Learning to Generate Maps from Trajectories

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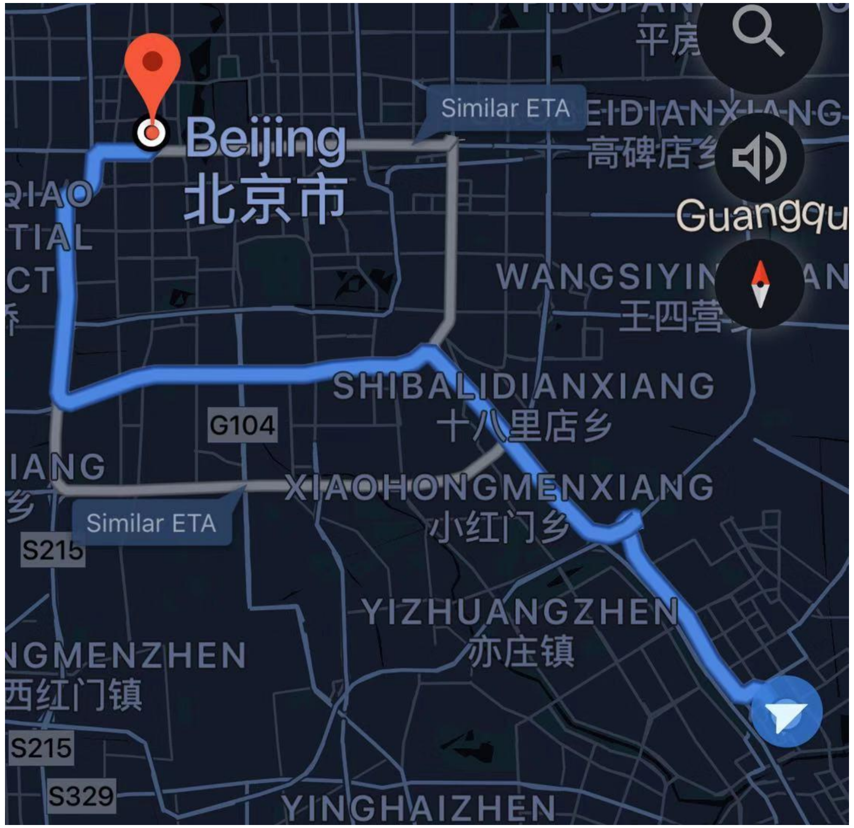
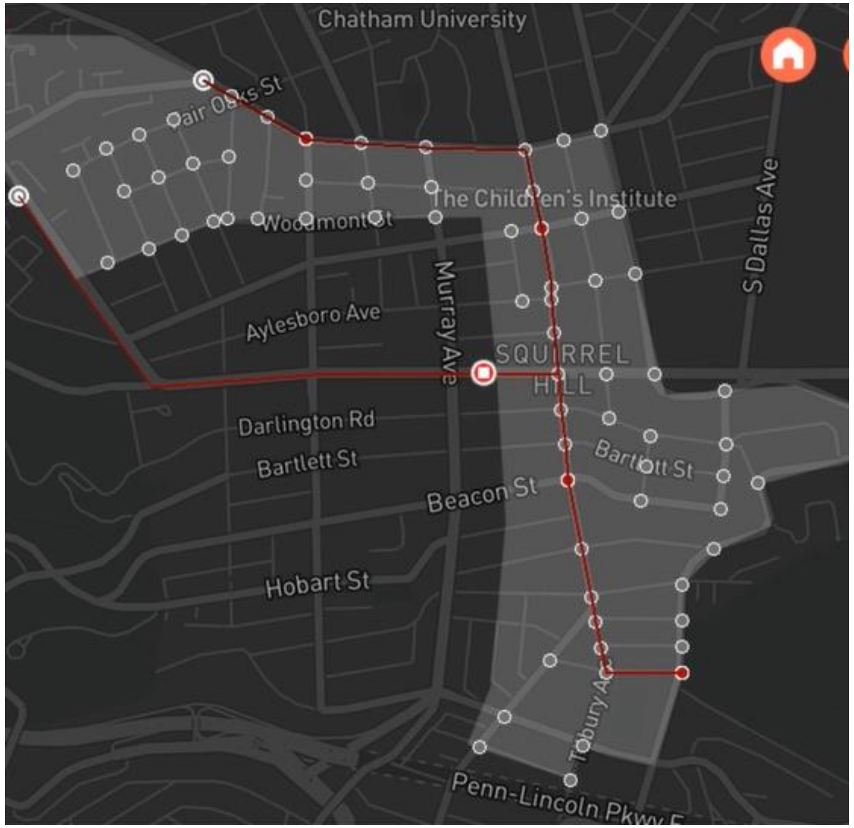
Increasing Demands of Accurate & Updated Maps

