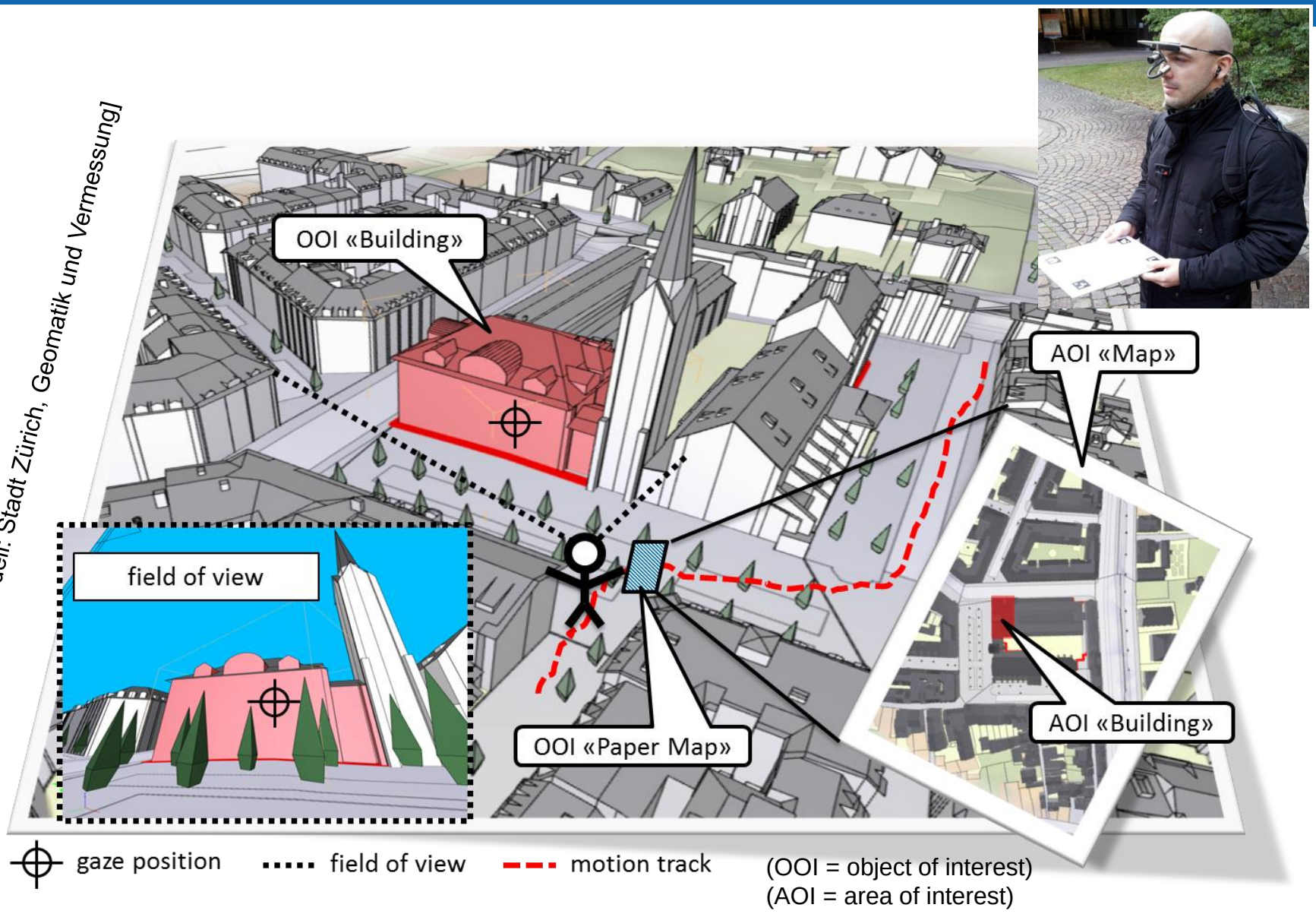


Location-Aware Mobile Eye Tracking

- Combined recording and analysis of position & gaze.
- Pilot study: Zurich audio guide
  [Kiefer, Straub, Raubal 2012]

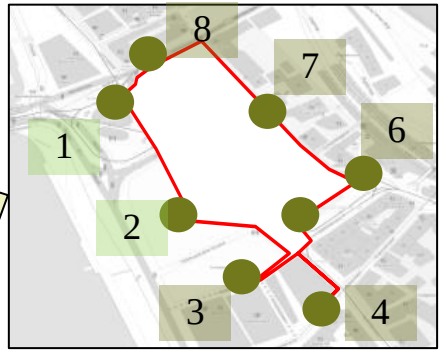


«You are at Bellevue. Cross the road South of the tram station and proceed to ‘Sechseläutenwiese’ square»


