Toward Fast and Accurate Map-to-Map Matching of City Street Maps

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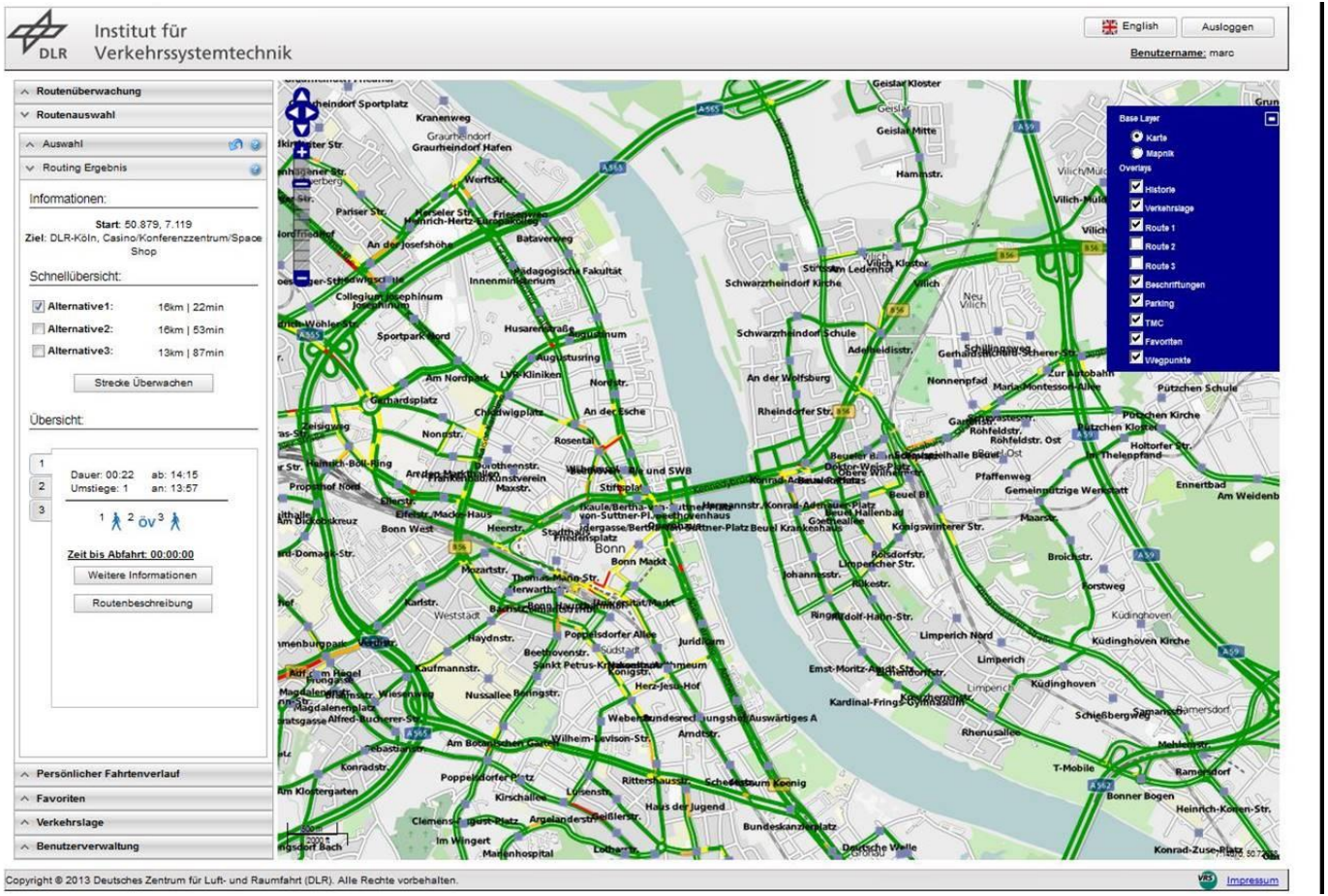
DLR

Motivation

- Frequently, various sources of geographic street-related data are **covering the same space**
- Many geospatial traffic services require **interoperability of the different datasets**
- This can be achieved by **road network matching**
- Examples of **previous work: Iterative Closest Points (Besl&McCay 1992), Buffer Growing (Walter 1997), NetMatcher (Mustière&Devogele 2008), Delimited-Strokes-Oriented Approach (Zhang 2007), Geometry Matching (Sämann 2014)**

- Use cases at the Institute of Transportation Systems, German Aerospace Center (DLR):
  - Dynamical location referencing for the transfer of congestion areas from a TeleAtlas- to a NAVTEQ-map)
    - “GIMME” (Ebendt&Touko Tchemadjeu, Eur. Transp. Res. Rev. **9,** 38 (2017))
  - Automatic relocation of link related data in an updated street map
    - More simple case of mapping between two maps from the same vendor
    - Again “GIMME” was used, this time within a framework called “Map2Map”


