Bicycle Travel Time Estimation via Dual Graph-Based Neural Networks

Ting Gao | Graph&Data@TU Delft

Supervisors: Elvin Isufi, Winnie Daamen, Serge Hoogendoorn

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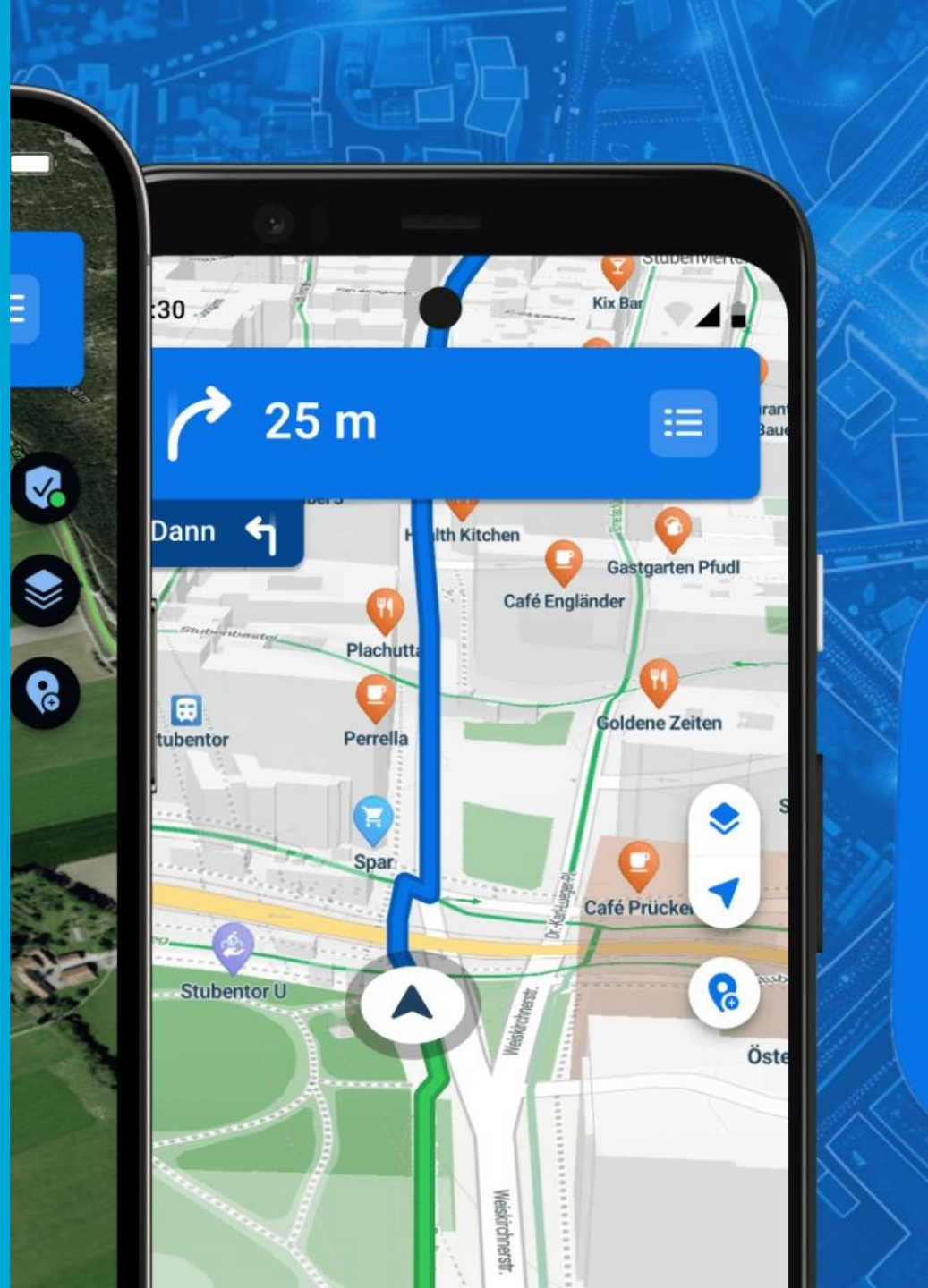

Agenda | 

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01

Motivation & Challenges

Motivation

Bicycles

- Sustainable transport mode
- Widespread popularity in the Netherlands

Travel time estimation

- Cyclists' route planning
- Insights for infrastructure upgrades
- Insights for traffic control