[© 3D Stadtmodell: Stadt Zürich, Geomatik und Vermessung]
OOI «Building»
AOI «Map»
field of view
OOI «Paper Map»
AOI «Building»
gaze position
field of view
motion track
(OOI = object of interest)
(AOI = area of interest)

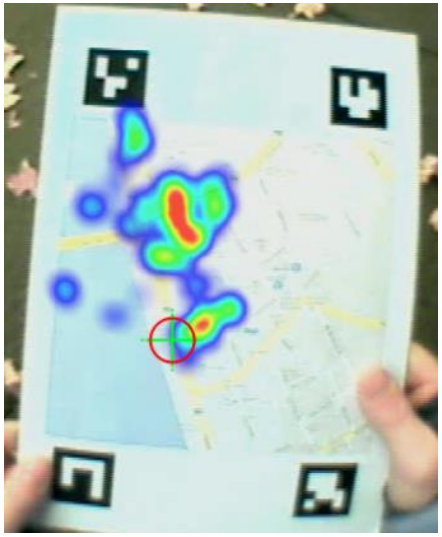
Detailed Map Usage

«You are at Bellevue. Cross the road South of the tram station and proceed to 'Sechseläutenwiese' square»



Hypothesis:

The process of self-localization can be observed from the gaze behavior on the map.

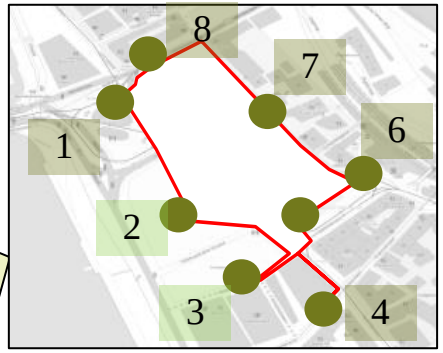


Participant 1: Success (heading South)

Participant 5: Failure (heading North)

Landmark Identification

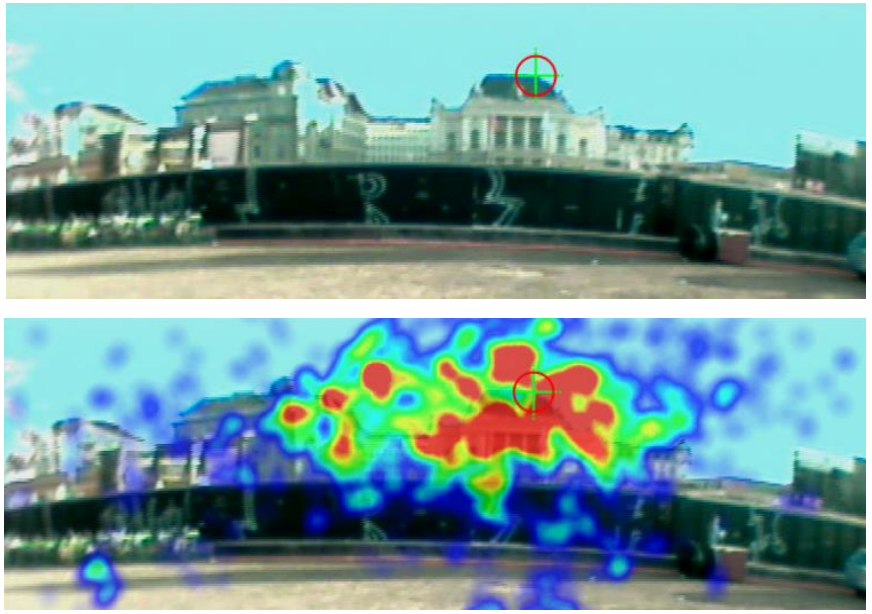
«Our next destination is the Opera. The prominent building is located at the Southern edge of ‘Sechseläutenwiese’ where the ‘Seefeld’ quarter starts.»



Hypothesis:

The process of landmark identification can be observed from the gaze behavior in the environment.

