Routing for Humans

Sebastian Ritterbusch

State of the Map 2019

Heidelberg, 23rd of September

I) Introduction

Urban routing for non-motorized participants

Routago
Safe Pedestrian Navigation

Routing for vulnerable traffic participants

- Use of the side of roads is obviously safer
- Choice of the side influences optimal path significantly
- Strongly preferred crossings at traffic lights and similar

Currently *publicly accessible* routing solutions

- Routing centered on roads — as if there were no cars

Using OSM data for scalable & robust routing

- Use of detailed annotations where available — now!

II) The TERRAIN Project

Part of the TERRAIN research project

Independent urban mobility for pedestrians with blindness and low vision through audio-tactile navigation

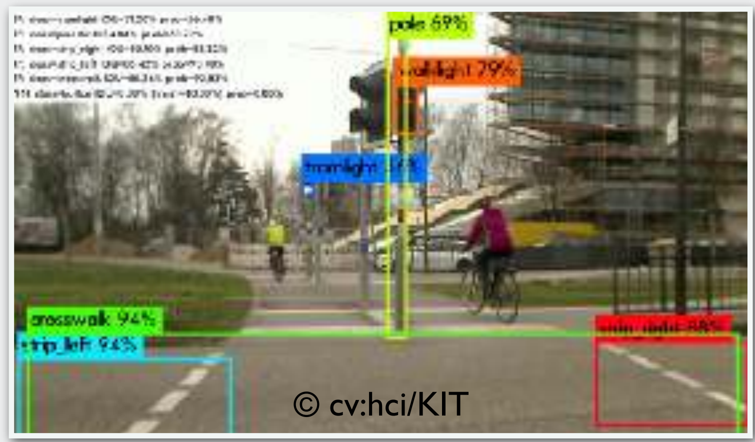
“Many no longer feel confident leaving their homes, because they don't know what obstacles they encounter outside.”

http://www.terrain-projekt.de/

Part of the TERRAIN research project

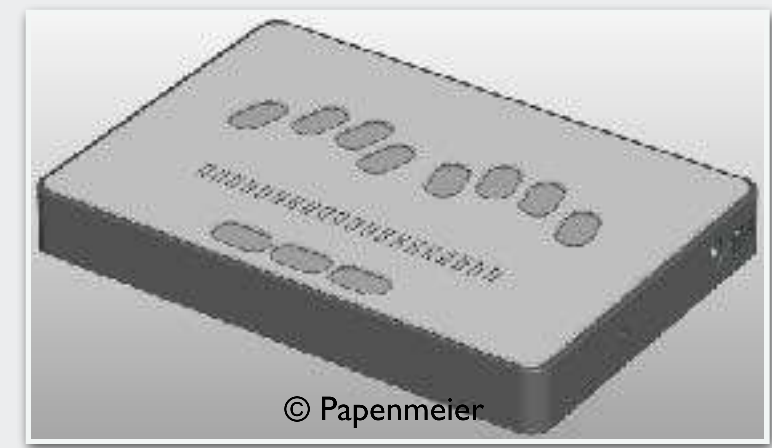
Routago
Safe Pedestrian Navigation

Scene Analysis by Computer Vision

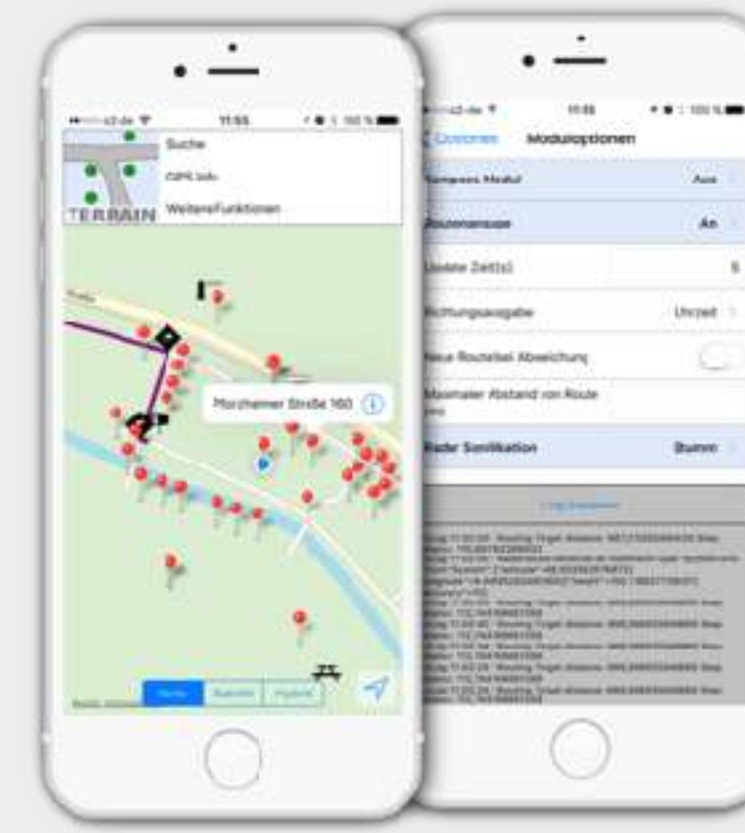


System Evaluation & Mobility Training

Innovative Braille Integration



User Centered Smartphone Solution



Multi-Modal Human-Computer Interaction

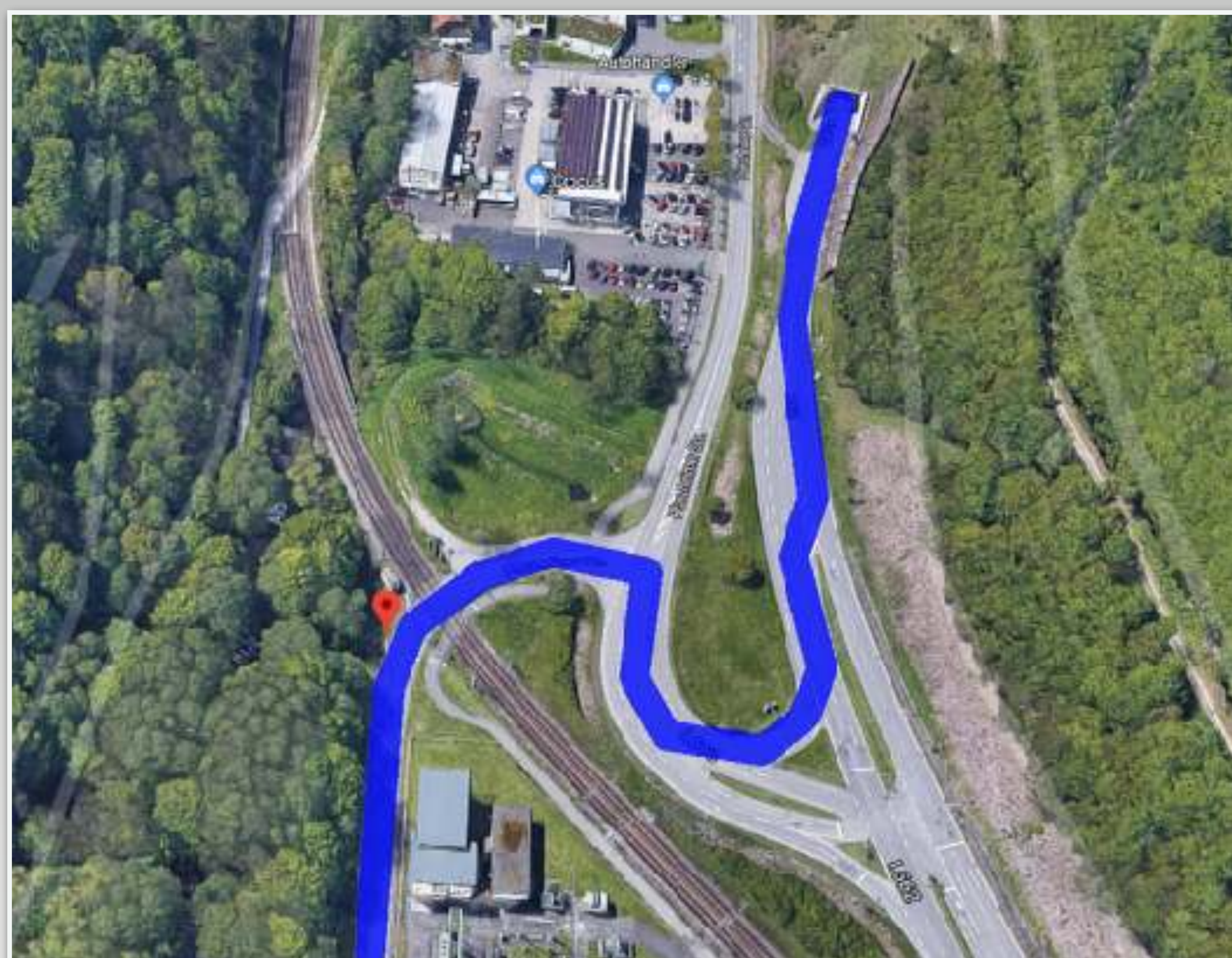
Roadside-aware Safe Routing

Experts and Citizens Involvement

http://www.terrain-projekt.de/

III) „Pedestrian Routing“ — today

„Pedestrian Routing“ on Smartphones - today



Manual reproduction of routing result

„Pedestrian Routing“ option on mobile solutions

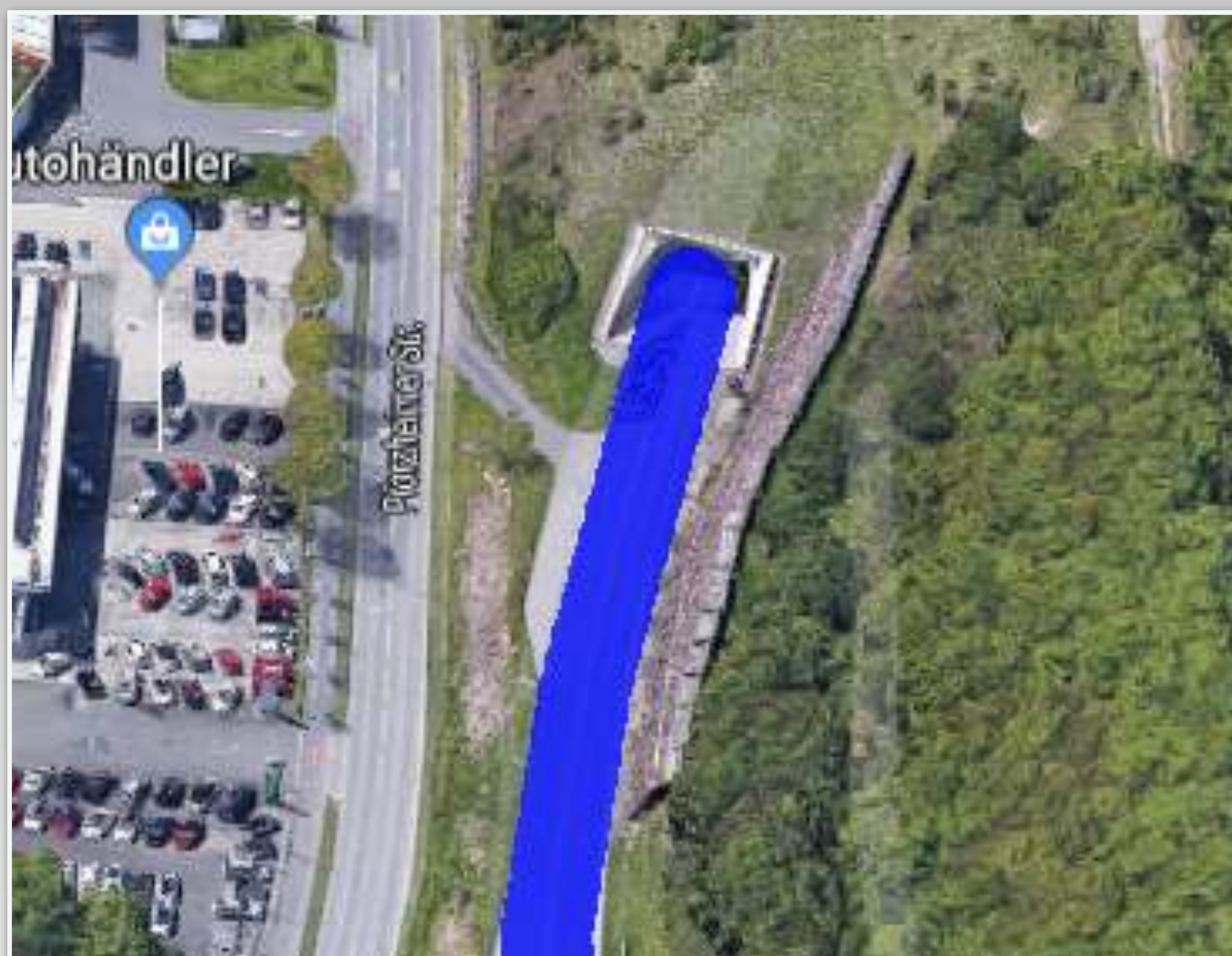
- Use of the same map data as vehicle routing
- Resulting routes often centered on roads
- Some provided routes are very dangerous

Very limited navigation instructions

- Instructions are aiming at car navigation
- No information when and where to cross
- Crossing features do not exist

