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

Rüdiger Ebendt, Louis Calvin Touko Tcheumadjeu

ITSC 2020
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
  - 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”
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  - Again “GIMME” was used, this time within a framework called “Map2Map”
Mission: Find a matching between all links of two maps of Berlin (source: HERE, target: OpenStreetMap)
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: \( C=16 \), 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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  - For every route segment, GIMME processes up to $C_k^k!$ 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: $C = 16$, and since $16!^k!^k = 0$ is greater than $50$ trillions, the original algorithm was much too complex to be applied.

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

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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:

  \[
  x, x_1, x_2, x_3
  \]

  \[
  y, y_1, y_2
  \]

  \[
  z, z_1
  \]

- 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 „calibration-preserving pre- or post-processing“ (C-3PO): What is the aim?

Aim: improve accuracy, but preserve validity of parameter calibration

Source: based on R. Sämann, master thesis

\[ a = \frac{A}{L} \]
Improving accuracy 2(4)

• Strategy „calibration-preserving pre- or post-processing“ (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).
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Improving accuracy 3(4)

• Strategy „calibration-preserving pre- or post-processing“ (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)

Apply shortest path routing to close matching gaps on highway routes (as caused by too short candidate segments).

- Increases the true positive rate

Strategy "calibration-preserving pres- or post-processing" (C-3PO):

How is this achieved?

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

Improving accuracy 3(4)

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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

• Strategy "calibration-pre-reserving-pre-processing" (C-3PO)

How is this achieved?

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

Improving accuracy 3(4)

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Improving accuracy 3(4)

- 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

- Strategy "calibration - preserving preprocessing" (C3PO):
  - How is this achieved?

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

Improving accuracy
Improving accuracy 3(4)
Improving accuracy 4(4)

• Strategy „calibration-preserving pre- or post-processing“ (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

<table>
<thead>
<tr>
<th>FRC</th>
<th>$n$</th>
<th>Positives [%]</th>
<th>Negatives [%]</th>
<th>$q_p$</th>
<th>$q_p^*$</th>
<th>$q_n$</th>
<th>$q_n^*$</th>
<th>$\Omega(q_{tn})$</th>
</tr>
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<tbody>
<tr>
<td>0-4</td>
<td>200,216</td>
<td>77.1</td>
<td>77.2</td>
<td>22.9</td>
<td>22.8</td>
<td>11.1</td>
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<td></td>
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<tr>
<td>0</td>
<td>962</td>
<td>89.0</td>
<td>93.1</td>
<td>11.0</td>
<td>6.9</td>
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<td>5,358</td>
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<td>n/a</td>
<td>3.7</td>
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<td>0.5</td>
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<tr>
<td>2</td>
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<td>4.5</td>
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<td>0.9</td>
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<td></td>
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<tr>
<td>3</td>
<td>11,570</td>
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<tr>
<td>4</td>
<td>164,080</td>
<td>73.2</td>
<td>n/a</td>
<td>26.8</td>
<td>n/a</td>
<td>13.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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