Institut für
Verkehrssystemtechnik
DLR
English
Ausloggen
Benutzername: marc
Routenüberwachung
Routenauswahl
Auswahl
Routing Ergebnis
Informationen:
Start: 50.879, 7.119
Ziel: DLR-Köln, Casino/Konferenzzentrum/Space Shop
Schnellübersicht:
Alternative1: 16km | 22min
Alternative2: 16km | 53min
Alternative3: 13km | 87min
Strecke Überwachen
Übersicht:
1
2
3
Dauer: 00:22 ab: 14:15
Umstiege: 1 an: 13:57
1 2 ÖV 3
Zeit bis Abfahrt: 00:00:00
Weitere Informationen
Routenbeschreibung
Persönlicher Fahrtenverlauf
Favoriten
Verkehrslage
Benutzerverwaltung
Base Layer
Karte
Mapnik
Overlays
Historie
Verkehrslage
Route 1
Route 2
Route 3
Beschriftungen
Parking
TMC
Favoriten
Wegpunkte
Bonn
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Impressum

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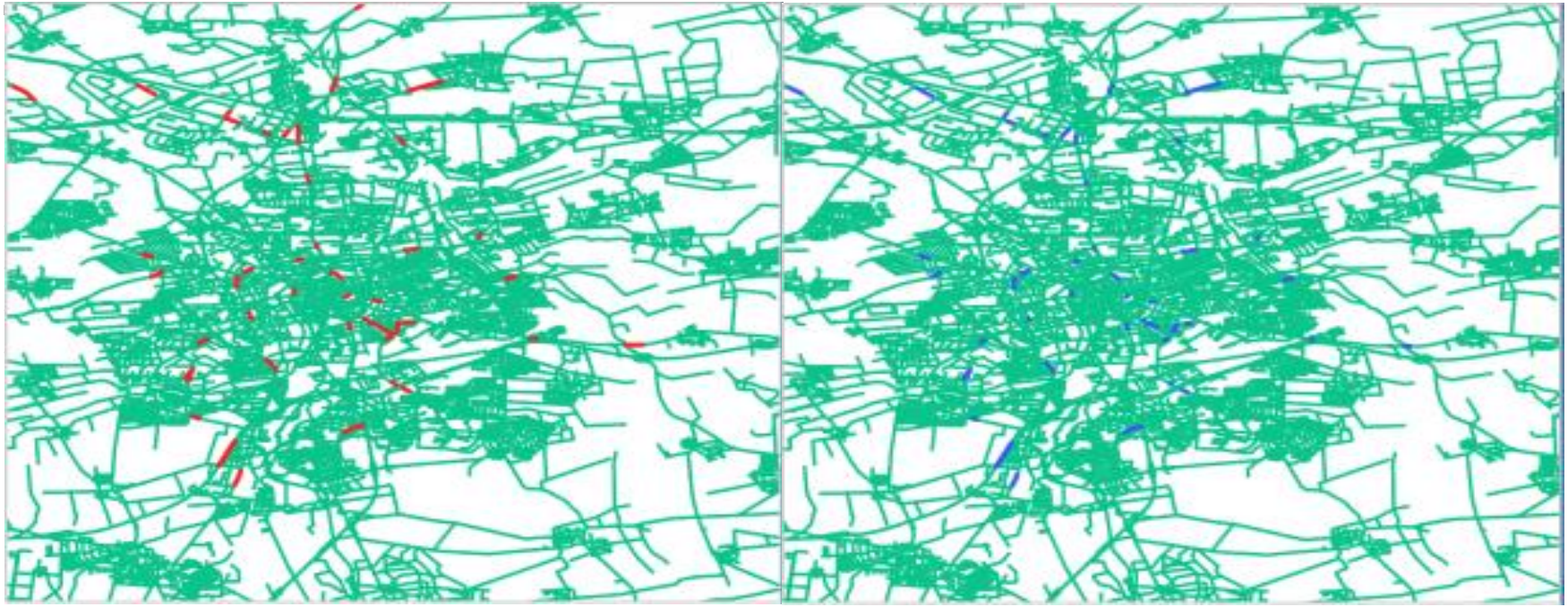

Made with QGIS (https://qgis.org)