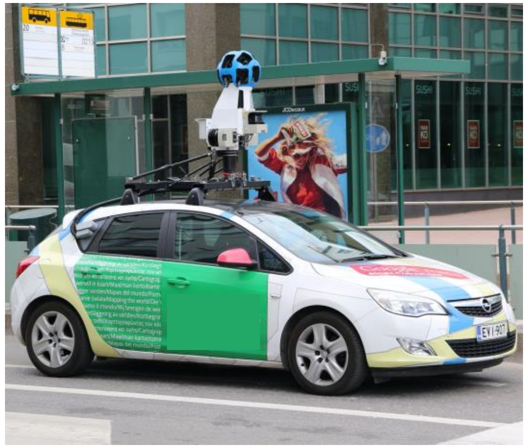


Navigation



Route Planning & Real-time Scheduling

Traditional Map Data Collecting Methods

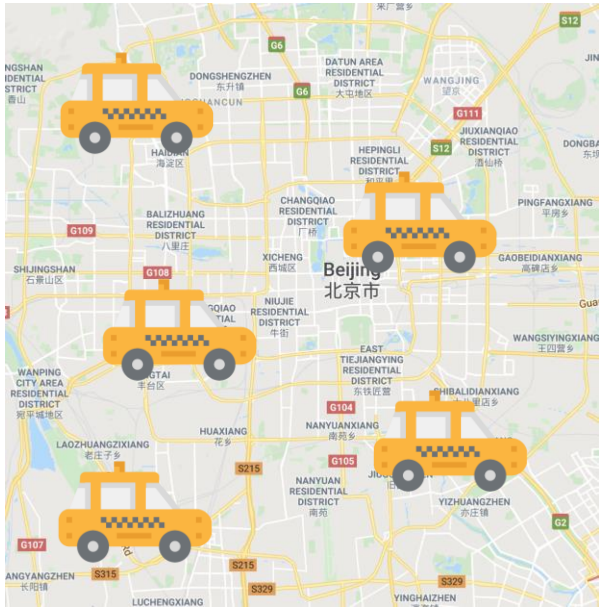


On-field Study

Low Spatial Coverage

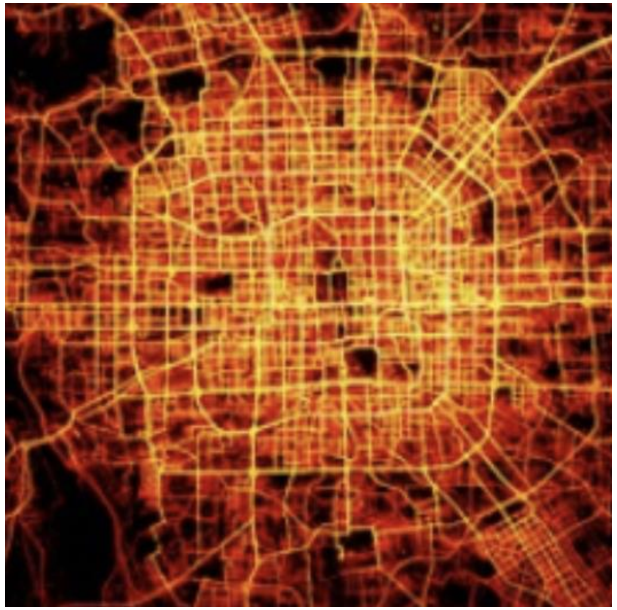
Dynamic Traffic Status