„Pedestrian Routing“ on Smartphones - today

Routago
Safe Pedestrian Navigation



Manual reproduction of routing result

Images © 2018 Google
Map data © 2018 GeoBasis-DE/BKG (2009), Google Deutschland

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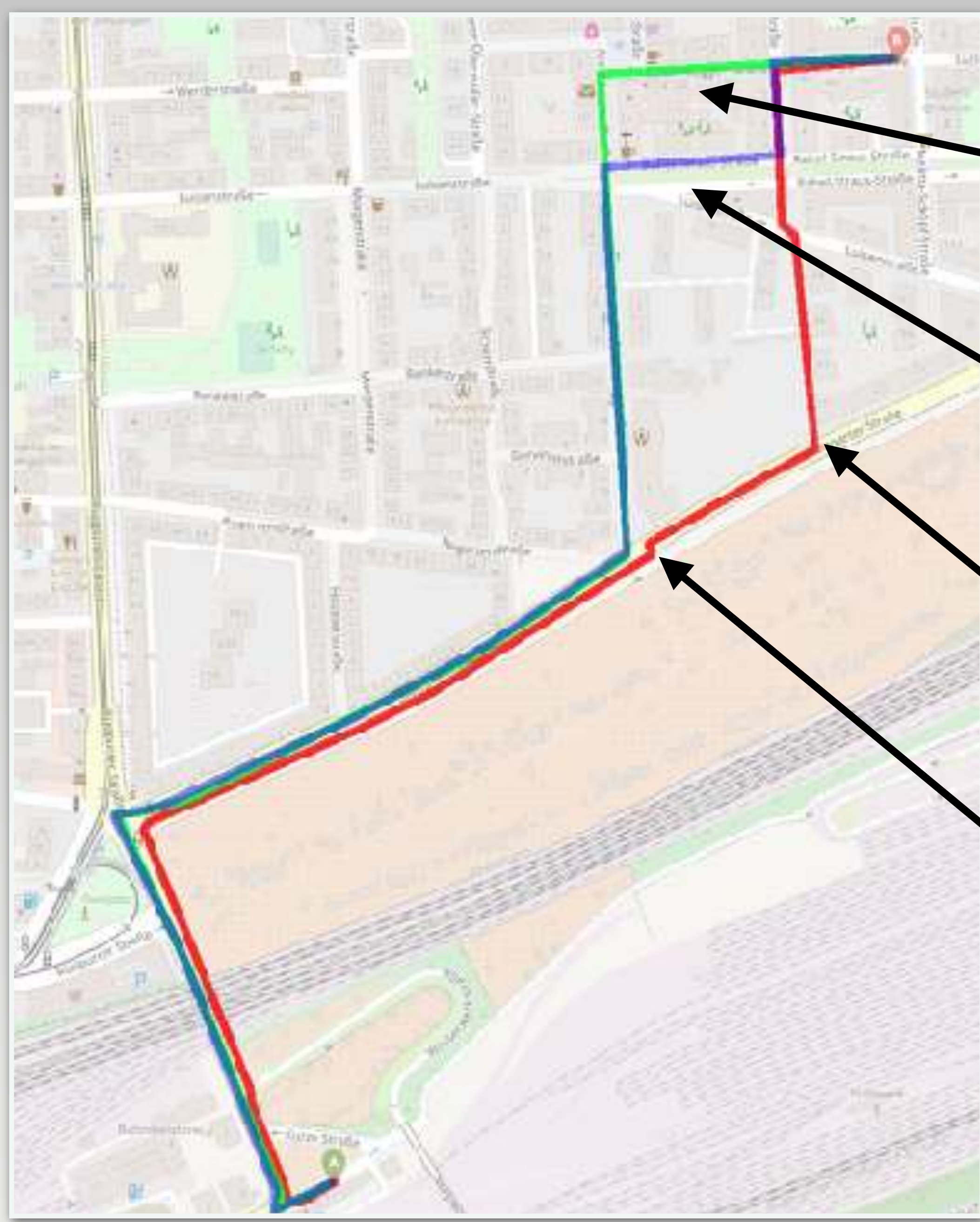
Current pedestrian routing services compared

Routago
Safe Pedestrian Navigation



Apple Maps

Google Maps

ORS

Traffic Lights

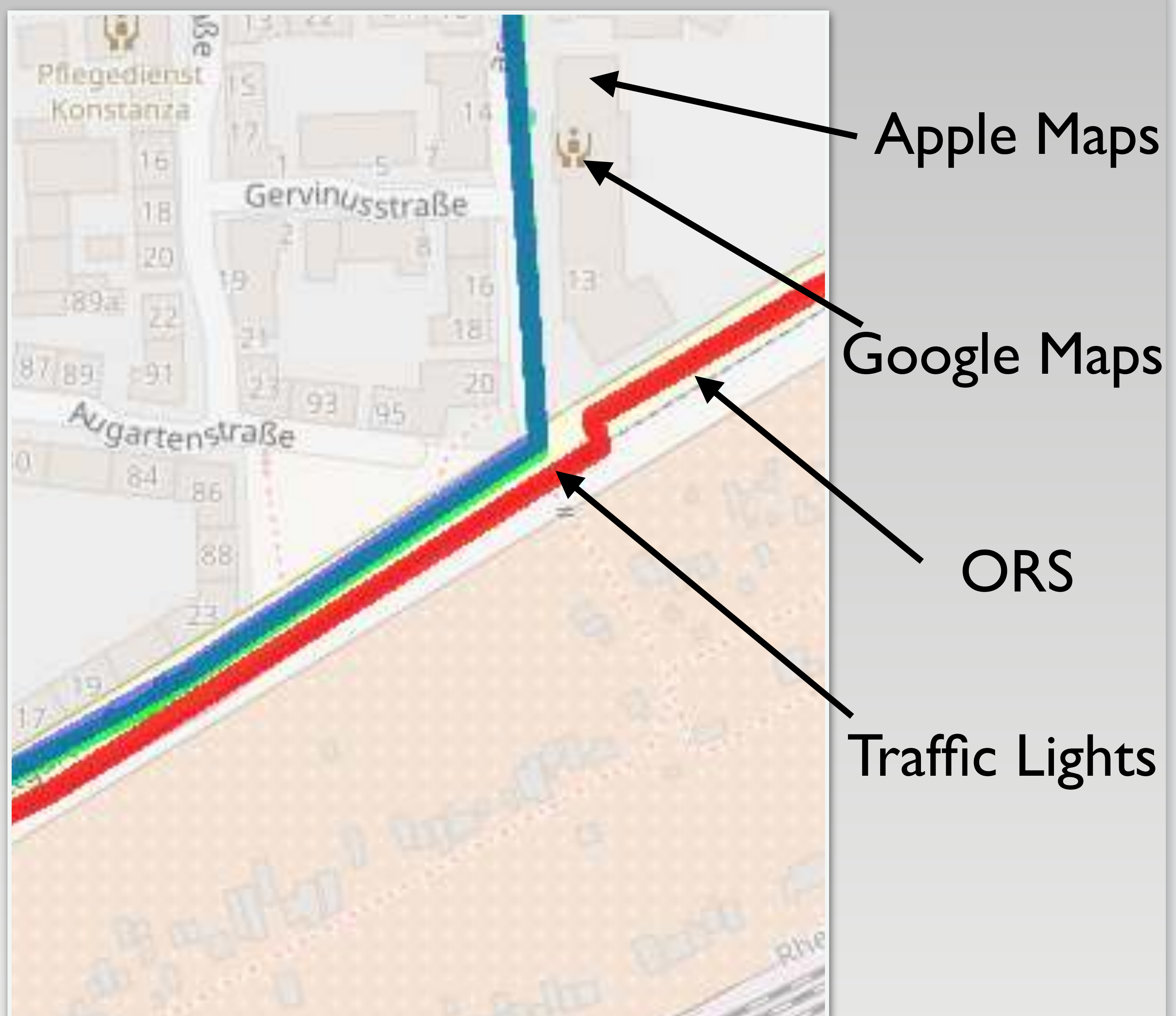
Leaflet, Map data © OpenStreetMap contributors

Pedestrian routings compared

- Google and Apple Maps
  - Paths are centered on streets
  - Traffic lights or sidewalks are ignored
- OpenRouteService (GraphHopper/OSM)
  - Prefers and uses *separate*, *explicit* sidewalks
  - Analyzes elevation and takes soil conditions into concern
  - Switches onto street at pedestrian traffic light

Available public services rely on (rarely) given explicitly pedestrian paths and sidewalks.

Current pedestrian routing services compared



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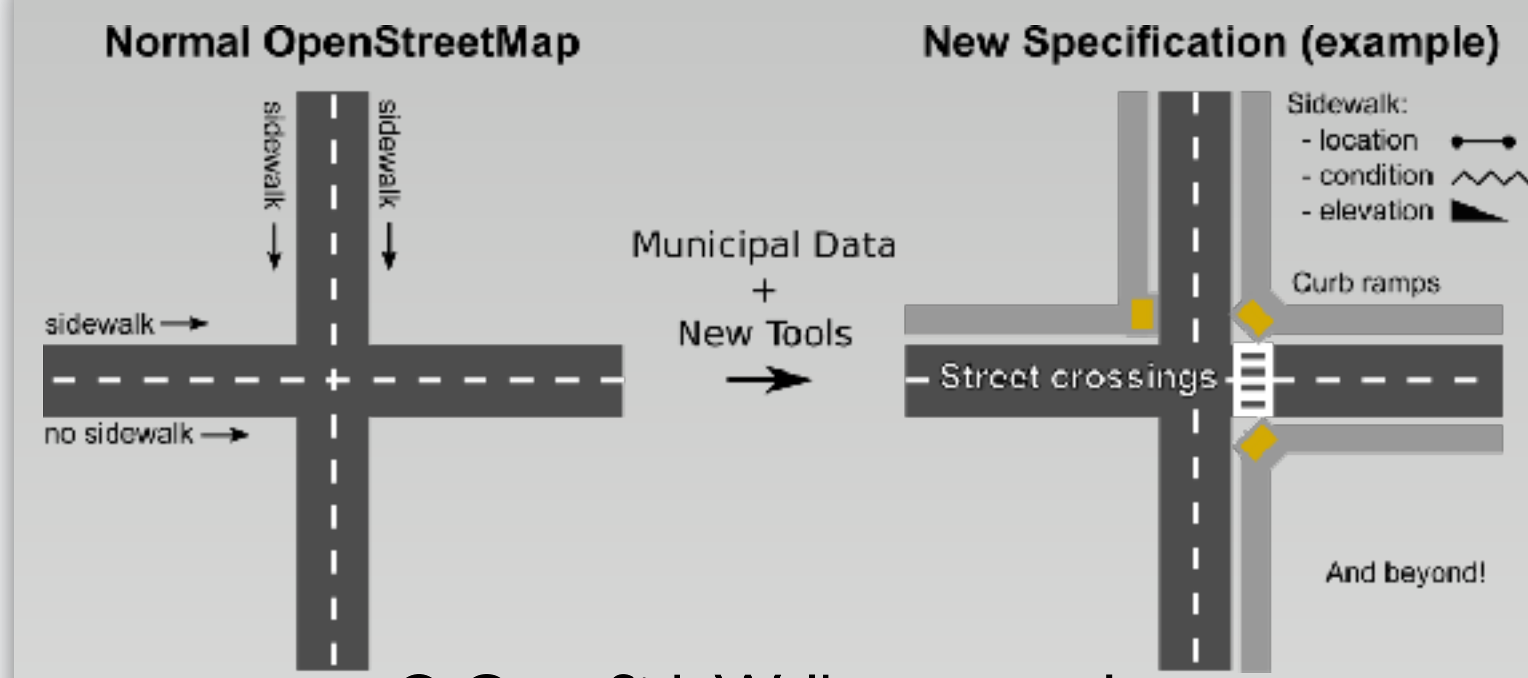
IV) Solutions