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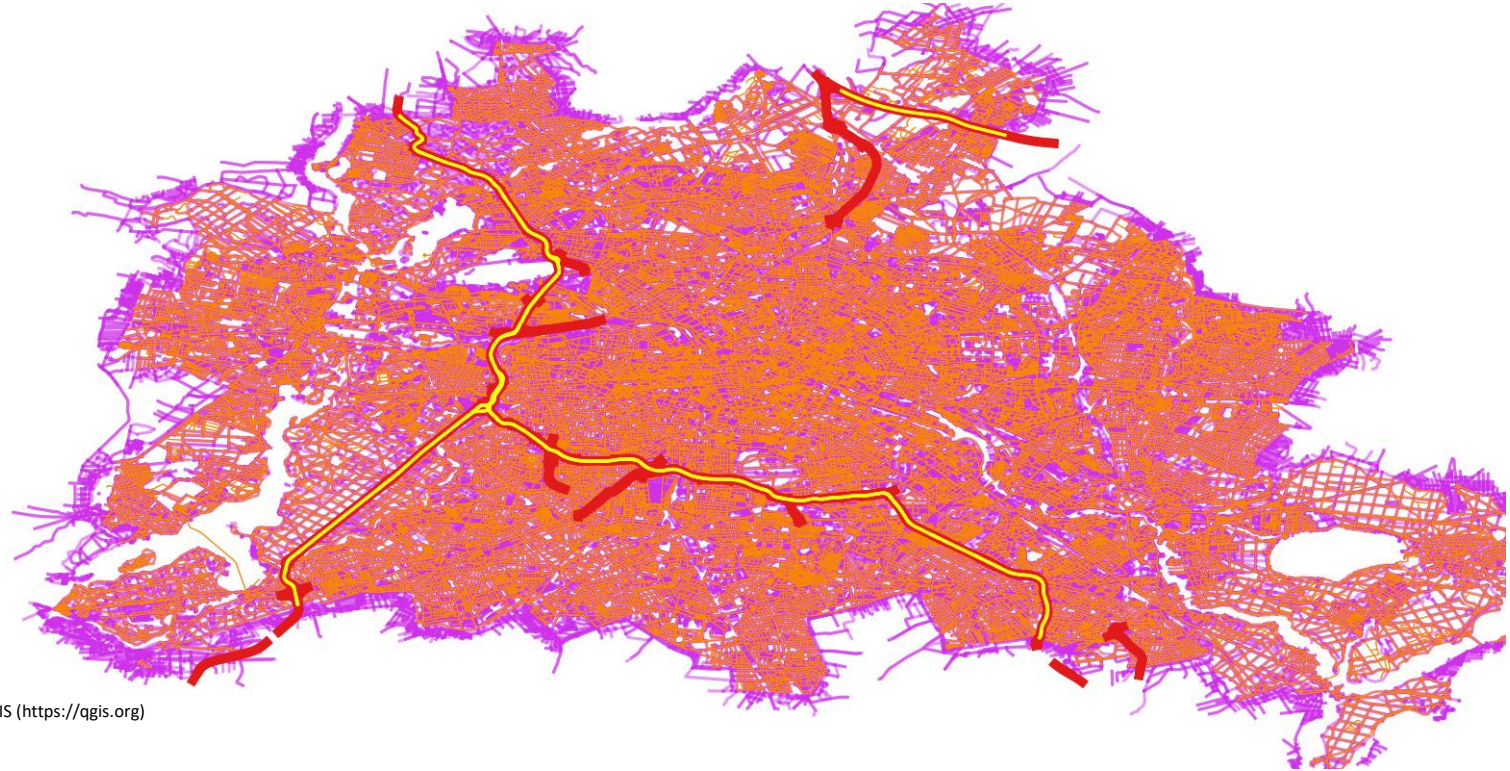
Mission: Find a matching between all links of two maps of Berlin (source: HERE, target: OpenStreetMap)



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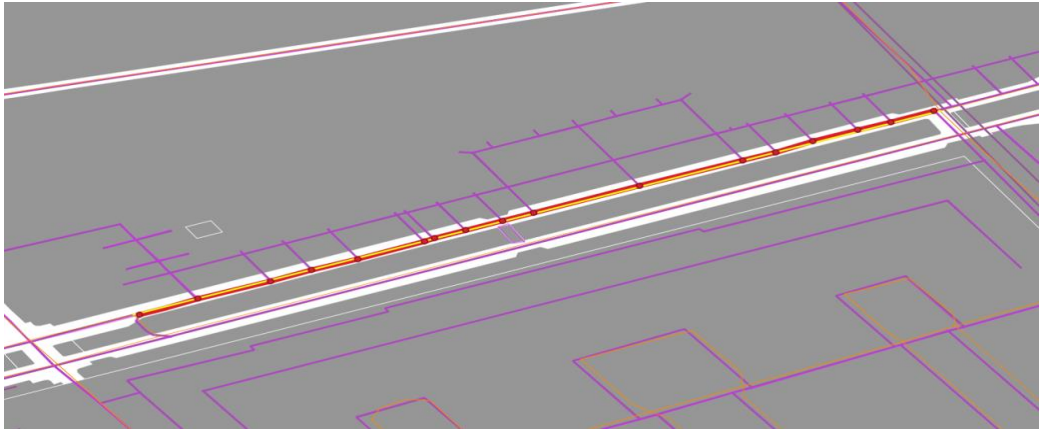
Problem

- Intermediate step: first, a **mapping from routes to routes** is established
- For every route segment, GIMME processes up to $\sum_{k=0}^{C} \frac{C!}{k!}$ permutations of subsets of the set of all matching candidates - C is the empirical maximum size of a candidate set
- Previous experiments with maps of Potsdam, Germany: C=3, short run times
- Recent experiments with maps of Berlin, Germany: $\boldsymbol{C}$**=16**, and since $\sum_{k=0}^{16} \frac{16!}{k!}$ is **greater than 50 trillions**, the **original algorithm was much too complex to be applied**.