Crowdsourcing GPS Trajectories



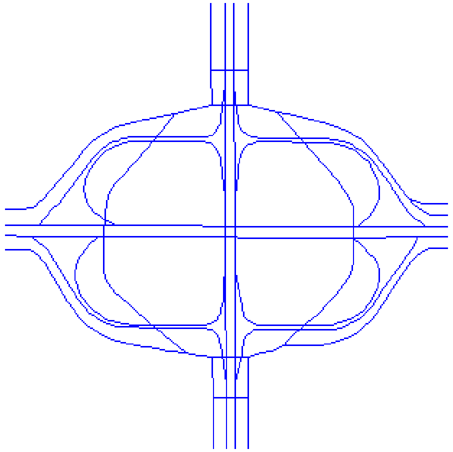
Massive Moving Objects

GPS Devices

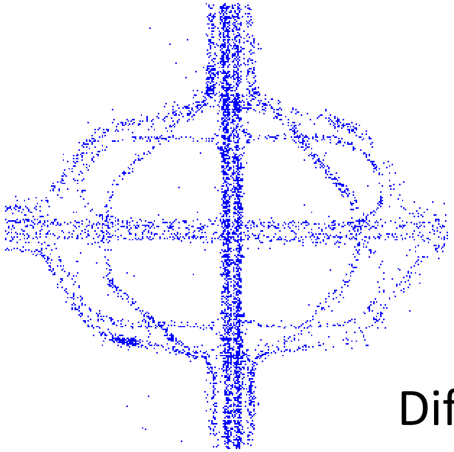


Real-time City-wide Map Information

Challenges

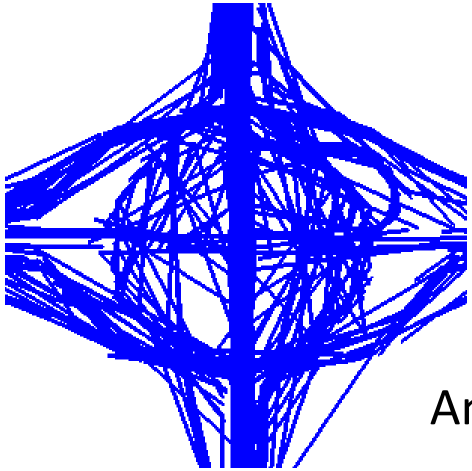


Ground Truth Map



Positioning Error (~15 meters)