OpenSideWalks / AccessMap project



© OpenSideWalks proposal

© AccessMap © MapBox © OpenStreetMap

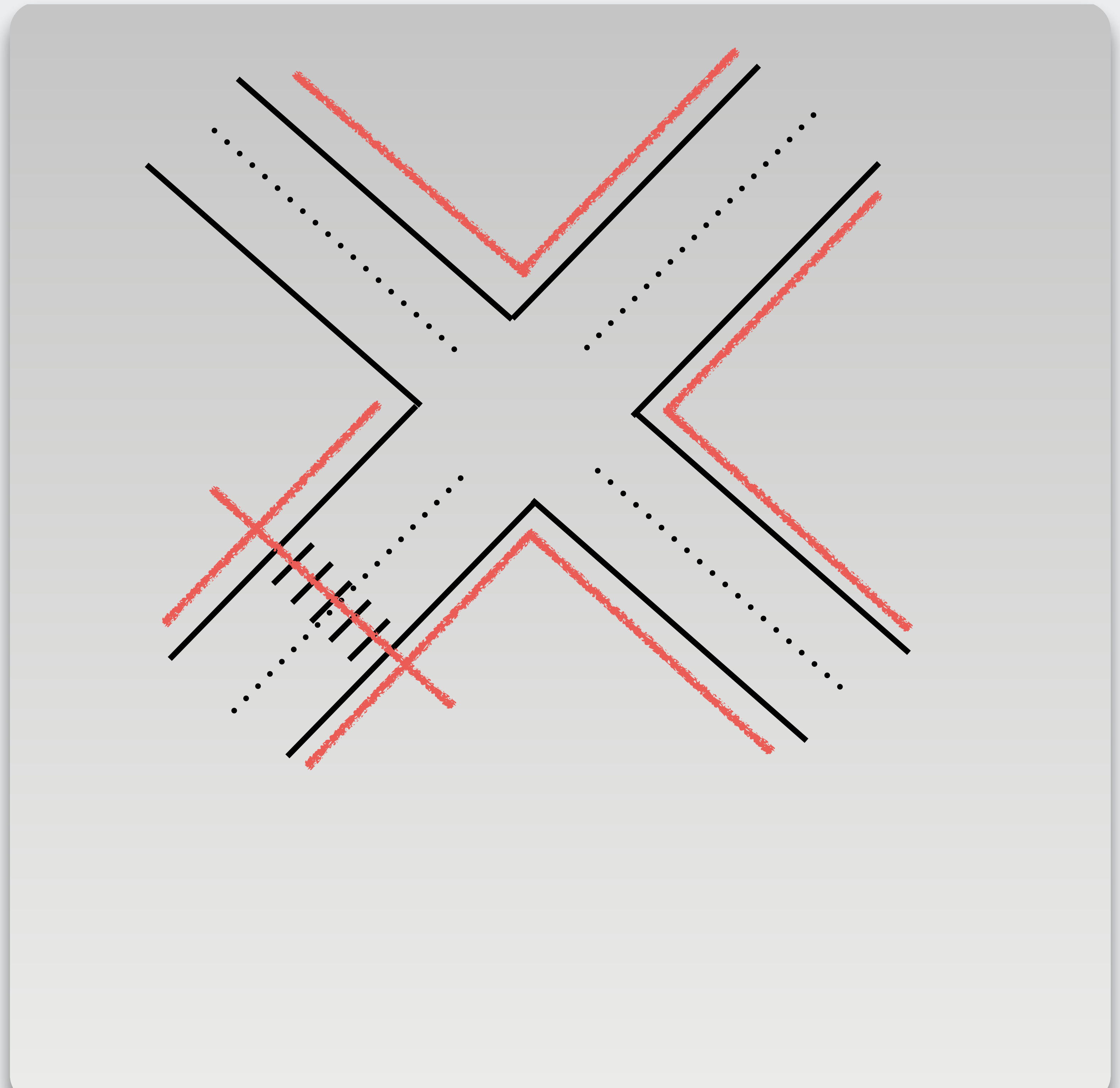
Sidewalks as first class citizens

- Use of many data sources (municipality, height maps, …)
- Combination and synthesis with *significant resources*
- Extending OpenStreetMap by OpenSideWalks proposal
- *Akquisition campaigns and continuous updates*
- Considering various requirements (blind, wheelchair, …)
- Emphasis on *metropolitan areas*
- Routing with traditional OSM path finding

[1] Bolten, Mukherjee, Sipeeva, Tanwwer, Caspi: A pedestrian-centered data approach for equitable access to urban infrastructure environments. IBM Journal of Research and Development, 61(6), 10-1 (2017).

Schmitz, Ertl: Rule-based transformation of map data

Routago
Safe Pedestrian Navigation



Pedestrian paths by map transforms

1. Pedestrian paths parallel to roads („sidewalk“-tag(!))
2. Additional orthogonal paths at crossings

[1] Schmitz, B., and Ertl, T.: Rule-based transformation of map data. In Pervasive Computing and Communications Workshops (PERCOM Workshops), 2012 IEEE International Conference on (pp. 578-583). IEEE (2012).
[2] Schmitz, B., and Ertl, T.: Individualized route planning and guidance based on map content transformations. In International Conference on Computers for Handicapped Persons (pp. 120-127). Springer, Cham (2014).

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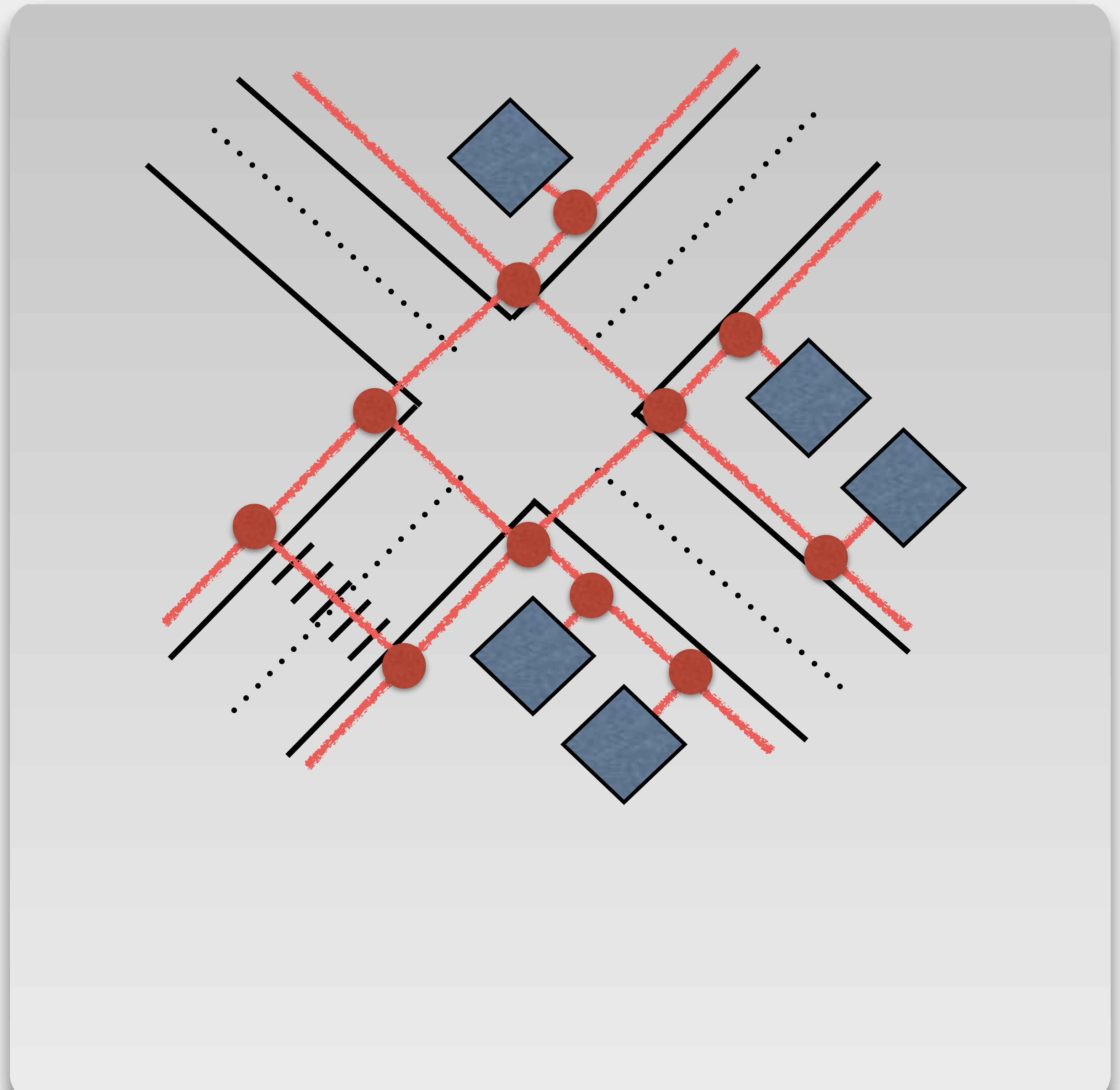

Pedestrian paths by map transforms

1. Pedestrian paths parallel to roads („sidewalk“-tag(!))
2. Additional orthogonal paths at crossings
3. Orthogonal paths at intersections
4. Topological connections of paths at intersections
5. Topological connections of paths at crossings
6. Cut off overhanging paths
7. Add paths to house entrances

[2] Schmitz, B., and Ertl, T.: Rule-based transformation of map data. In Pervasive Computing and Communications Workshops (PERCOM Workshops), 2012 IEEE International Conference on (pp. 578-583). IEEE (2012).
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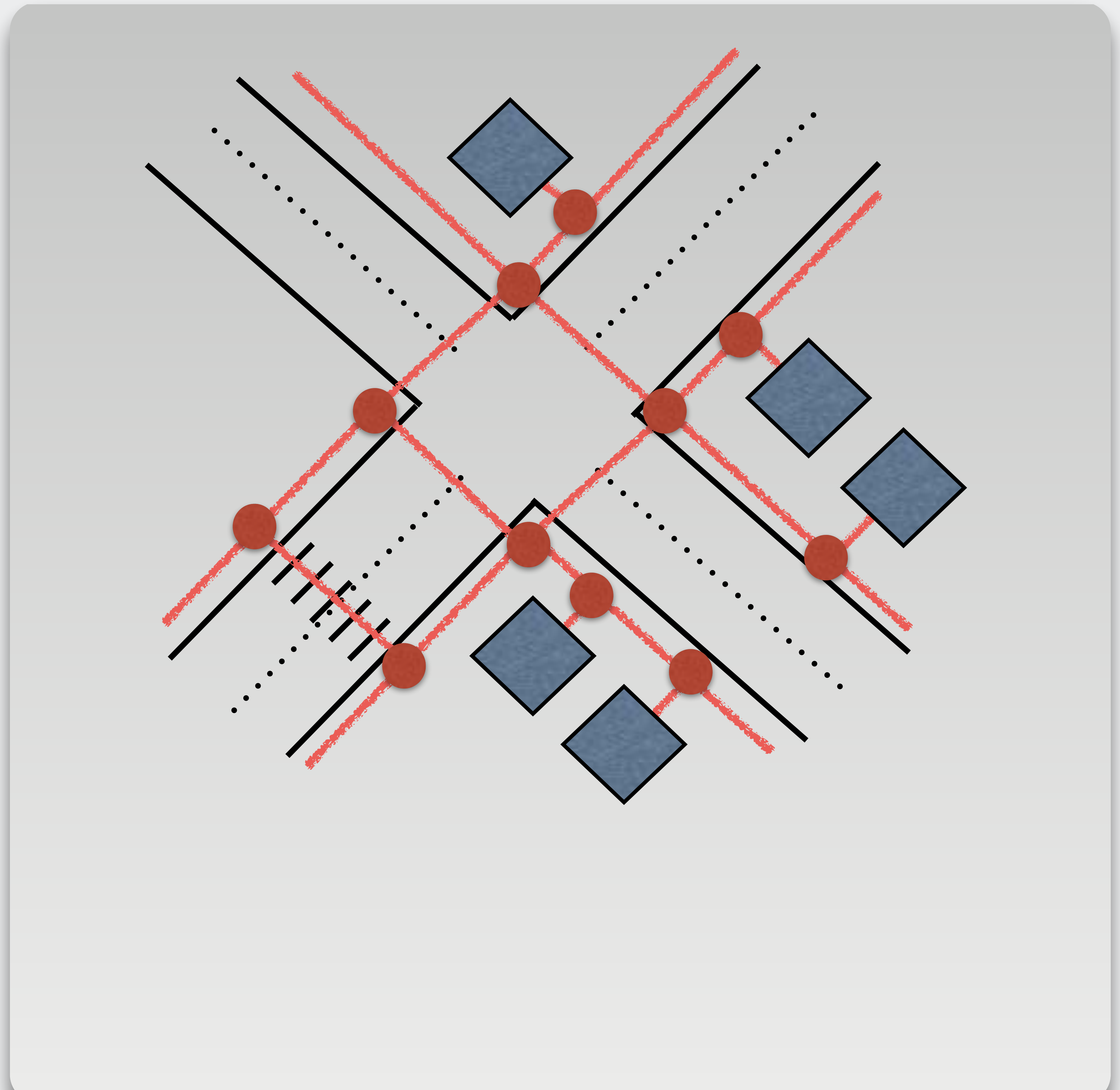
Safe Pedestrian Navigation



Pedestrian paths by map transforms

- Extension of map by missing sidewalk paths
- Applying *individual cost function* at *transform time*
- Application of *global transform* to „sufficiently large“ tile
- Resulting map network open for all OSM path finding

[2] Schmitz, B., and Ertl, T.: Rule-based transformation of map data. In Pervasive Computing and Communications Workshops (PERCOM Workshops), 2012 IEEE International Conference on (pp. 578-583). IEEE (2012).
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V) Transparent Expansion