Other building *Opera*



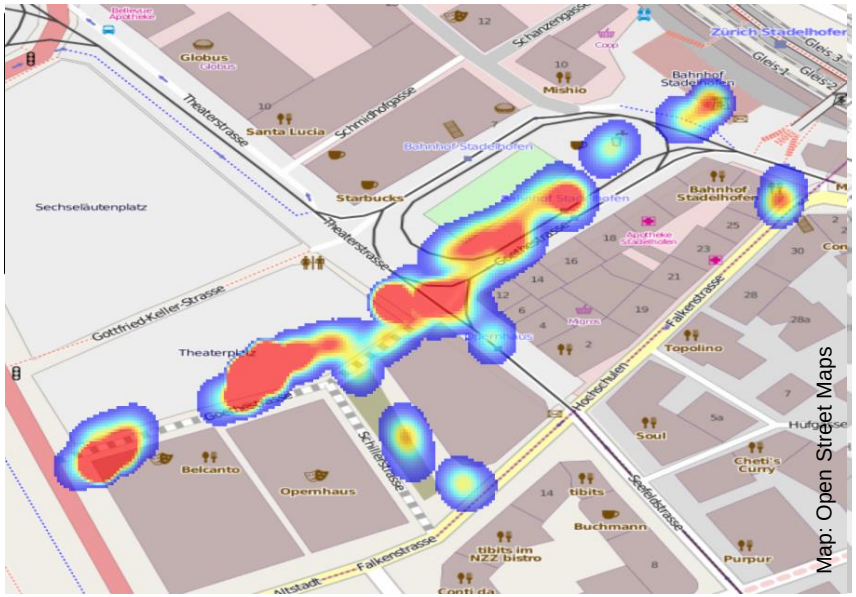
Gaze distribution for landmarks

Positions of Map Usage

«Our next destination is the old NZZ building at the intersection ‘Theaterstrasse’/’Falkenstrasse’. The building is next to the Opera. The entrance is close to the tram station ‘Opernhaus’ and facing South towards the ‘Seefeld’ quarter.»

Hypothesis:

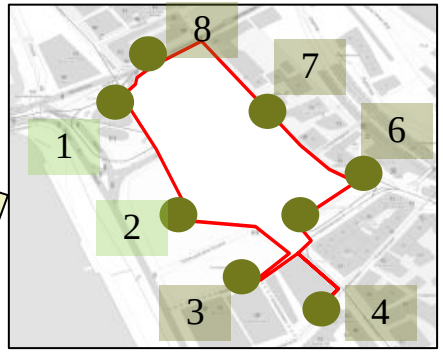
Critical decision points can be determined from map usage (fixations on the map).



Motion tracks of all participants, annotated with AOI ‘map’ (area of interest) Red: Fixation on map

Gazes in the Environment

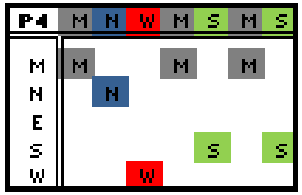
«You are at Bellevue. Cross the road South of the tram station and proceed to 'Sechseläutenwiese' square»



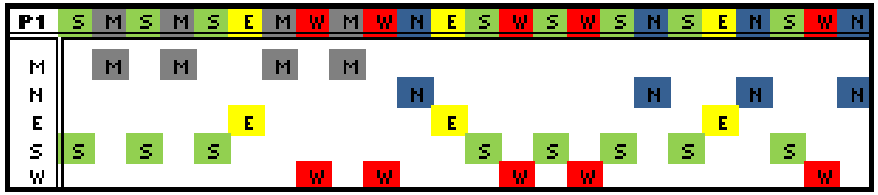
Hypothesis:

The process of self-localization can be observed from the gaze behavior in the environment.