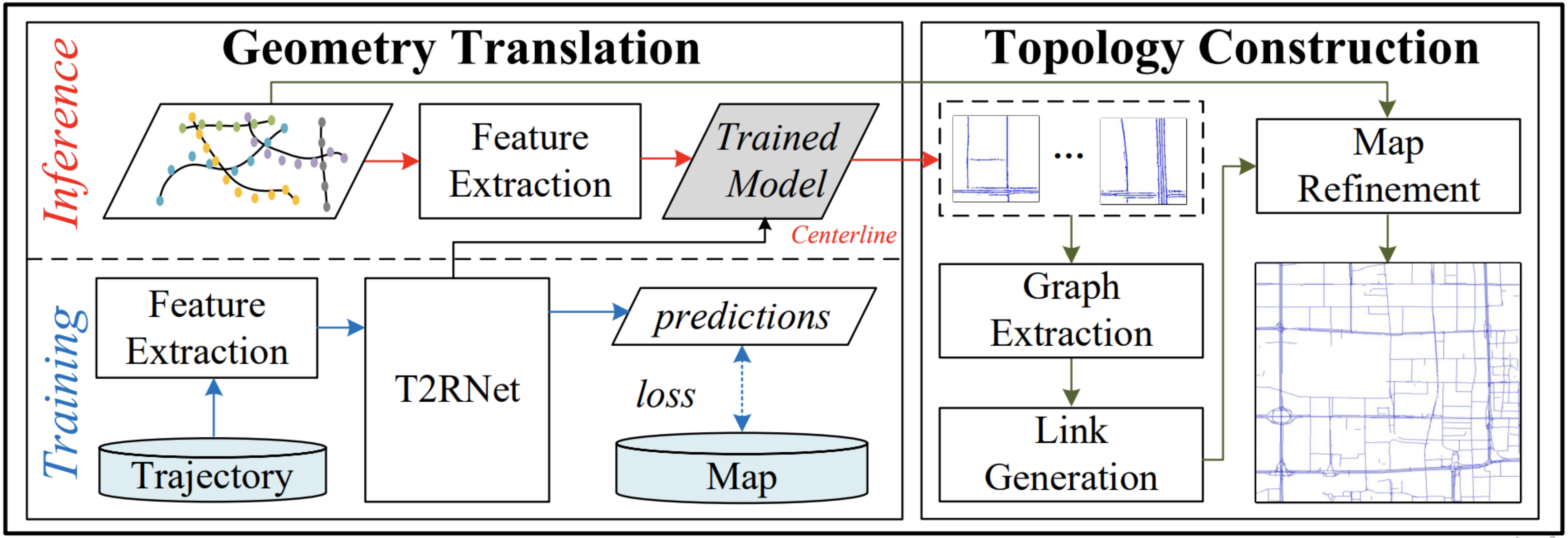
Difficult to Distinguish Spatially Close Roads



Low Sampling Rate (30s/pt)

Ambiguous Underlying Traversing Routes

Framework of DeepMG

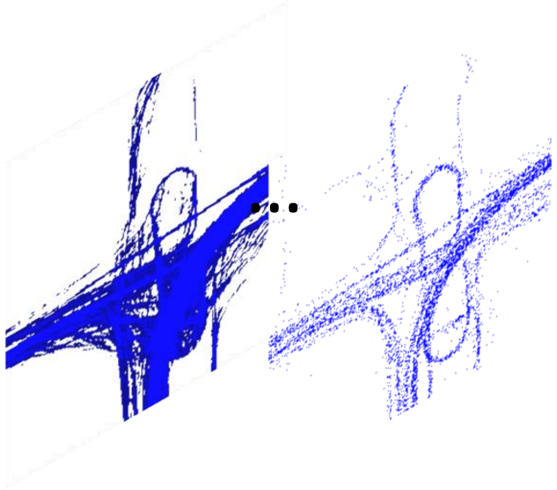


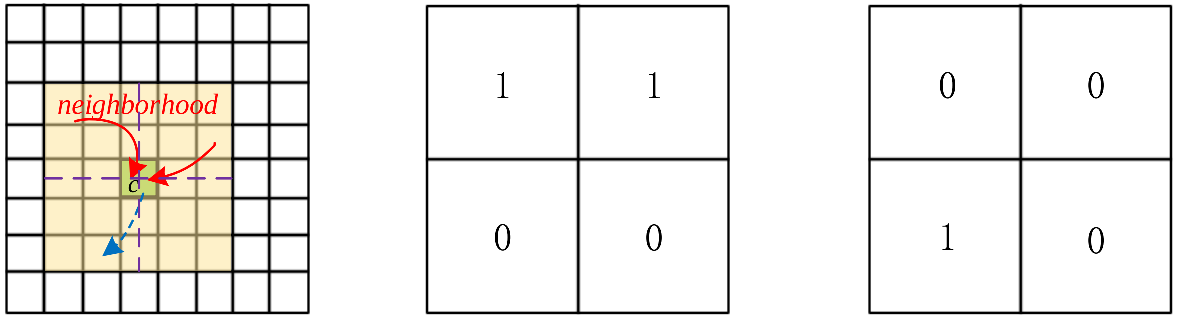
Geometry Translation (1/2)