Transparent Expansion: OSM data

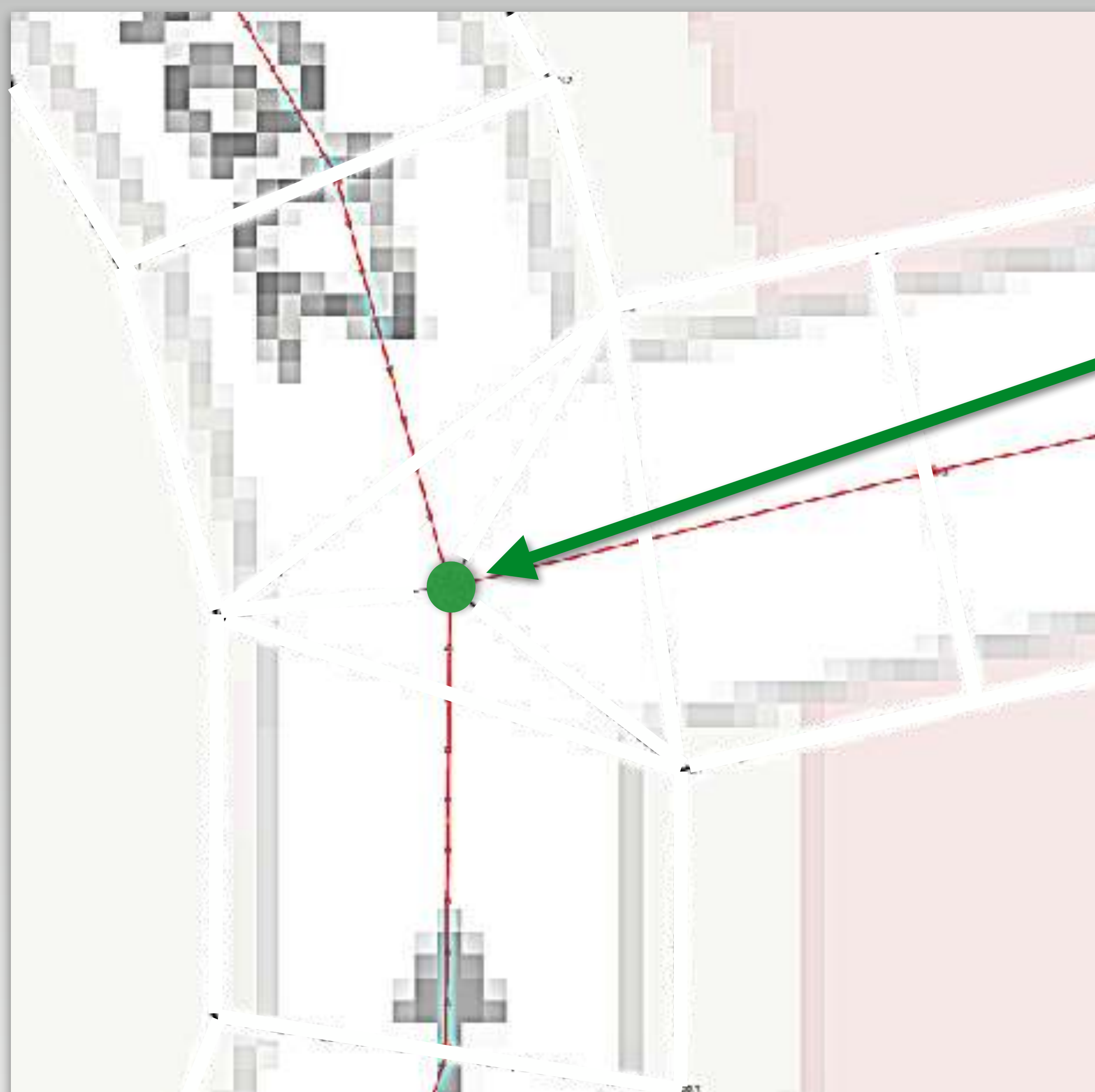
JOSM, Map data © OpenStreetMap contributors

OpenStreetMap's pedestrian paths & sidewalks

- Explicit pedestrian paths
  - Pedestrian paths can be given explicitly (green lines)
  - Shared paths are defined by specific tags
  - Path quality and special conditions may be given
  - Position is explicitly defined
- Implicit sidewalks
  - Sidewalks are implicitly given as properties to roads (gray lines)
  - Implicit position may be estimated by heuristics and road widths
- Data quality and completeness varies a lot

[4] Ritterbusch, S. and Kucharek, H.: Robust and Incremental Pedestrian Path Network Generation on OpenStreetMap for Safe Route Finding." International Conference on Computers Helping People with Special Needs. Springer, Cham, 2018.

Transparent Expansion: Topological Expansion



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Local **topological expansion of OSM network**

1. An OSM point with ***n*** ways expands to ***n*** virtual points

[4] Ritterbusch, S. and Kucharek, H.: Robust and Incremental Pedestrian Path Network Generation on OpenStreetMap for Safe Route Finding.“ International Conference on Computers Helping People with Special Needs. Springer, Cham, 2018.

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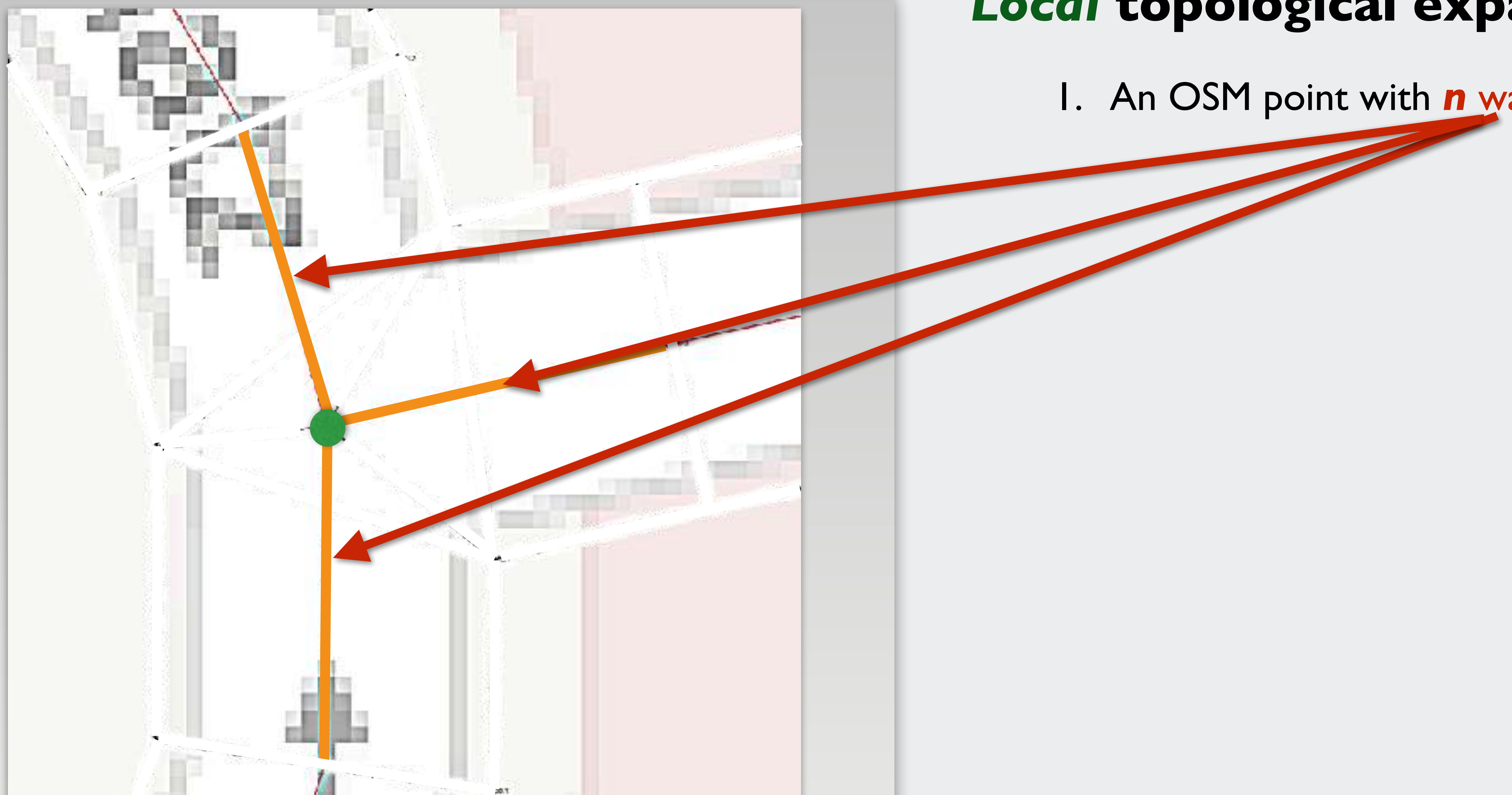

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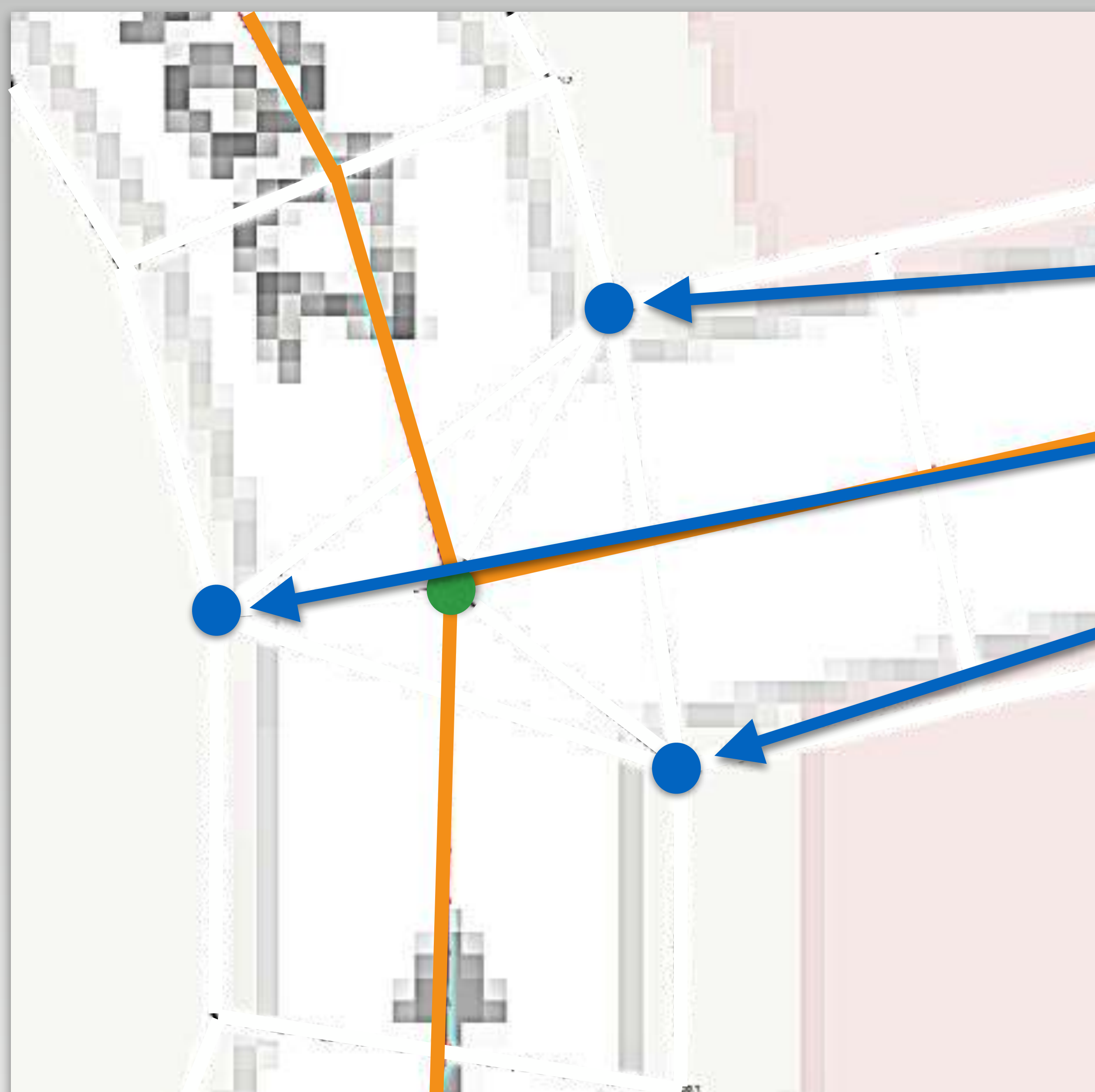

JOSM, Map data © OpenStreetMap contributors

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1. An OSM point with ***n*** ways expands to ***n*** virtual points

(!) Exact position of virtual points shown only for illustration, it is **not** relevant for the algorithm

[4] Ritterbusch, S. and Kucharek, H.: Robust and Incremental Pedestrian Path Network Generation on OpenStreetMap for Safe Route Finding.“ International Conference on Computers Helping People with Special Needs. Springer, Cham, 2018.