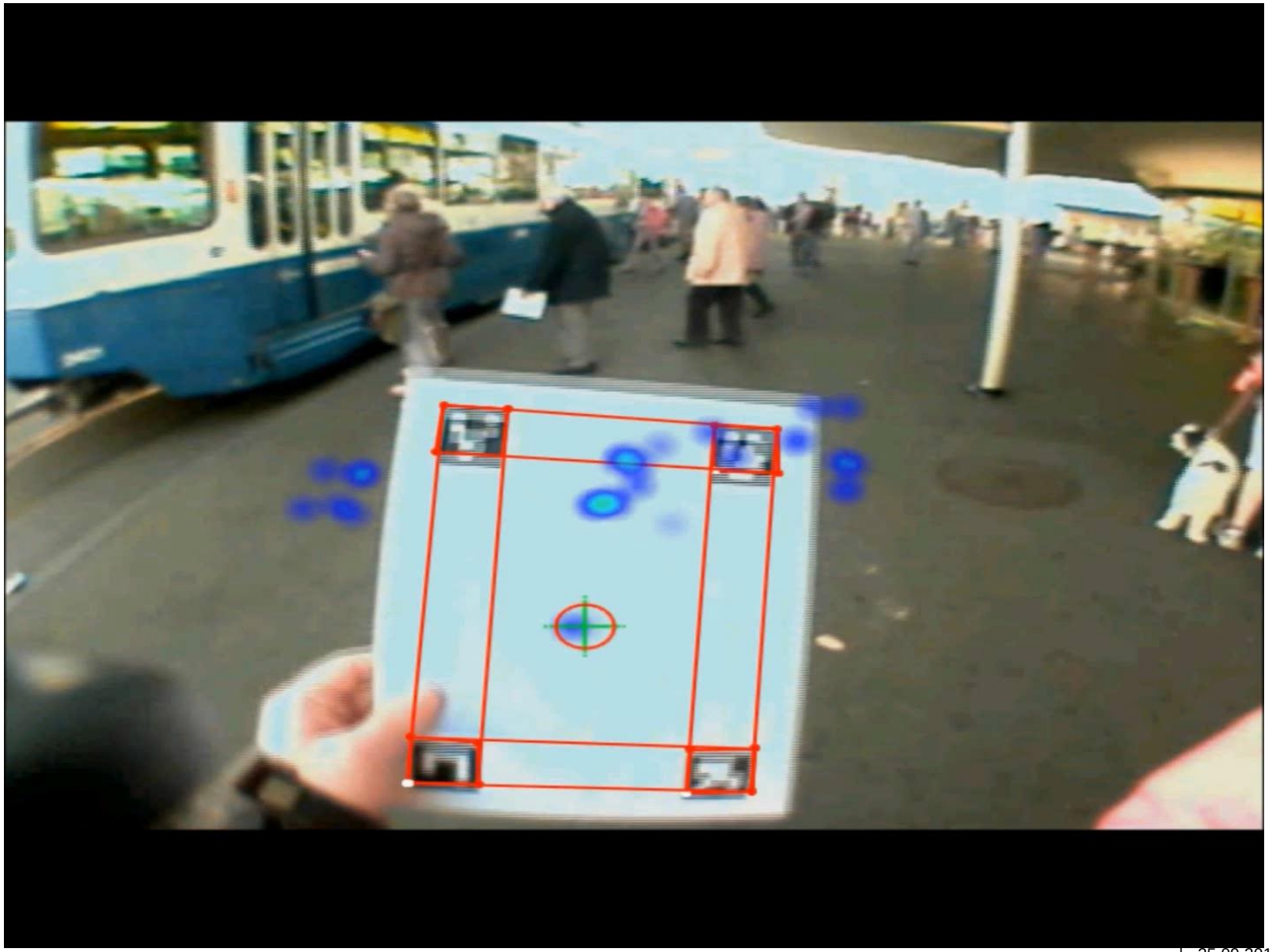
Participant 1: Success



Participant 5: Failure (heading North)



Sequence analysis for cardinal directions (N, E, S, W) and map (M)



Keep an eye on traffic!

Ongoing Study: Self-Localization

- Self-Localization
  - «Please mark your position on this map»
  - Map symbols and corresponding landmarks
  - Some landmarks visible
- Requires visual search and logical inference
  - Eye tracking measures only search

Ongoing Study: Self-Localization

- Self-Localization
  - «Please mark your position on this map»
  - Map symbols and corresponding landmarks
  - Some landmarks visible
- Requires visual search and logical inference
  - Eye tracking measures only search