- Feature Extraction
  - For each $I \times J$ Region Tile

Spatial View ($\mathbb{R}^{11 \times I \times J}$)

Transition View ($\mathbb{Z}_2^{2 \times T \times T \times I \times J}$)





(a) Transitions S/E at c. (b) Local Incoming Matrix. (c) Local Outgoing Matrix.

Point, Line, Speed, Direction (8 channels)

Each grid cell has an incoming and an outgoing matrix

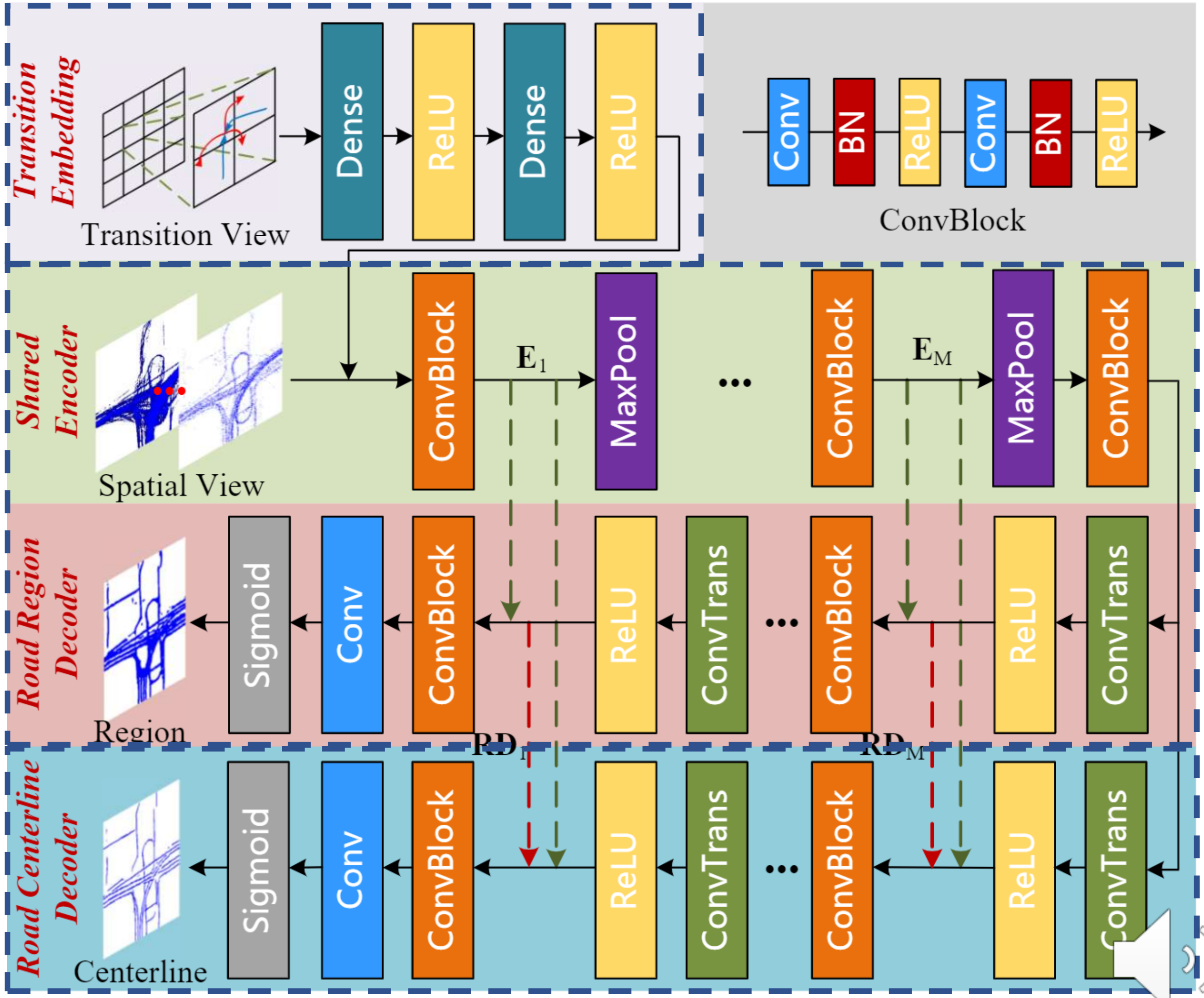
Geometry Translation (2/2)