Problem



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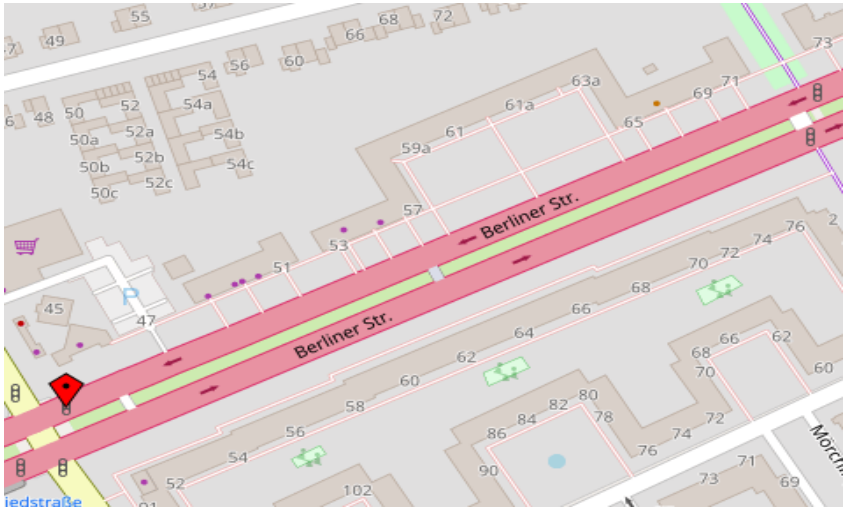
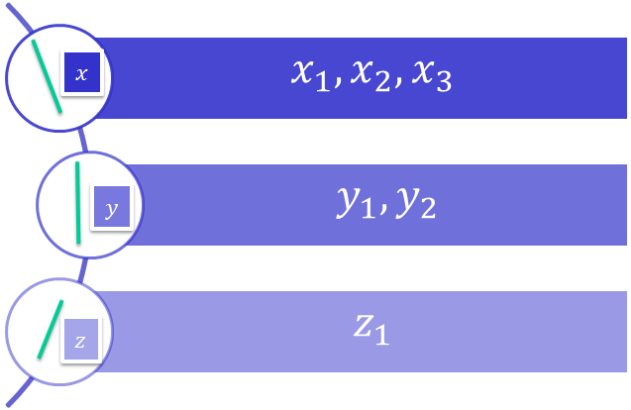


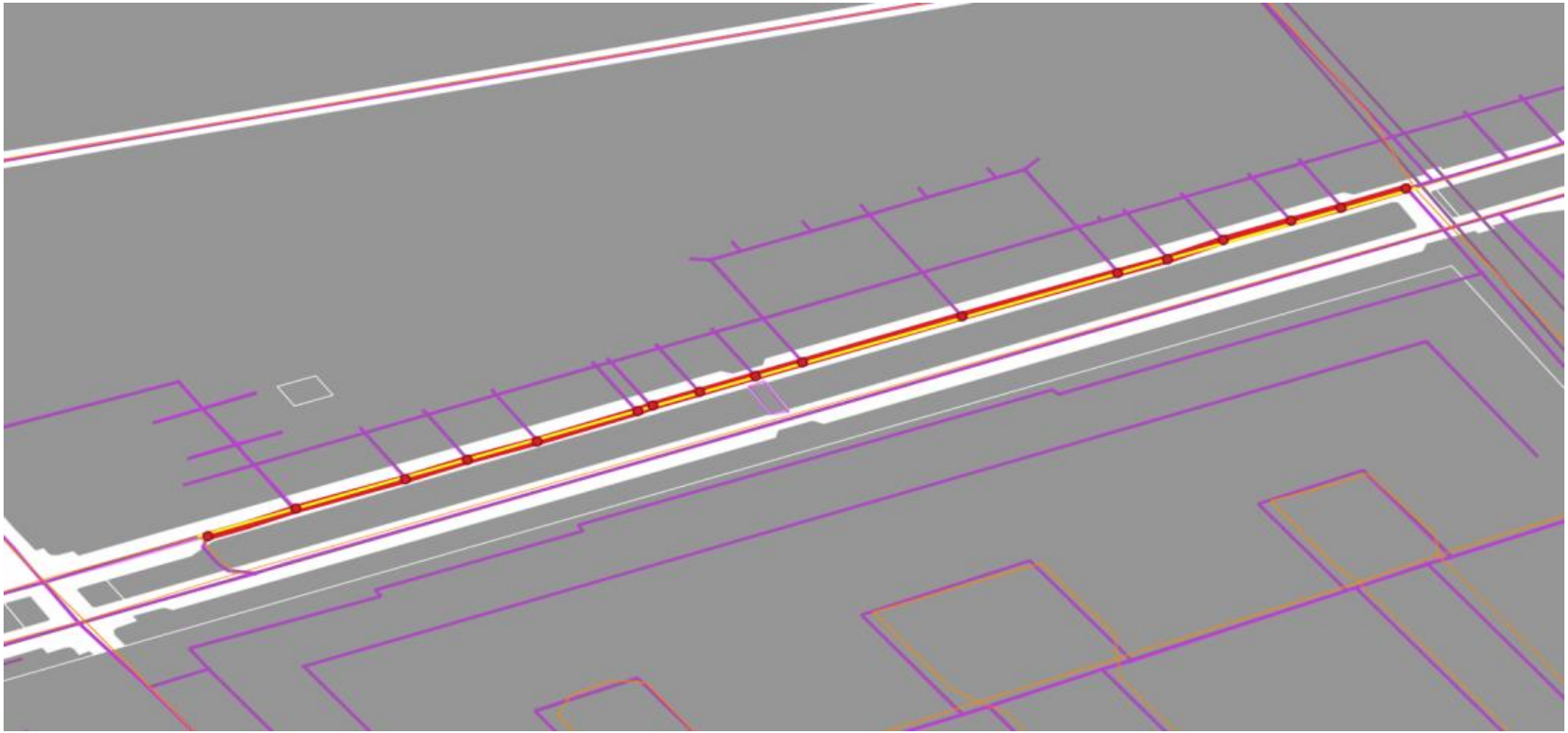
Solution

- GIMME matches source routes with target routes
- For every route segment, a list of matching candidates is established, for example:



- The subgraph spanned by the resulting set of candidates is first copied, then **simplified by path contraction** (that is, by removal of intermediate vertices of degree 2), and finally the original network is augmented by this auxiliary graph

Solution



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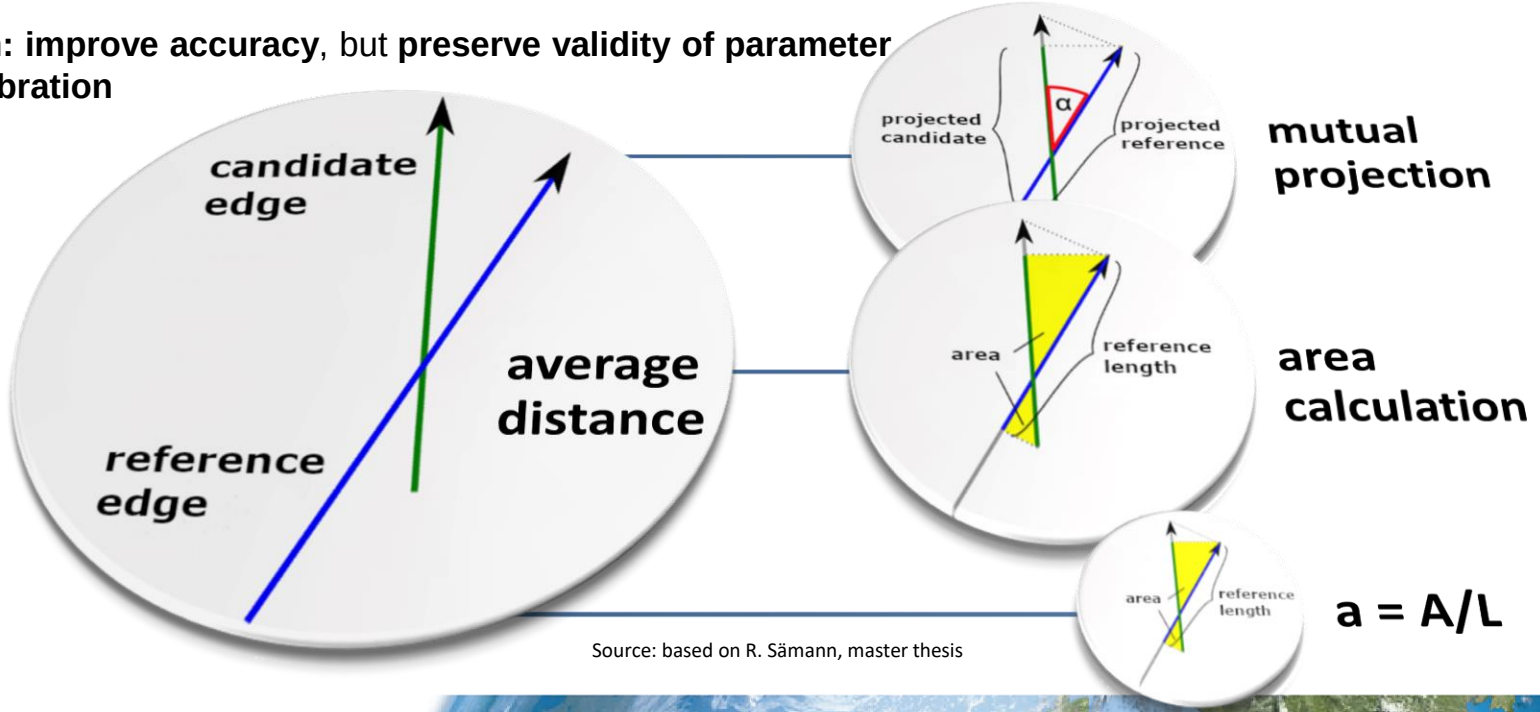
Improving accuracy 1(4)

- Strategy „**c**alibration-**p**reserving **p**re- or **p**ost-pr**o**cessing“ (C-3PO): What is the aim?

Aim: improve accuracy, but **preserve validity of parameter calibration**



Source: based on R. Sämann, master thesis

Improving accuracy 2(4)

- Strategy „**c**alibration-**p**reserving **p**re- or **p**ost-pr**o**cessing“ (C-3PO): How is this achieved?

    1. Pre-processing of input data

        – *Ex Ante Path Contraction:*
        Source routes for GIMME are paths along vertices of degree 2 and between vertices of a degree different from 2, such as start vertices or vertices representing (T- or multiway) junctions.

        – It is **easier to find a matching target route** for such source routes since they show a **good directional continuity** and **high homogeneity of functional use** of their segments.