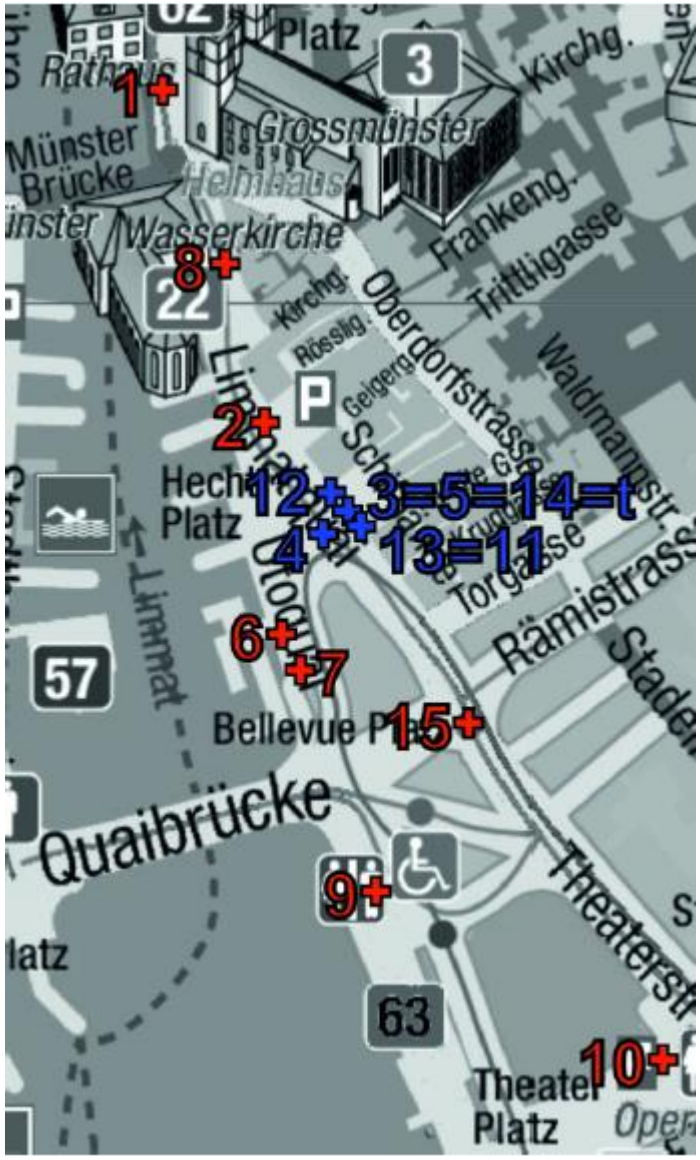
Research Questions

- RQ1
  - Do successful participants spend more visual attention on map symbols that have a visible corresponding landmark than unsuccessful participants?
  - (A distribution measure.)
- Results
  - “yes” for both RQ

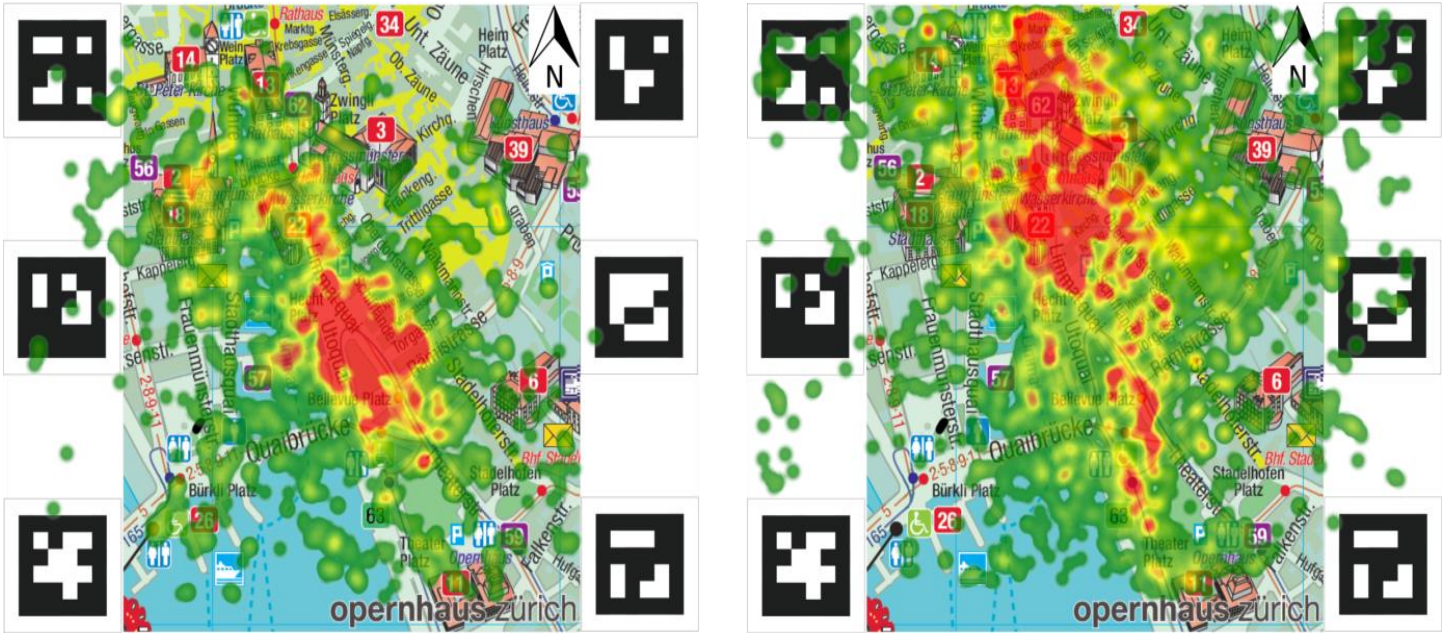
- RQ2
  - Do successful participants have more switches of visual attention between symbols on the map and their corresponding landmarks in the environment?
  - (A sequence measure.)