- T2RNet
  - Transition Embedding
  - Shared Encoder
  - Road Region Decoder
  - Road Centerline Decoder
- Optimization
  - Dice Loss [Milletari F, et al. 2016]

$$\mathcal{L}_{Dice}(\hat{\mathbf{Y}}, \mathbf{Y}) = 1 - \frac{2\sum_i^I \sum_j^J \hat{Y}_{ij} Y_{ij} + \epsilon}{\sum_i^I \sum_j^J \hat{Y}_{ij} + \sum_i^I \sum_j^J Y_{ij} + \epsilon}$$

  - Multi-task Loss

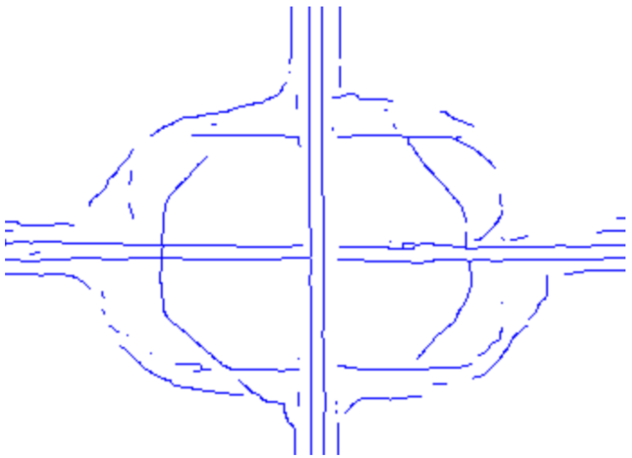
$$\mathcal{L}(\boldsymbol{\theta}) = (1-\lambda)\mathcal{L}_{Dice}(\hat{\mathbf{Y}}_c, \mathbf{Y}_c) + \lambda \mathcal{L}_{Dice}(\hat{\mathbf{Y}}_r, \mathbf{Y}_r)$$

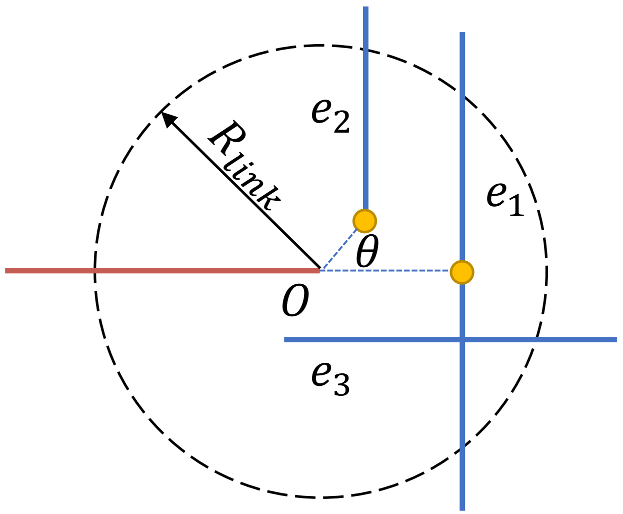


Milletari F, et al. "*V-net: Fully convolutional neural networks for volumetric medical image segmentation*". 3DV. 2016.