Improving accuracy 2(4)

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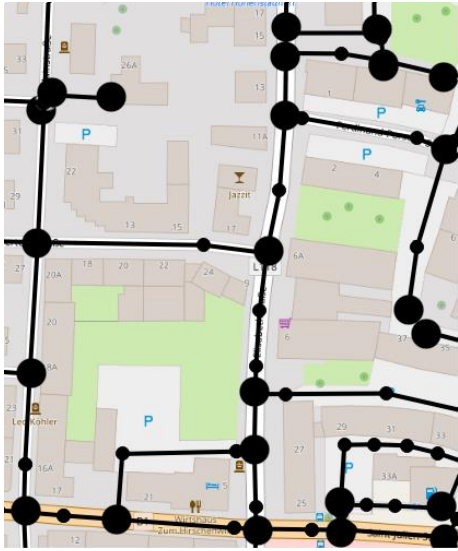


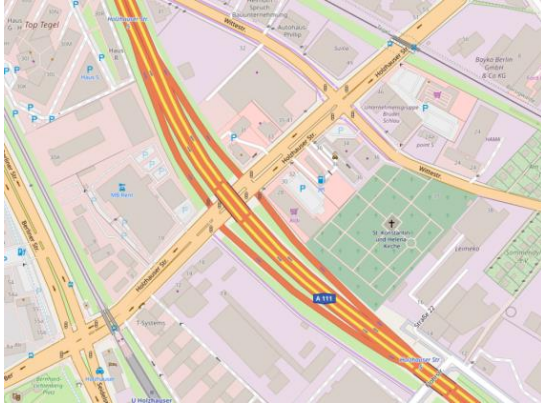
Example for a route subject to path contraction

- The longest contractable route in our experiments with maps of Berlin, Germany, is in the highway subnet, has 22 segments and a length of ~3.2 km (Berliner Str. between Adlershof and Schönefeld Nord).

Example for a route subject to path contraction

Made with QGIS (https://qgis.org)

Improving accuracy 3(4)



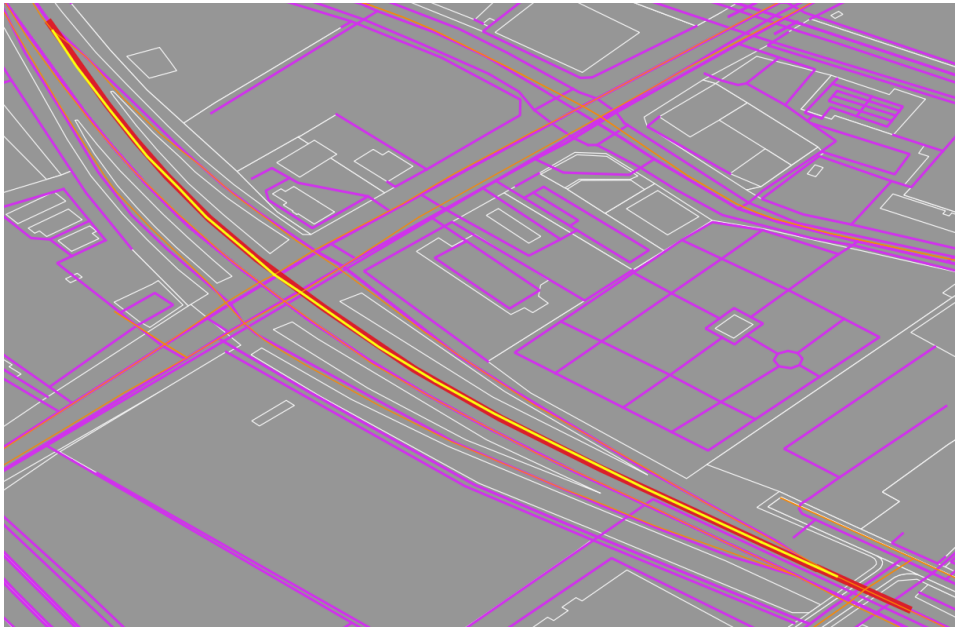
- Strategy „**c**alibration-**p**reserving **p**re- or **p**ost-pr**o**cessing“ (C-3PO): How is this achieved?

  2. Post-processing of output data (that is, of the tentative result) (I)

     – *Ex Post Construction of True-Positives:*
       Apply shortest path routing to close matching gaps on highway routes (as caused by too short candidate segments)

     – **Increases the true-positive rate**

Improving accuracy 3(4)



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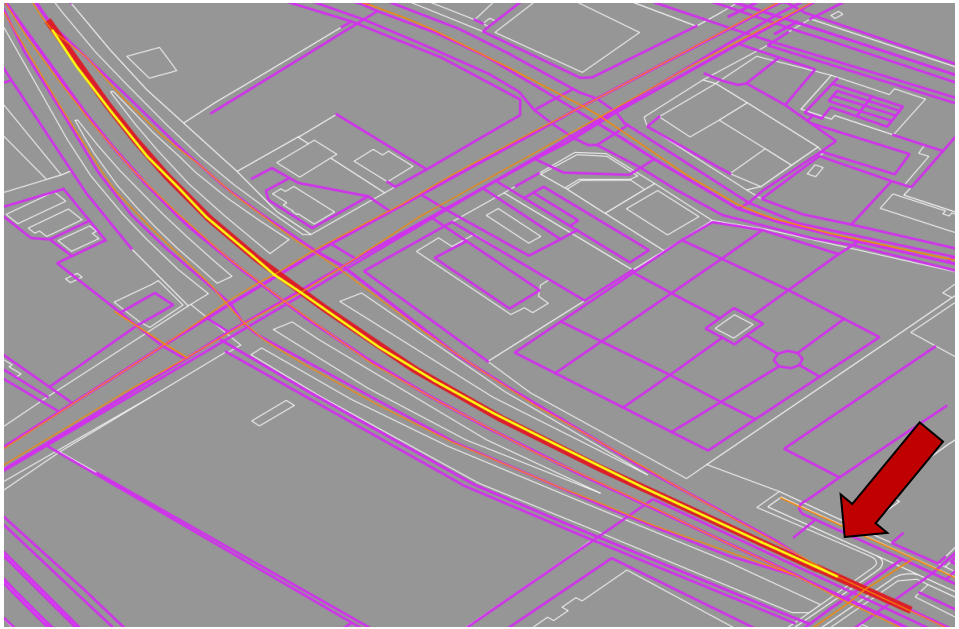
Improving accuracy 3(4)