Participants' solutions for self-localization (Hechtplatz study)

t = true position



Gaze Distribution as Heatmaps

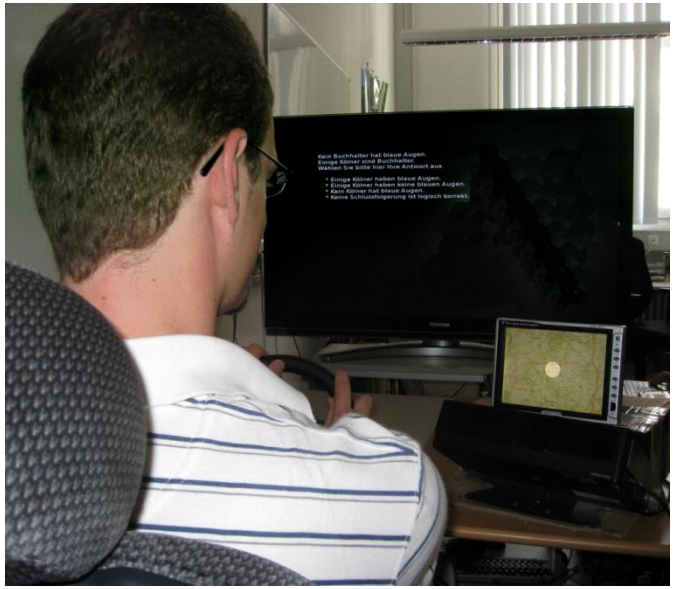


Methodological Challenges

- Outdoor studies
  - Less controllable than lab studies
    - Pedestrians interfering with participants, trucks parking in front of signs...
  - Generalizability to other areas
- Ensuring unfamiliarity with environment
  - Tourist participants: have they looked at a map before?
  - Approaching the starting point: avoid cognitive map building

Human Computer Interaction with eye tracking

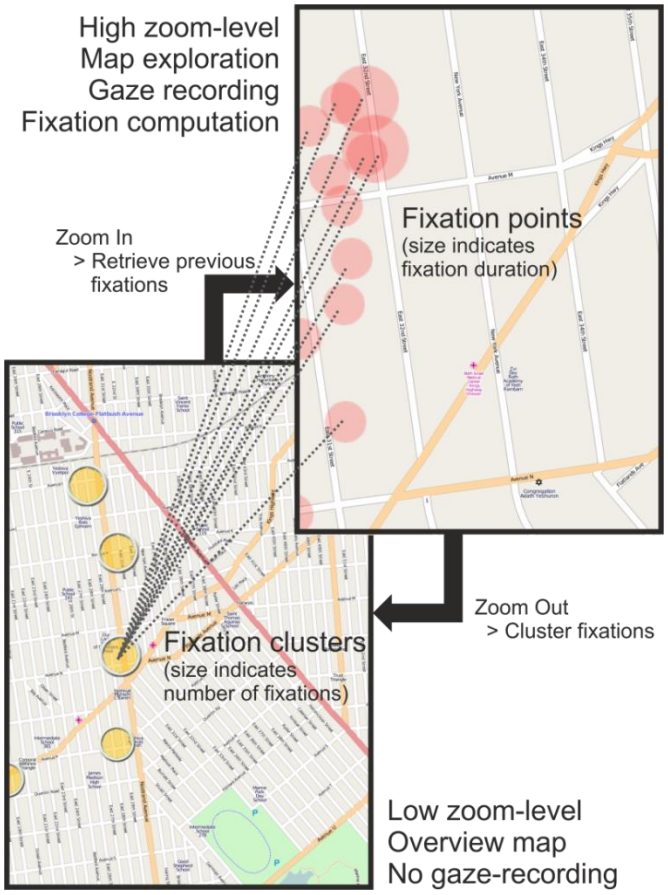
- Attentive Interfaces: content adapted dynamically based on gazes
- Examples:
  - Prediction of information needs (pre-caching)
  - Gazemarks as placeholders during context change