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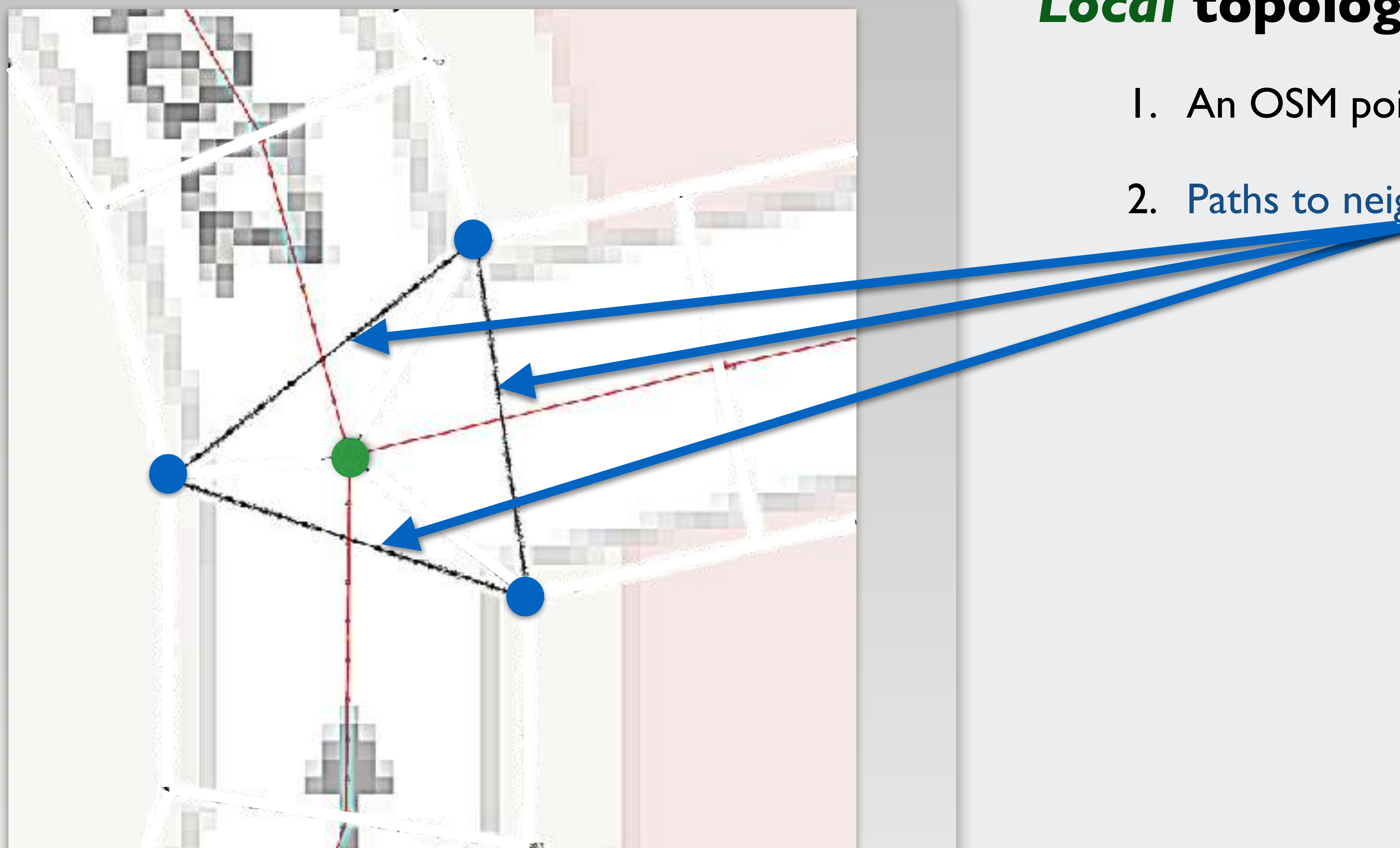

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1. An OSM point with ***n*** ways expands to ***n*** virtual points
2. Paths to neighboring points and originating OSM point

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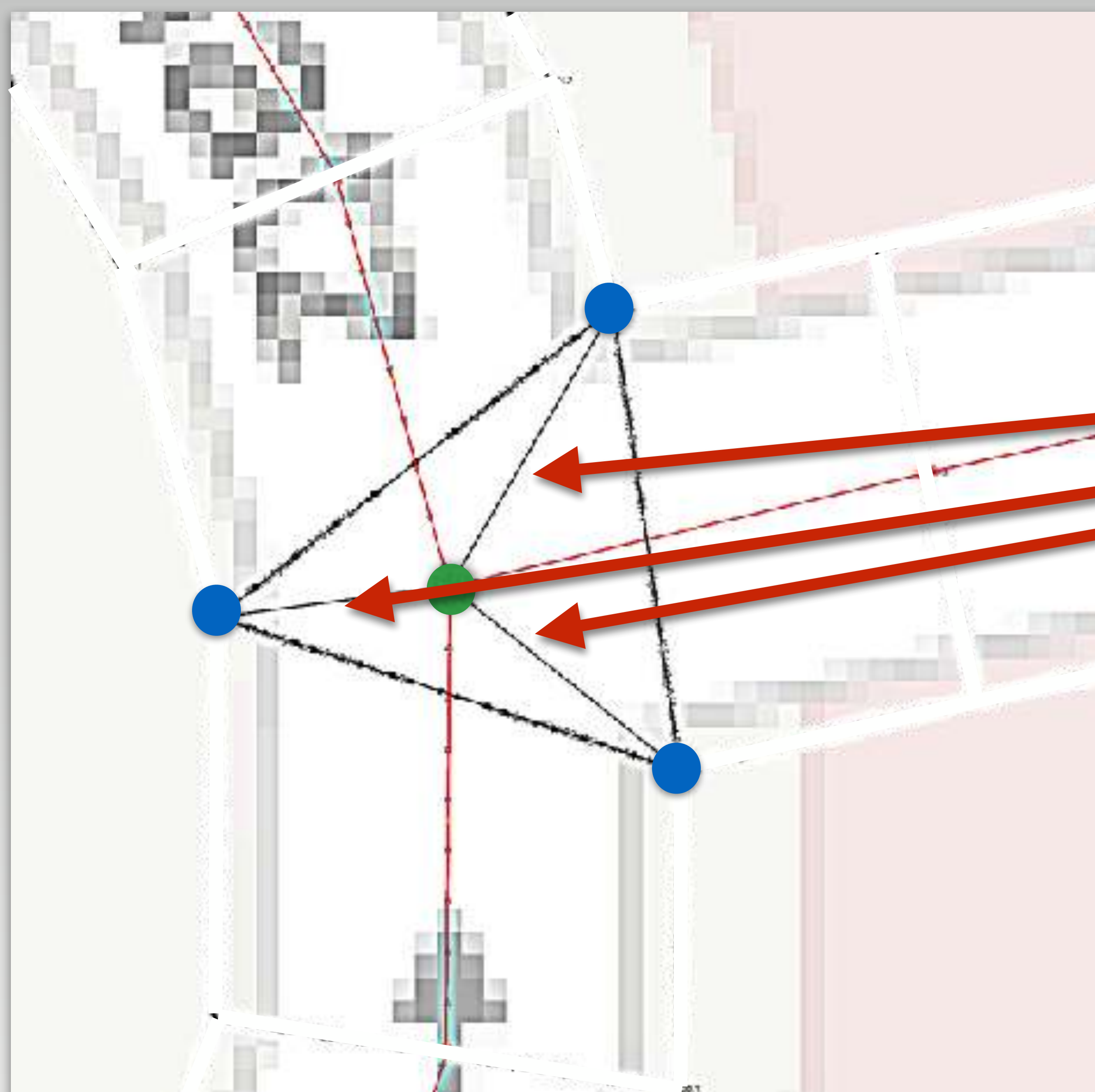

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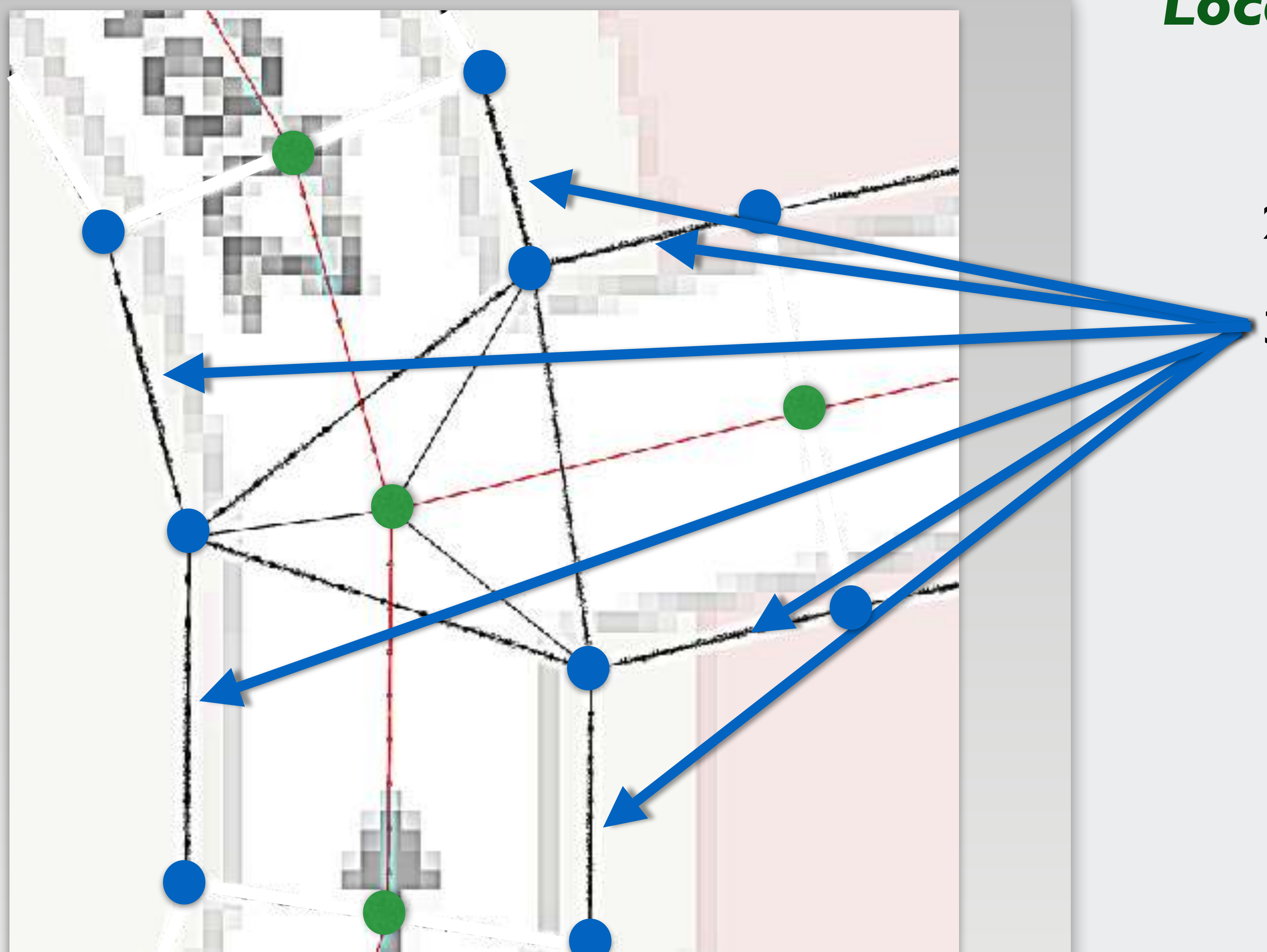
Routago
Safe Pedestrian Navigation



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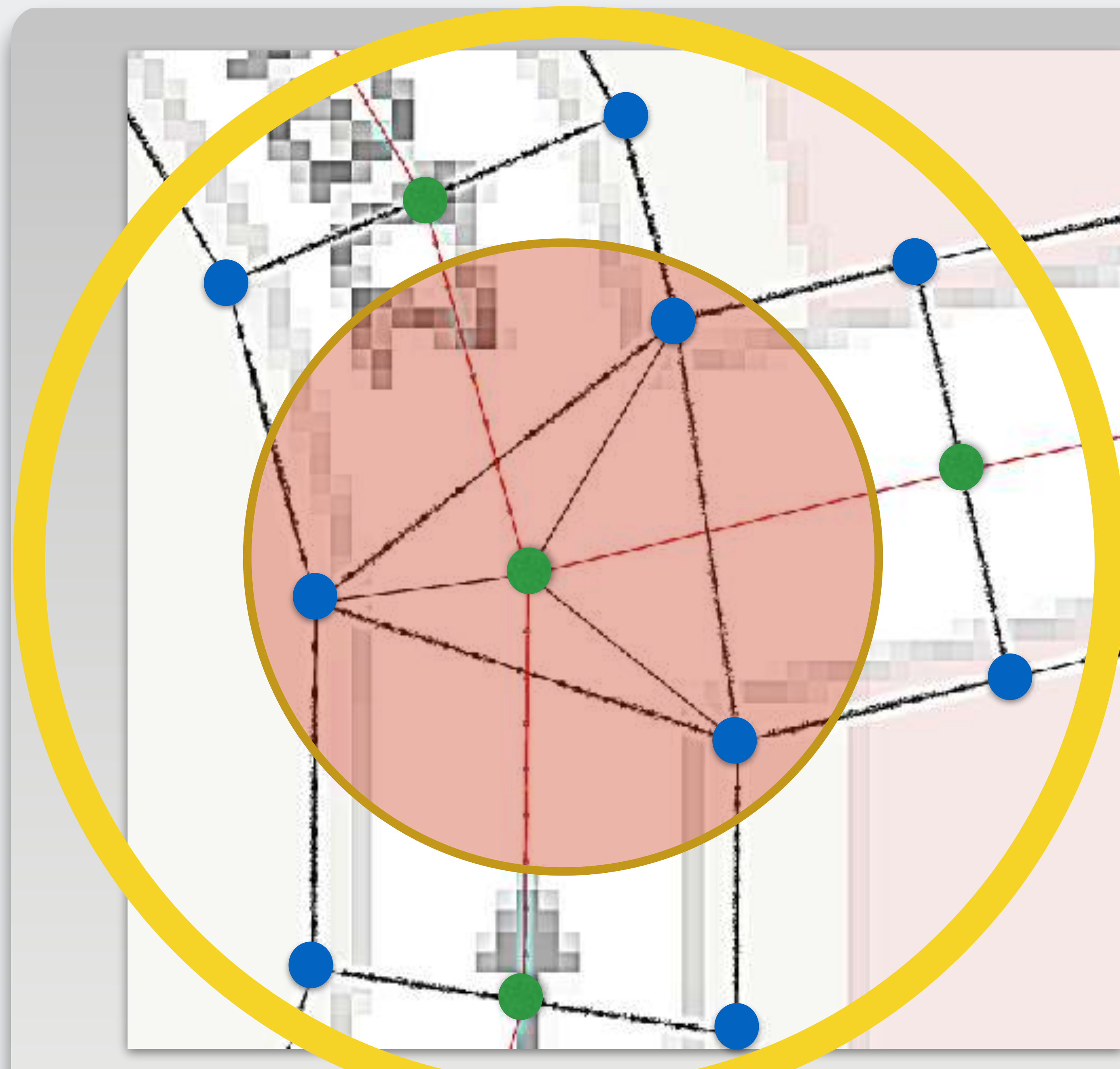

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Local topological expansion of OSM network

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2. Paths to neighboring points and originating OSM point
3. Paths to corresponding virtual points of OSM neighbors

- Needed look-up is local up to next OSM neighbor
- Geometric path position is computed later on demand
- Centered paths only for dedicated pedestrian paths

[4] Ritterbusch, S. and Kucharek, H.: Robust and Incremental Pedestrian Path Network Generation on OpenStreetMap for Safe Route Finding.“ International Conference on Computers Helping People with Special Needs. Springer, Cham, 2018.