Topology Construction (1/2)

- Graph Extraction
  - Merge predicted tiles
  - Extract road segments
- Link Generation
  - For each dead end



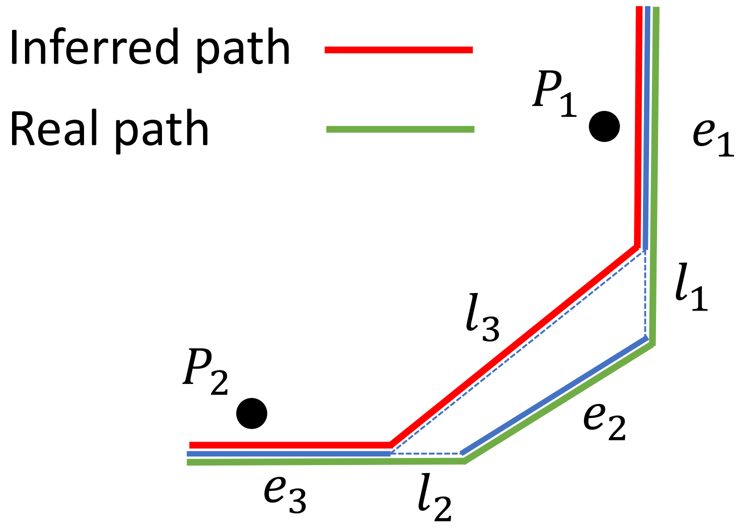


- Case 1: intersects another edge on the extension
- Case 2: has smooth transition to the closest dead end of another edge

Topology Construction (2/2)

- Map Refinement
  - Perform trajectory map matching on the linked map [Yuan J, et al. 2010]
  - Remove edges and links with low support

If the map matching is directly applied…



Proposed solution

$$dist(P) = \sum_{e_i \in P} \omega(e_i) \cdot len(e_i)$$

$$\omega(e_i) = \begin{cases} \alpha, & e_i \text{ is a generated link} \\ 1, & e_i \text{ is a predicted edge} \end{cases} \quad \alpha > 1$$

Yuan J, et al. "*An Interactive Voting-based Map Matching Algorithm*". MDM. 2010.

Evaluation

- Datasets
  - Trajectory
    - <oid, timestamp, latitude, longitude>
  - Map
    - Node: <latitude, longitude>
    - Edge: <start_node, end_node>

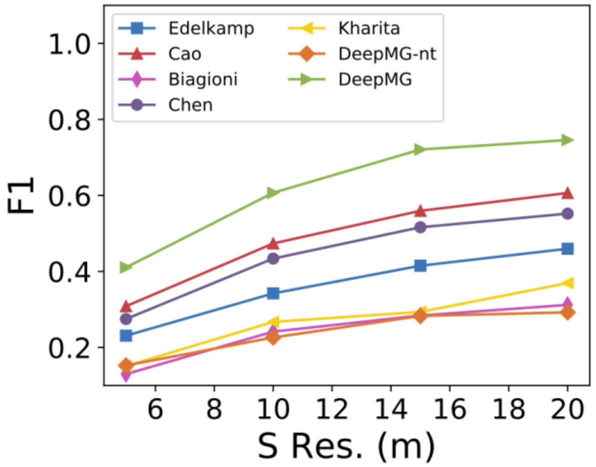
Dataset	TaxiBJ	TaxiJN
#Days	30	30
#Vehicles	500	70
Sampling Rate	$\sim$30s	$\sim$3s
Size (km^2)	16$\times$16 (5$\times$5)	16$\times$26 (5$\times$5)
#Points	3.1M (304K)	5.7M (322K)
#Trajectories	66,124 (13,462)	29,556 (3,954)
Roads (km)	2,772 (284)	2,048 (123)