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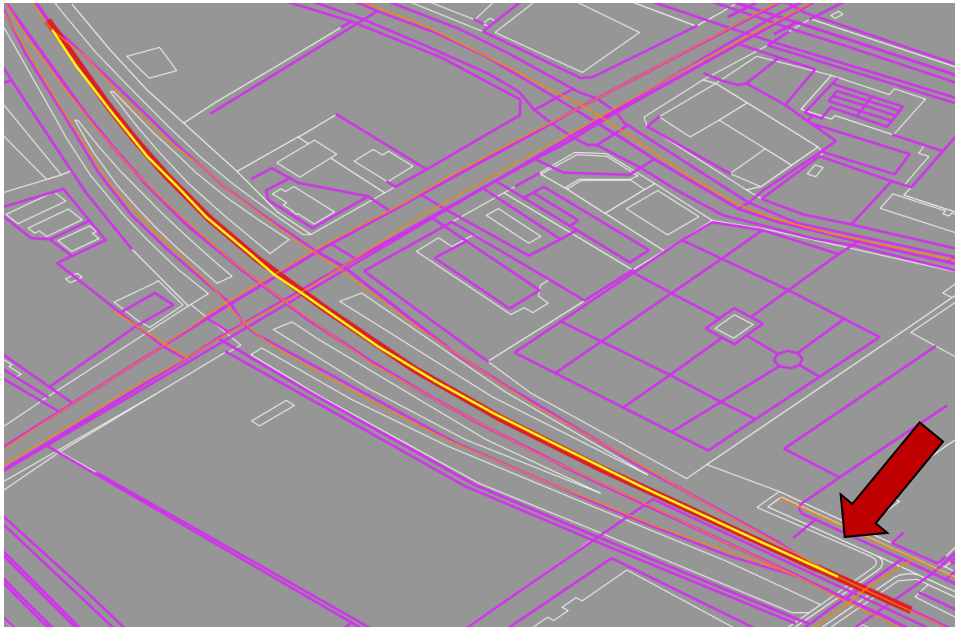
Improving accuracy 3(4)



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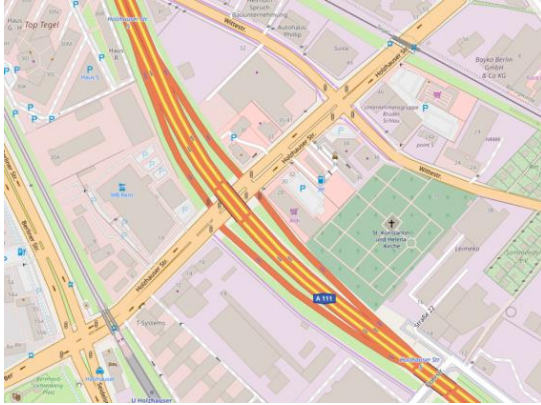

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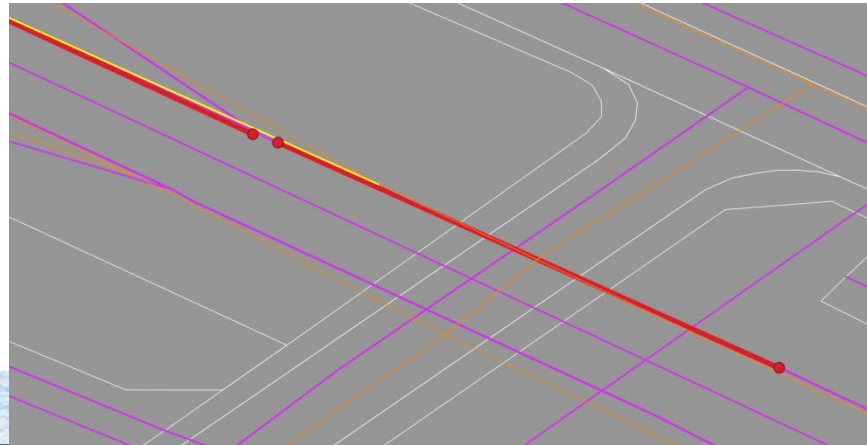
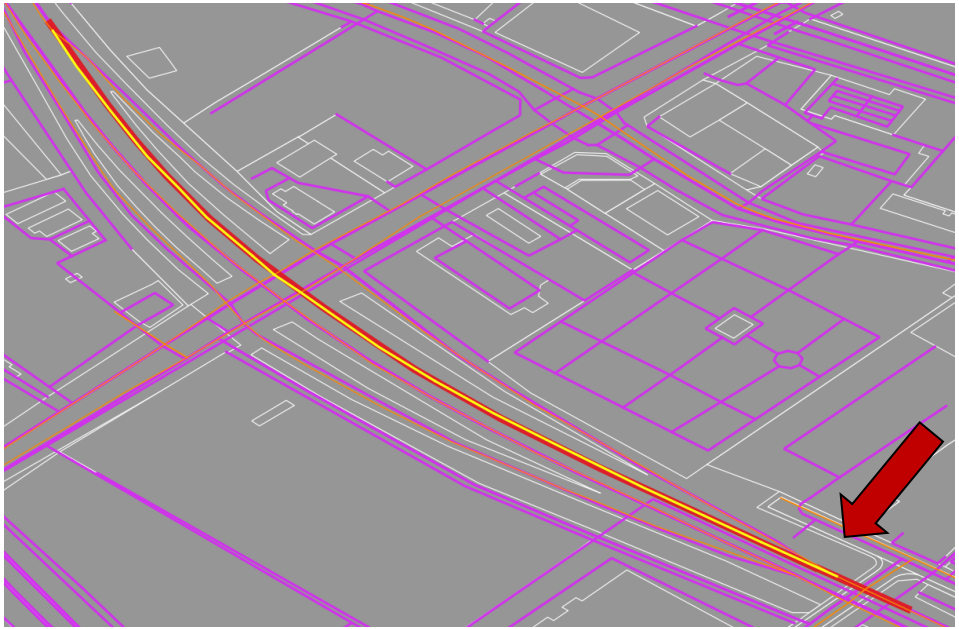