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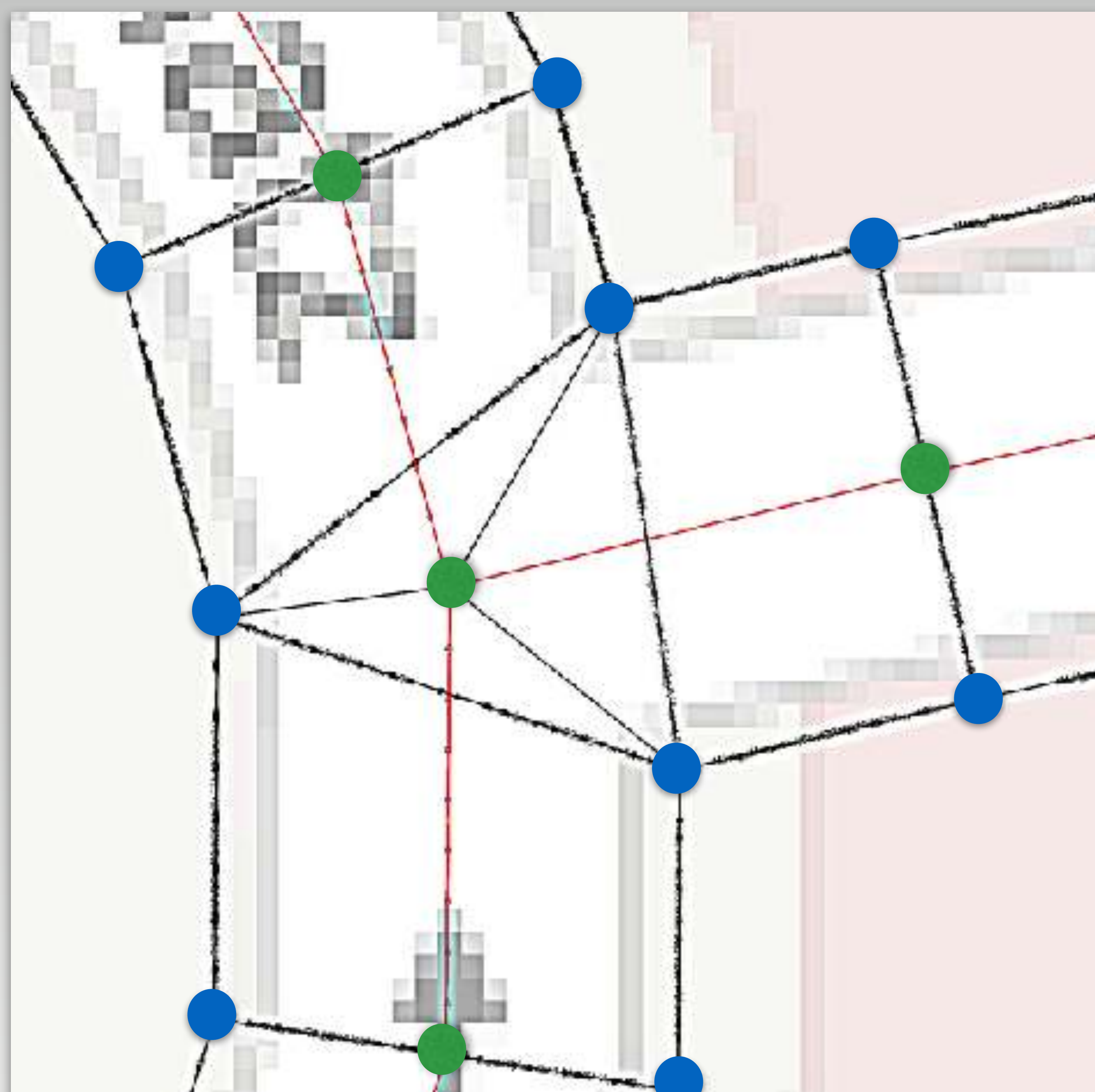

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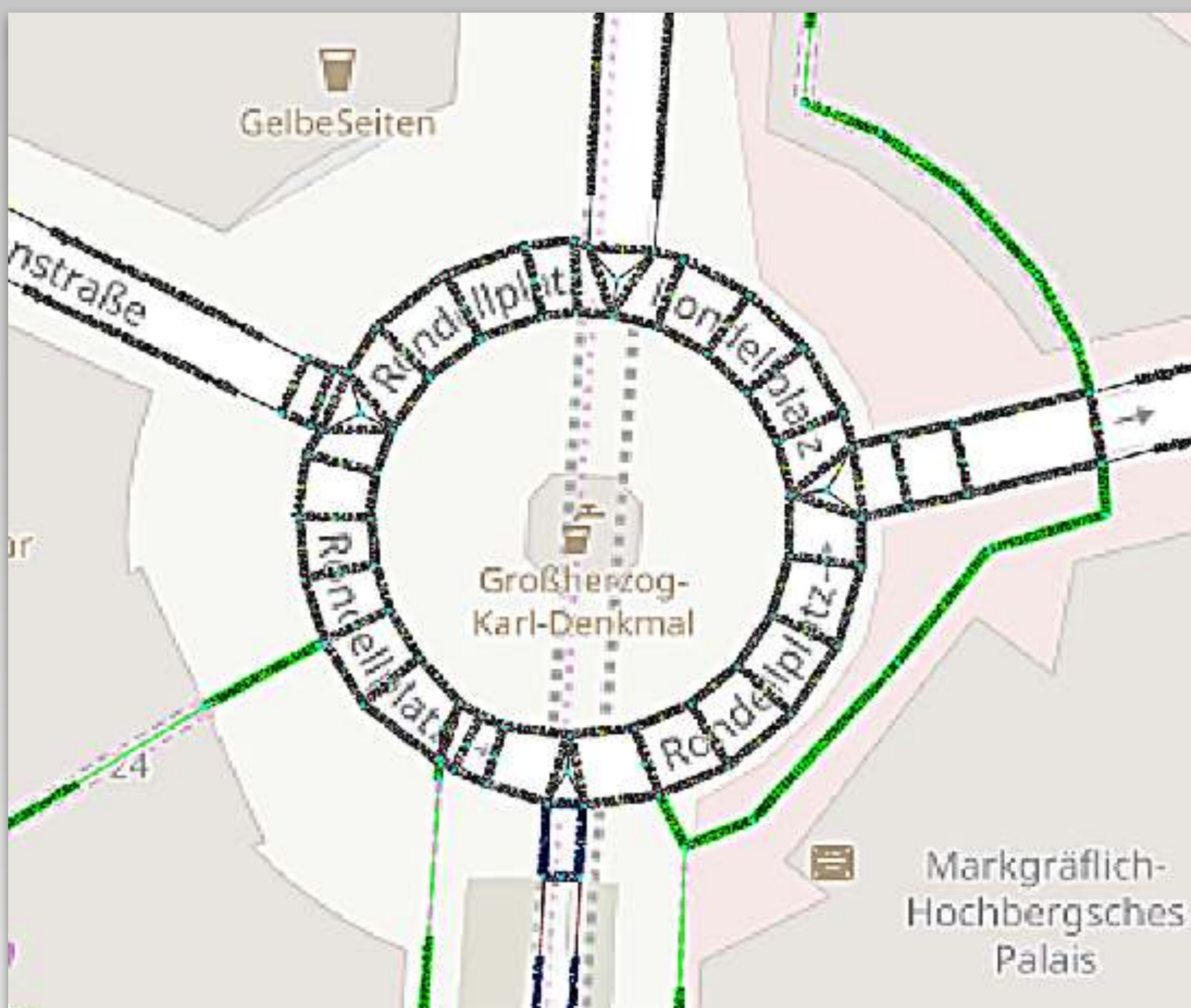
Transparent expansion on live OSM data

[4] Ritterbusch, S. and Kucharek, H.: Robust and Incremental Pedestrian Path Network Generation on OpenStreetMap for Safe Route Finding.“ International Conference on Computers Helping People with Special Needs. Springer, Cham, 2018.

Transparent Expansion: Pedestrian Routing



JOSM, © iXpoint, Map data © OpenStreetMap contributors

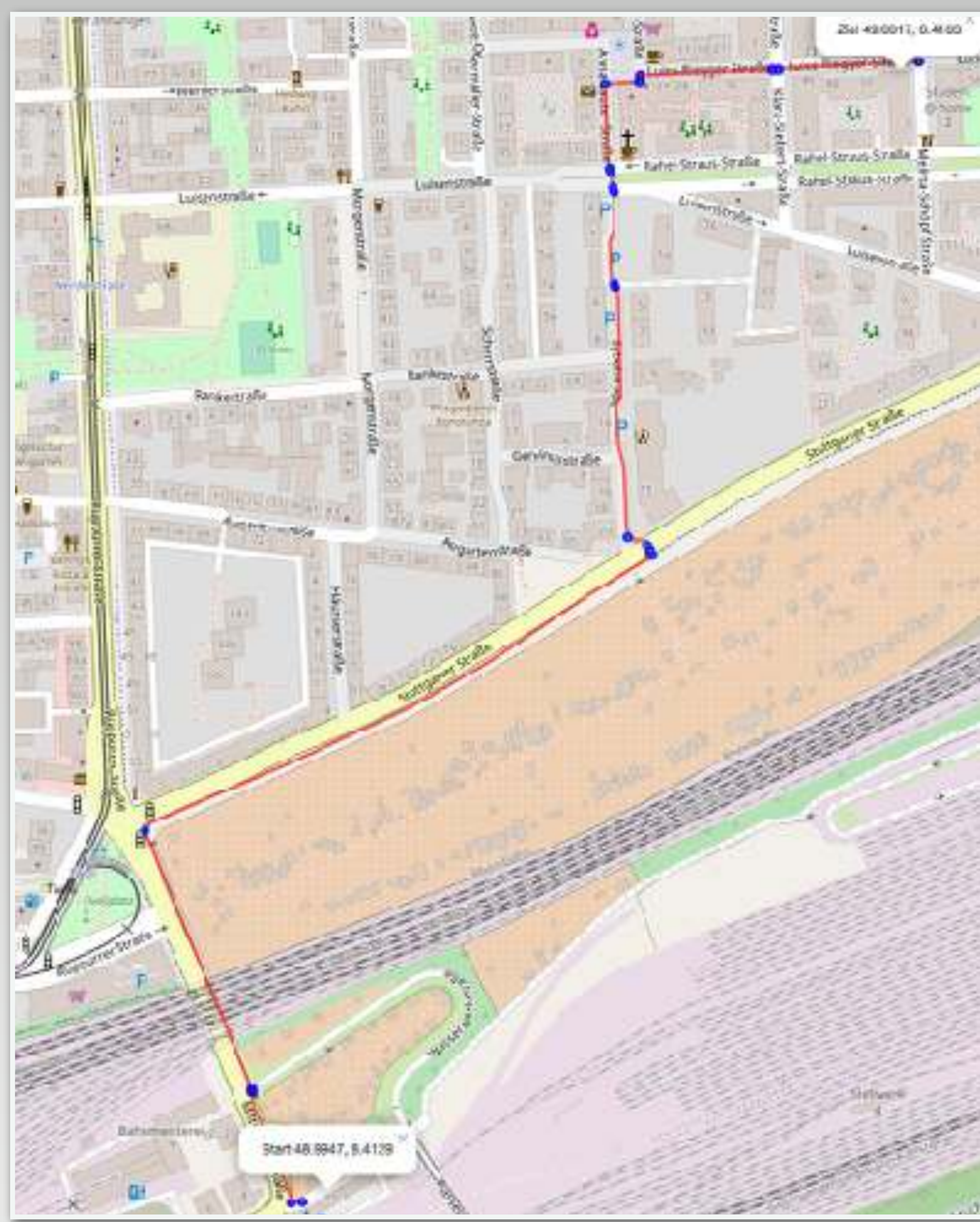
Detailed roadside-aware pedestrian routing

- Virtual path network with all roadsides and crossings
- Explicit pedestrian paths are seamlessly included
- Routing can access OSM-data *and* roadside information
- Path finding open to all traditional algorithms
- Crossings contain „along“ *and* „across“ data
- Routing cost matrix needs significant extensions
- Path preference is encoded in cost matrix only

Applications: Safe path routing, wheelchair routing, …

[4] Ritterbusch, S. and Kucharek, H.: Robust and Incremental Pedestrian Path Network Generation on OpenStreetMap for Safe Route Finding.“ International Conference on Computers Helping People with Special Needs. Springer, Cham, 2018.