Example: Gazemarks

Kern, D. et al. (2010) Gazemarks: gaze-based visual placeholders to ease attention switching. In: Proc. of the 28th international conference on Human factors in computing systems (CHI'10), ACM, pp. 2093-2102

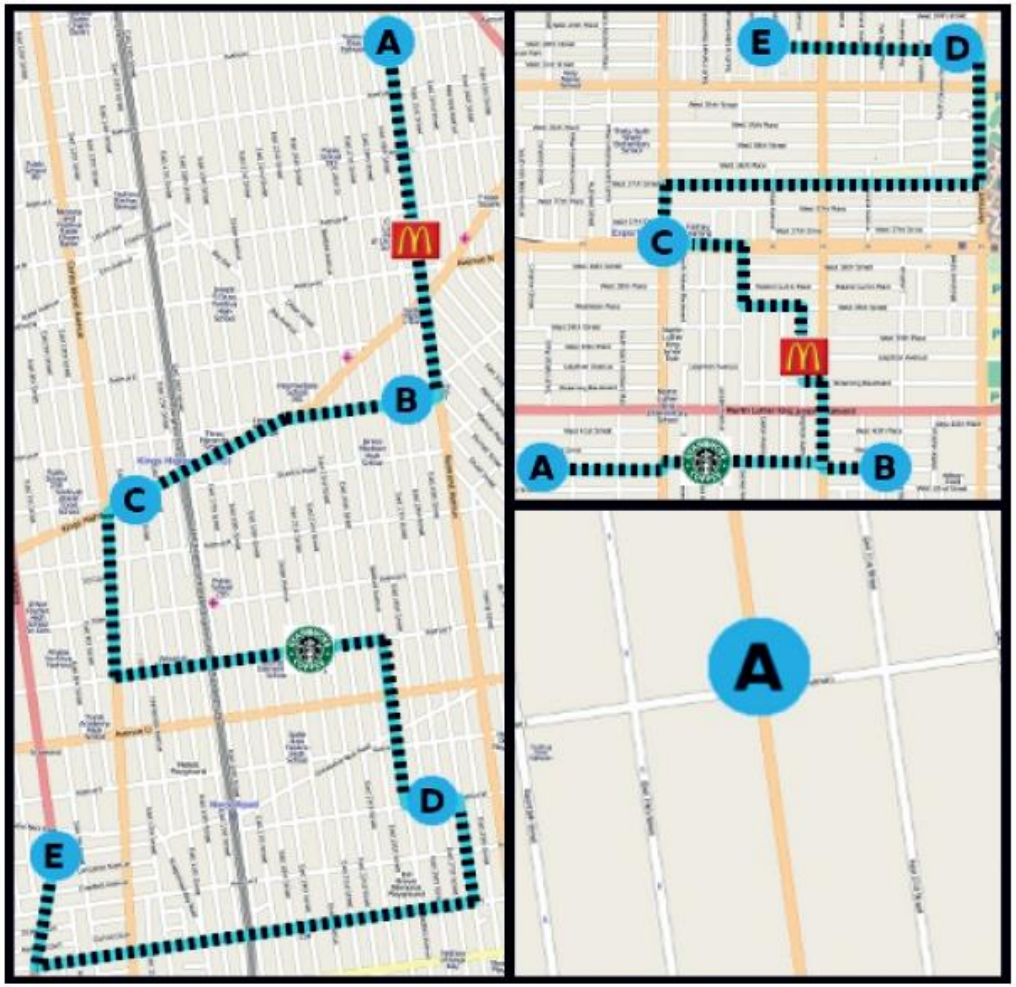
GeoGazemarks



- Providing gaze history for the orientation on small display maps
- History of a user's visual attention on a map as visual clue to facilitate orientation.

[Giannopoulos, Kiefer, Raubal 2012]

Experiment



- 7 point objects on each map (5 blue circles, 2 logos)
- Participants traverse vector sequence (A->E) then find their way to logos.

Results

Significant increase in efficiency and an increase in effectiveness for a map search task, compared to standard panning and zooming.