Improving accuracy 3(4)



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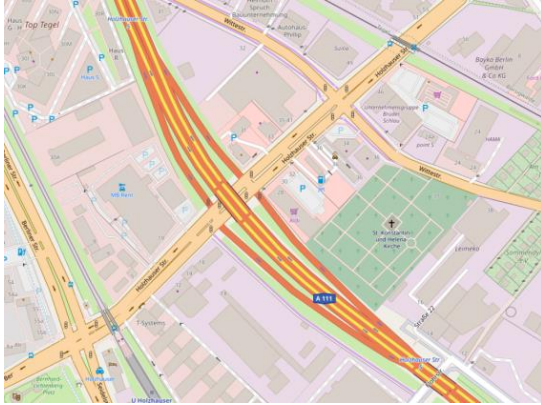

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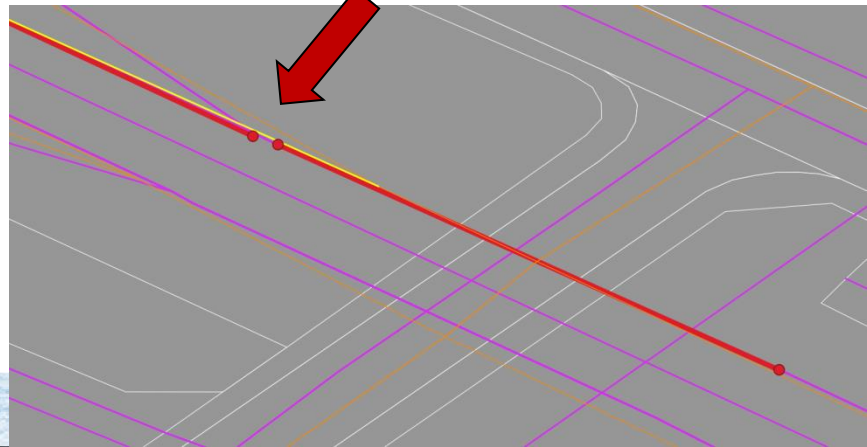

Improving accuracy 4(4)

- Strategy „**c**alibration-**p**reserving **p**re- or **p**ost-pr**o**cessing“ (C-3PO): How is this achieved?

  3. Post-processing of output data (II)

  – *Ex Post Confirmation of True Negatives:*
    Automatic (i.e., programmatic) **identification** of cases, where a road segment or a stretch of road is modeled **bidirectional in the source map**, whereas the homologous counterpart **in the target map is modeled unidirectional**.

  – Because a **matching** of the missing direction is **impossible due to an actual map difference, this must be a true negative**.

Results 1(2)

INTER-MAP MATCHING STATISTICS PER FUNCTIONAL ROAD CLASS

FRC	n	Positives [%]		Negatives [%]		
		q_{p}	q_{p}^{*}	q_{n}	q_{n}^{*}	$\Omega(q_{\mathrm{tn}})$
0-4	200,216	77.1	**77.2**	22.9	22.8	**11.1**
0	962	89.0	**93.1**	11.0	6.9	0.0
1	5,358	**96.3**	n/a	3.7	n/a	0.5
2	18,246	**95.5**	n/a	4.5	n/a	0.9
3	11,570	**94.6**	n/a	5.6	n/a	1.5
4	164,080	**73.2**	n/a	26.8	n/a	**13.4**

Results 2(2)

For this experiment, accuracy of GIMME (taking into account positives as well as negatives) was

- **92.7% without C-3PO**, and
- **96.2% with C-3PO**

Conclusion

An **update on the recent advances** in

- a framework for fast and accurate **matching of entire city street maps**, called **Map2Map**, and of its core,
- the **inter-map matching algorithm GIMME** (Geometry Inter-Map Matching Extension),

has been given.

A first basic implementation of a **general strategy for calibration-preserving pre- and post-processing** called **C-3PO** has been presented.

Experimental results demonstrated the effectiveness of the approach.

Thank you for your interest!

If you have any questions, please feel free to contact me at

- **ruediger.ebendt@dlr.de**

Source: Nate Grigg/Flickr