Transparent Expansion: Benchmark problem



Leaflet, iXpoint, Map data (C) OpenStreetMap contributors

Results on benchmark problem

- Routing using A* algorithm with preliminary cost matrix
- Sidewalks as well as dedicated pedestrian paths are used
- Pedestrian traffic light is chosen as suitable crossing
- Estimated sidewalk positions fit well to satellite imaging
- Given accurate GPS data, accurate guiding is feasible
- Segmenting and instruction generation in development

Route quality dependencies

- Cost matrix & map data quality

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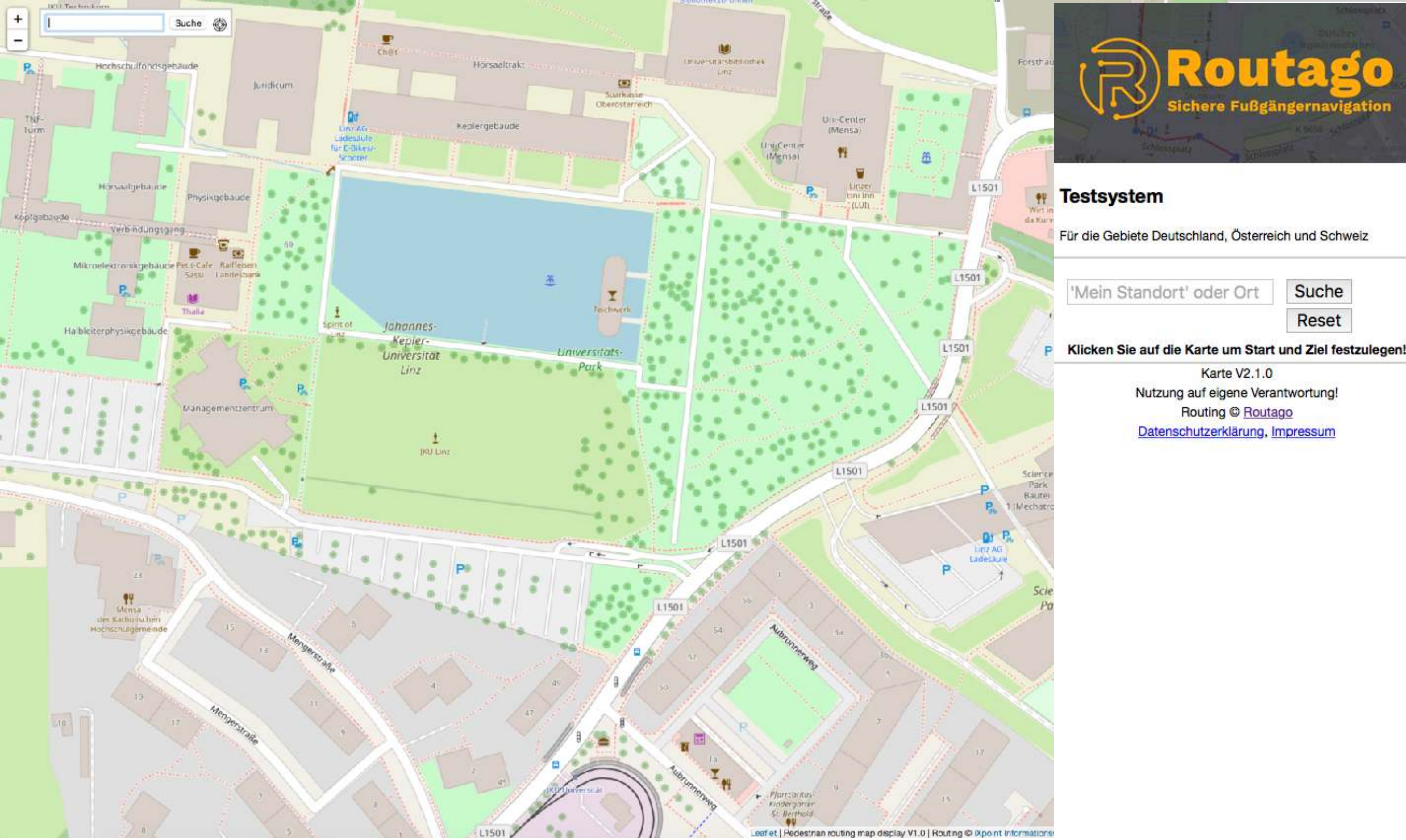
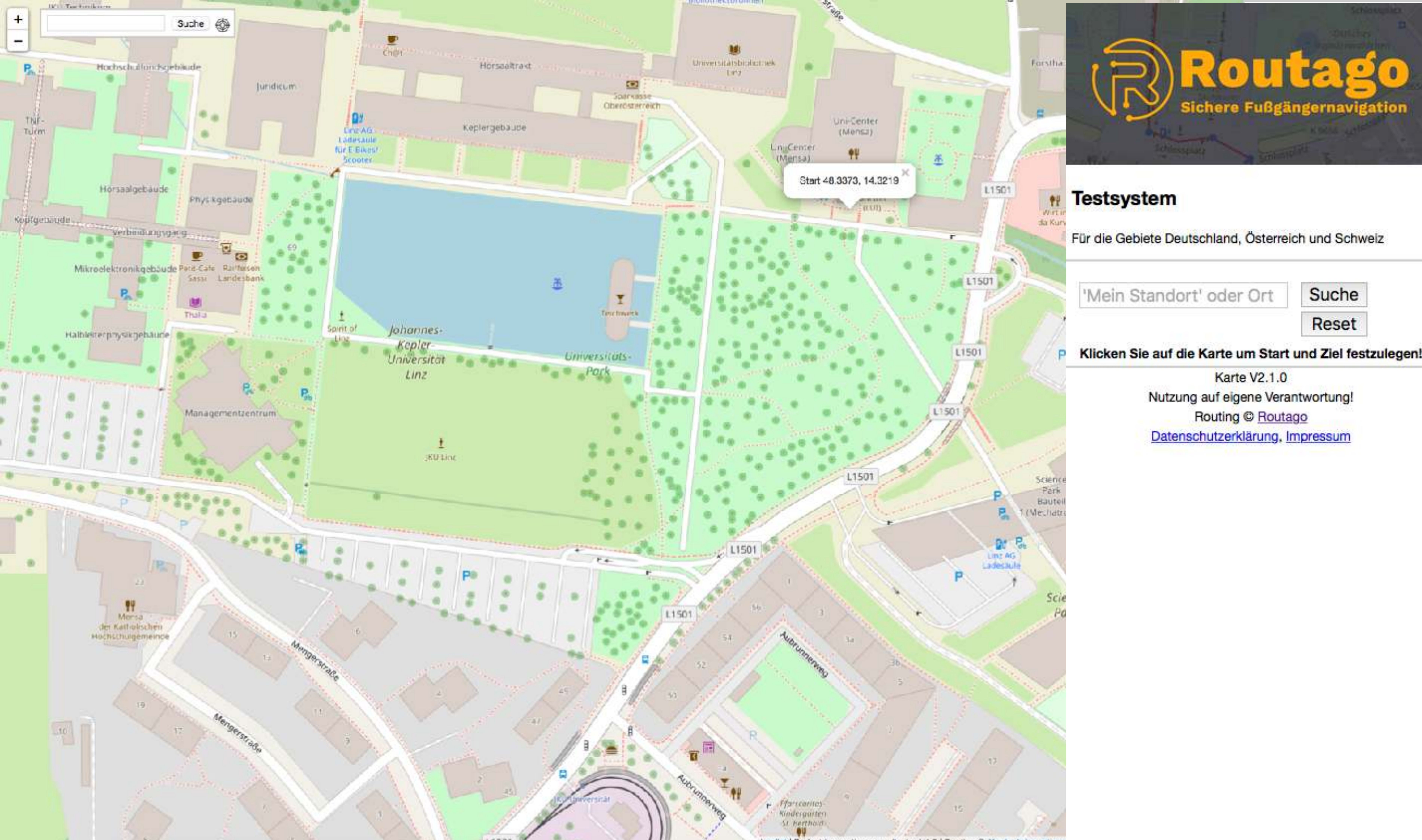
VI) Online Testinterface



https://routago.de/pedestrian-routing/



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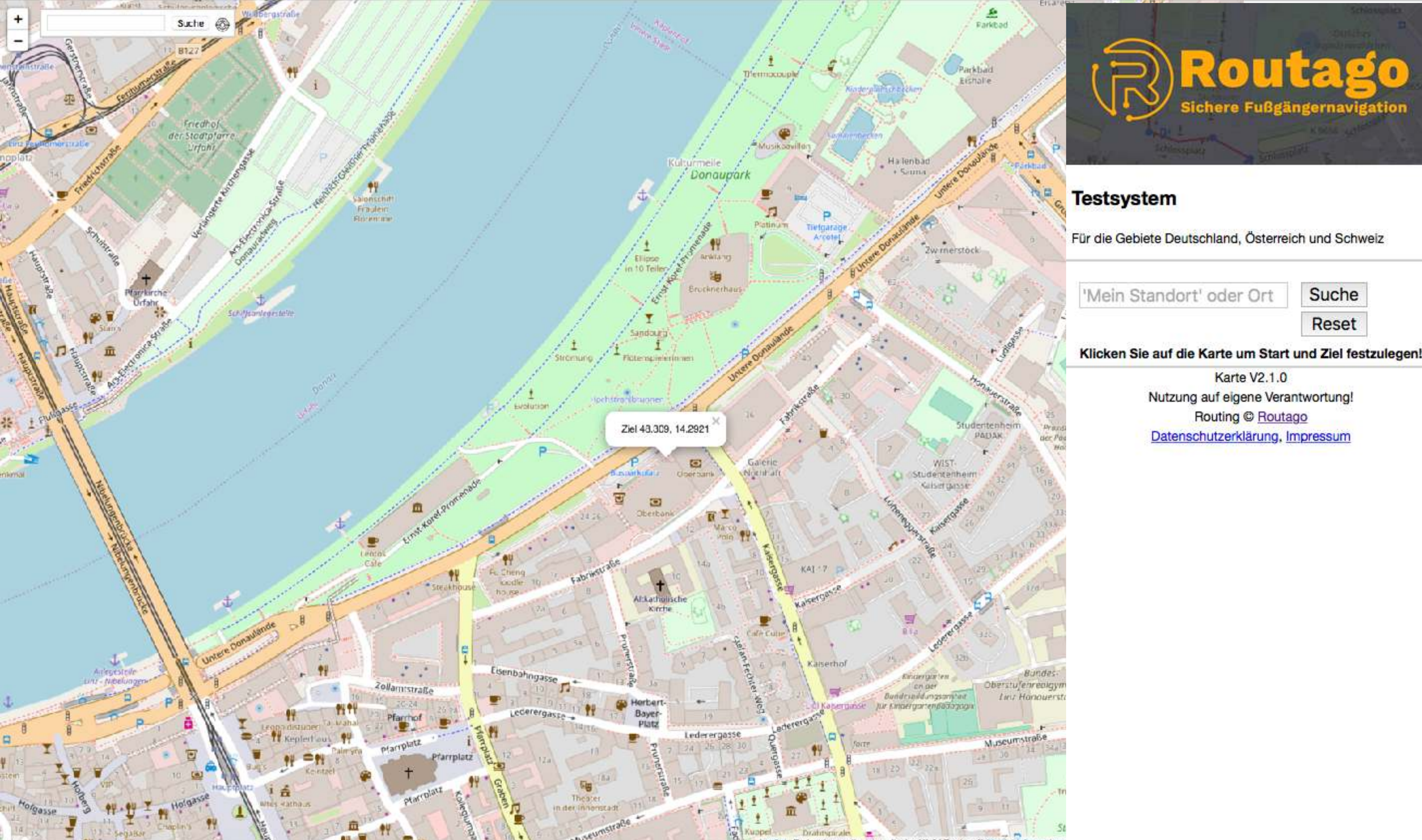