	Interaction Sequence Length	
	Median	Standard Deviation
Ggz	25.5	17.17
Std	75	52.6

Ggz = with GeoGazemarks, Std = without GeoGazemarks

$\mathbf{p < 0.001, Z = -4.799}$

Some conclusions

- Pervasive usage of mobile phones provides great opportunity to GI Scientists for modeling human mobility patterns.
  - Dynamic clustering of urban-scale mobility
  - Time series patterns of dynamic clustering
- Mobile eye-tracking provides novel ways to answer the 'why?' question in human wayfinding studies.
- Outdoor real-world studies are complex.
- Use of gaze history can enhance HCI on small display maps.

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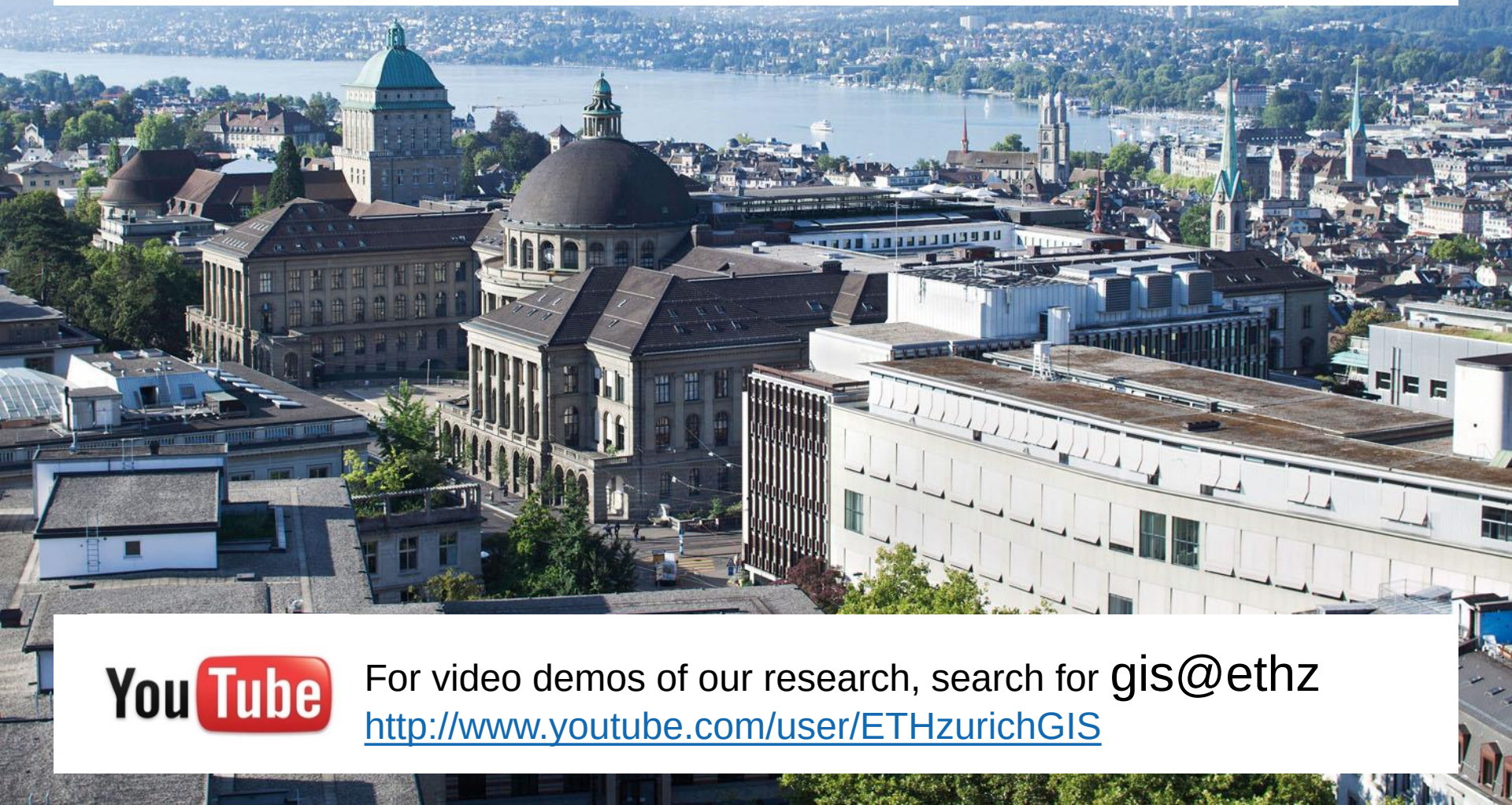
Thank you!



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