- Evaluation Metrics
  - Topological F1 [Biagioni, et al. 2012]
    - Repeat N times
      a. Select a random starting location
      b. Find reachable area within a maximum radius
      c. Compare generated map with GT using F1
    - Report the average F1 score

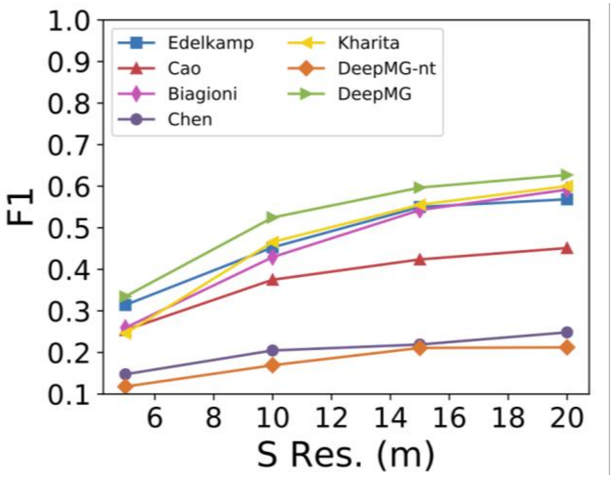
Biagioni J, Eriksson J. "*Inferring road maps from global positioning system traces: Survey and comparative evaluation*". Transportation research record. 2012.

Results

- Quantitative Comparison

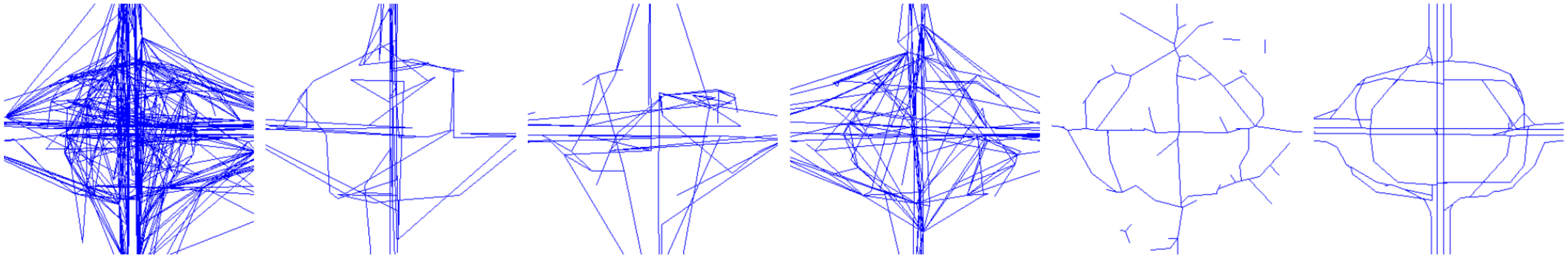


TaxiBJ (32.3% improvement)



TaxiJN (6.5% improvement)

- Visual Comparison



(a) Edelkamp. (b) Chen. (c) Kharita. (d) Cao. (e) Biagioni. (f) DeepMG.

Practice in JD.COM: Resident Area Map Generation from JD Couriers' Trajectories

JD iCity x 京东物流 JD Logistics

Conclusion

- A valuable but challenging task
  - Position errors
  - Low sampling rate
- Our method
  - Geometry translation (T2RNet)
    - Convolutional network: learns the structure of the road network
    - Auxiliary task: helps the centerline inference
  - Topology construction (Link + Prune)
    - Trajectories as transition evidences
- Results
  - Superior than traditional methods
  - More effective on low-sampling rate datasets

Thanks!

JD iCity

JD Urban Spatio-Temporal Data Engine (JUST)

Ruan S., et al. "*Learning to Generate Maps from Trajectories*". AAAI. 2020.