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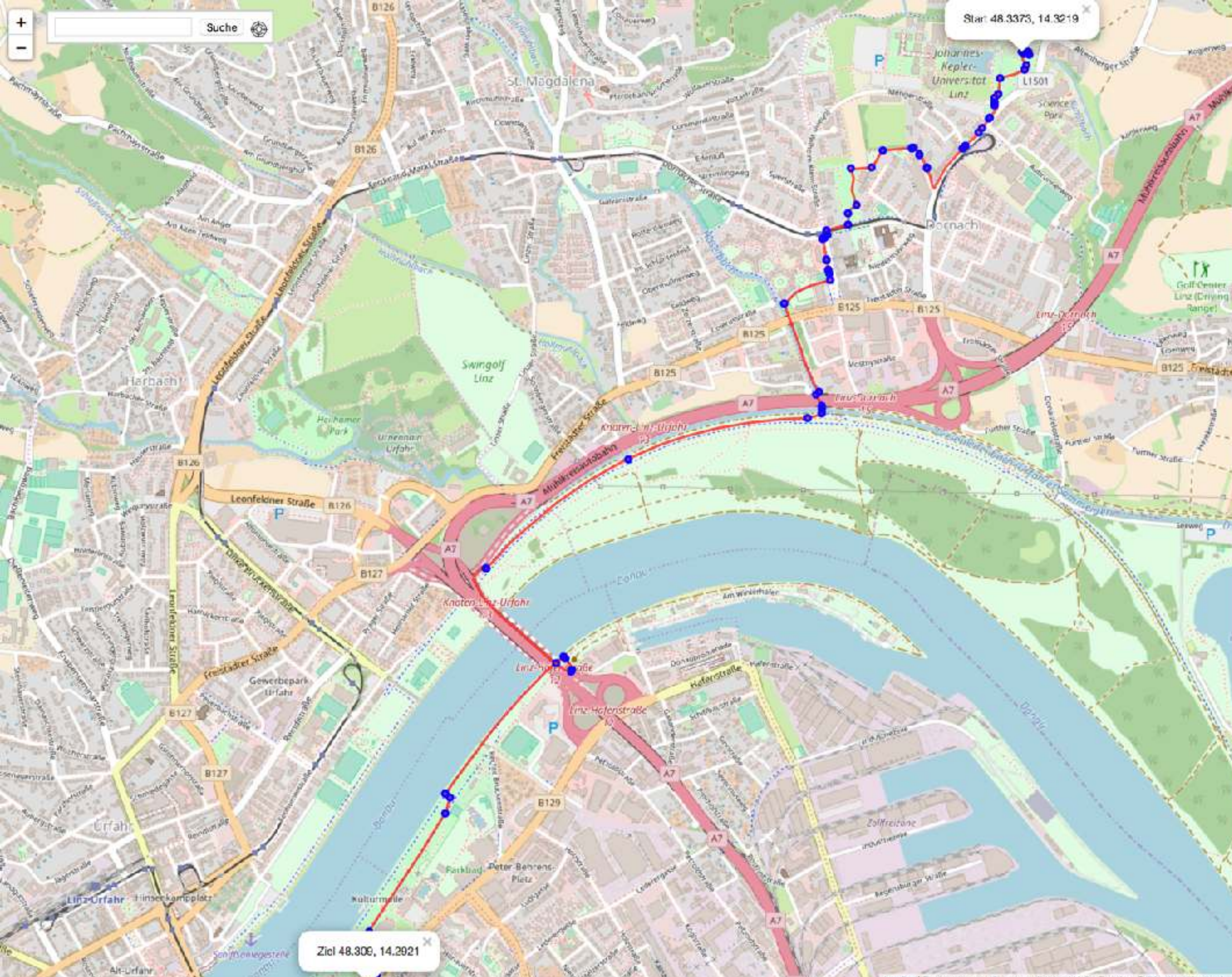


Routago

Sichere Fußgängernavigation

Testsystem

Für die Gebiete Deutschland, Österreich und Schweiz

'Mein Standort' oder Ort | Suche | Reset

Klicken Sie auf die Karte um Start und Ziel festzulegen!

Route

Entfernung: 5.7 km
Zeit: 68 min

- auf Zufahrt auf linker Seite
- Nach 6 m: Links auf Fußweg
- Nach 147 m: Links weiter auf Fußweg
- Nach 56 m: Links auf Zufahrt auf linker Seite
- Nach 15 m: Rechts Zufahrt überqueren
- Nach 2 m: Leicht links auf Weg
- Nach 17 m: Links auf Fußweg
- Nach 16 m: Geradeaus Zufahrt überqueren ohne Markierung
- Nach 2 m: Geradeaus auf Fußweg
- Nach 2 m: Geradeaus Zufahrt überqueren ohne Markierung
- Nach 5 m: Links auf Fußweg
- Nach 58 m: Rechts weiter auf Fußweg
- Nach 4 m: Links weiter auf Fußweg
- Nach 37 m: Geradeaus auf platform auf linker Seite
- Nach 22 m: Geradeaus auf Fußweg
- Nach 63 m: Links weiter auf Fußweg

https://routago.de/pedestrian-routing/

VII) Modes of Human Locomotion

Numerous Modes of Human Locomotion

Routago
Safe Pedestrian Navigation

„Standard“ pedestrian

Hiking

Wheelchair

Blind pedestrians

Young ones

Elder persons

Various personal e-mobility

Multi-modal transportation

Various distinct needs

Regional regulation, laws and habits

Large variety in mapping quality

Traditional programmatic approach

Routago
Safe Pedestrian Navigation

```
  sidewalk="none"
end

if foot=="yes" then
  foot="designated"
end

if highway=="primary" or highway=="construction" or highway=="primary_link"
  if sidewalk=="none" then
    factor=factor*100.0
  else
    if sidewalk=="" then
      factor=factor*5.0 -- no mention
    elseif sidewalk~="both" then
      factor=factor*4.0 -- left or right
    else
      factor=factor*2.0 -- both
    end
  end
elseif highway=="secondary" then
  if sidewalk=="none" then
    factor=factor*80.0
  else
    if sidewalk=="" then
      factor=factor*4.0 -- no mention
    elseif sidewalk~="both" then
      factor=factor*3.0 -- left or right
    else
      factor=factor*1.5 -- both
```

Programmatic weighting for each mode

- Manual modeling of demands
  - „White box“ interpretation of expert knowledge
- Exact assumptions on regional representation
  - Demand for specific tags only implemented regionally
- Either quite general or continuous manual adaption
  - Usually not feasible…

Statistical weights on annotation combinations

Routago
Safe Pedestrian Navigation

Statistical weights based on routing learning sets

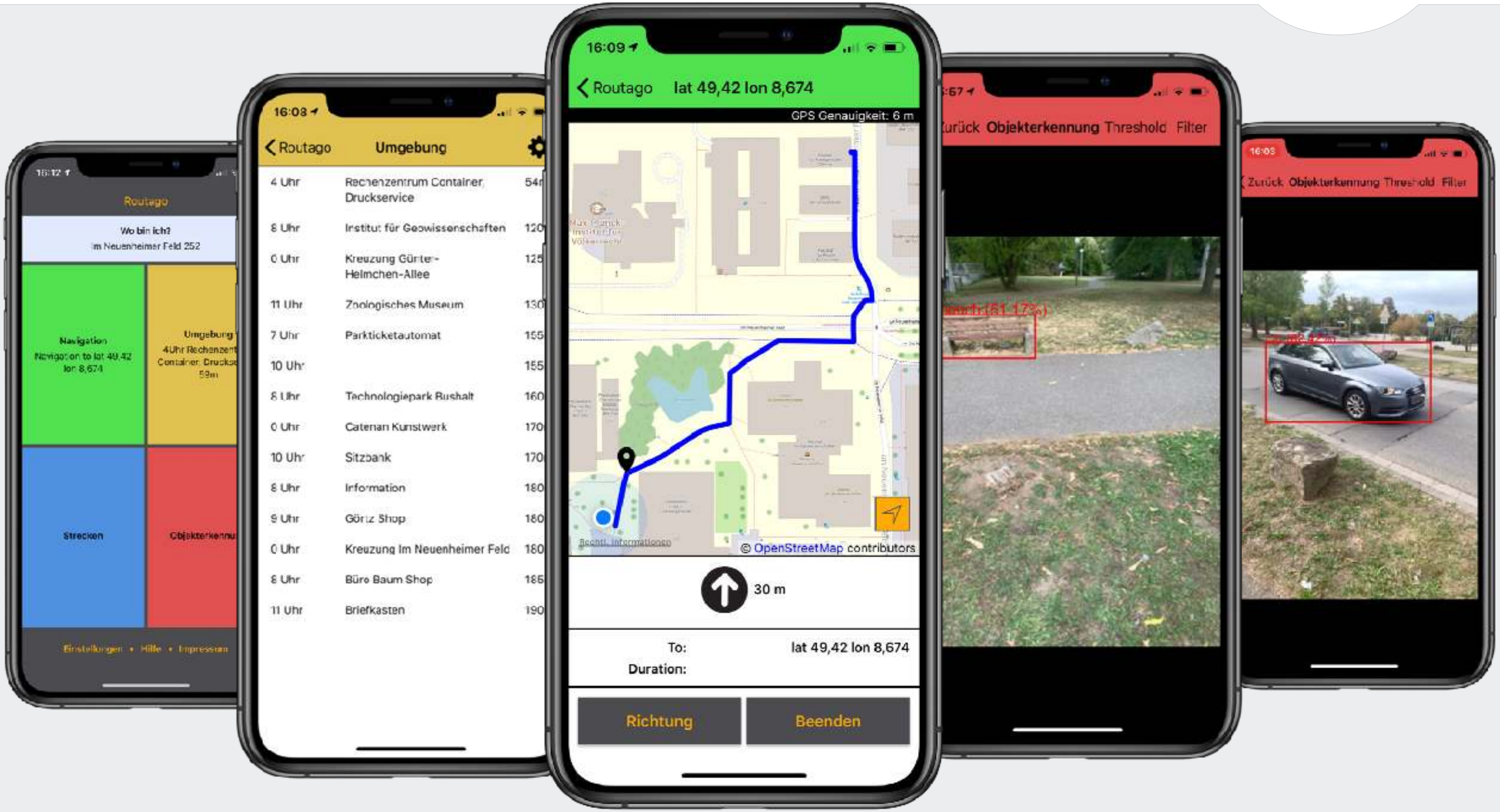
- Directly based on expert knowledge (proposed routes)
  - No interpretation, modeling or programming needed
- Automated and robust pattern recognition
  - Exploiting mapping reality, for highly attributed and low detail areas
- Automated adaption to map or rule updates
  - Nightly weight updates using „ground truth“ expert knowledge
- Scalable to various modes of locomotion
  - Any interest group may be supported with individual weighting
- Directly applicable to additional databases
  - Accessibility cloud and municipal data

Aiming to provide good routes with what OSM provides us.

VIII) Closing Remarks

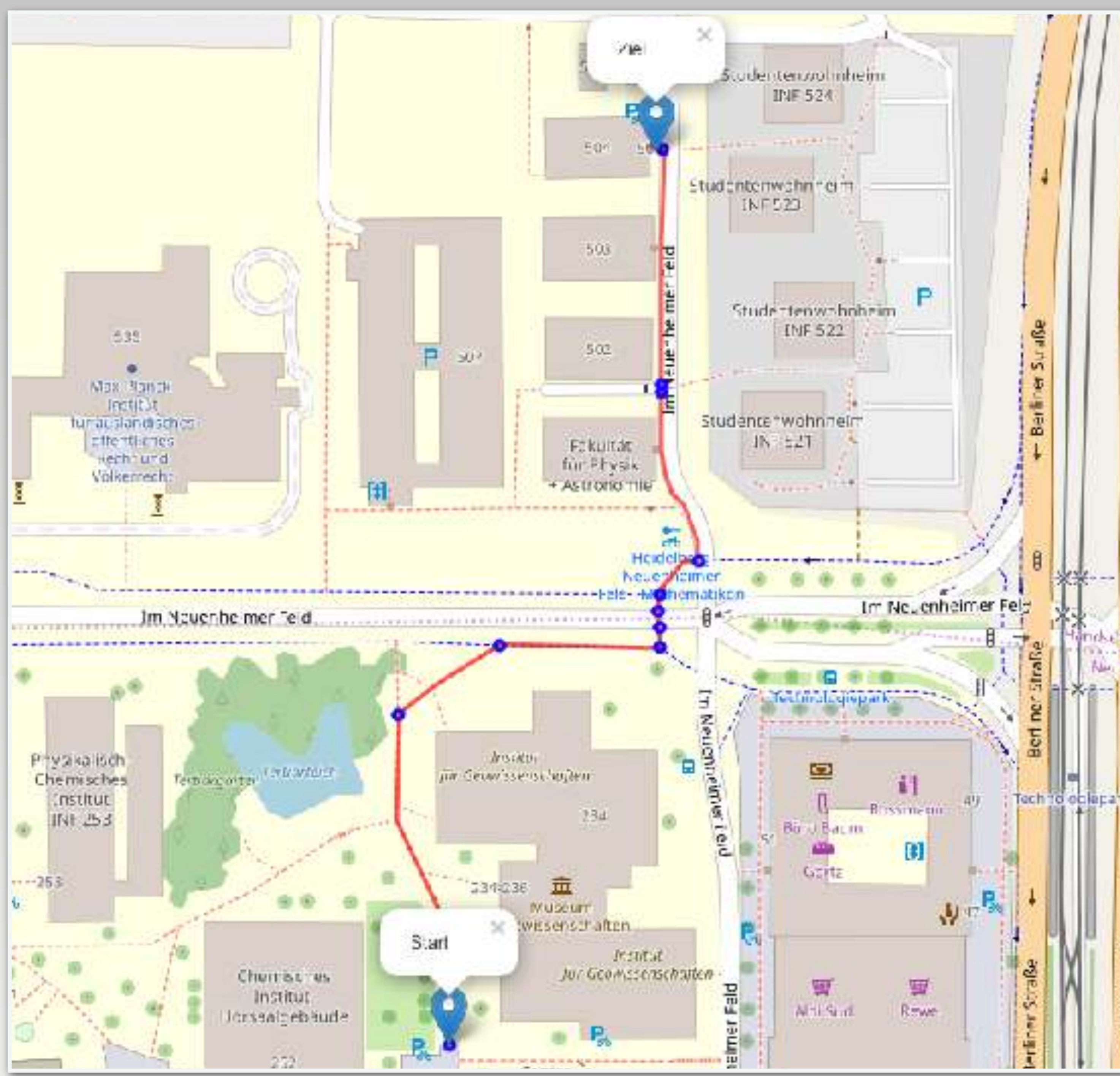
Routago App will be available very soon

Routago
Safe Pedestrian Navigation



Final design subject to change

Routago — Sidewalk aware Routing for Humans



Feasibility of true human locomotion routing

- OSM provides information that was not used before

Various modes of human locomotion

- Experts & interest groups aided to build learning sets

Robustness for various data quality

- Statistical approach aims at the best we can now get

Scalability for large scale use

- Local network extension on-the-fly as it is needed

Dealing with mapping fallacies or contradictions

- Bundling challenges, informing experts on problems