Research contribution

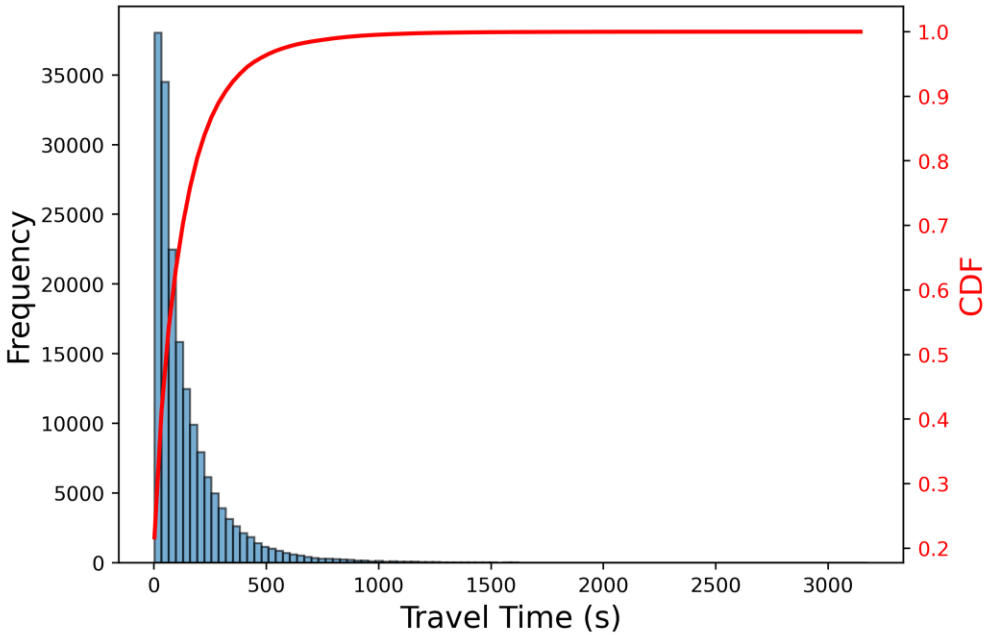
- Early stage of bicycle travel time estimation

Motivation | Challenges

- Limited availability of structural cycling data.
- The diverse and complex behaviors of cyclists.
- The lack of strict road constraints for cycling and frequent rule violations.

Why not just apply car-traffic methods?

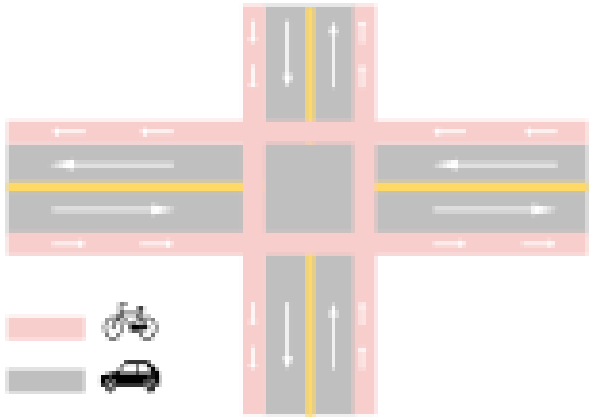
- Incompatible GPS Data Quality
- Volatile Travel Times
- Lack of Cycling-Specific Travel Behavior Integration



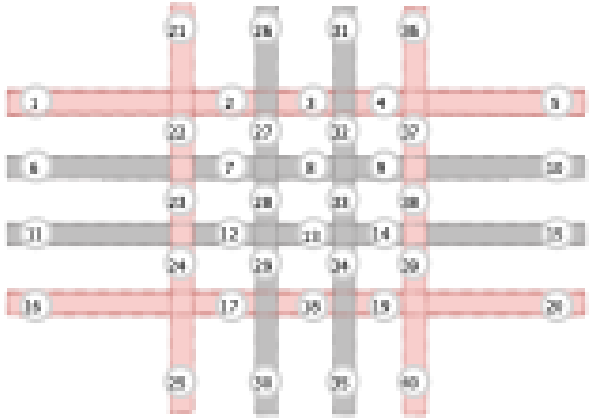
02

Problem definition

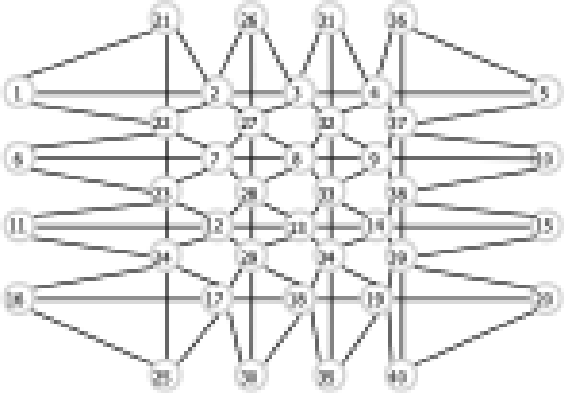
Road line network



Intersection



OpenStreetMap linestring representation

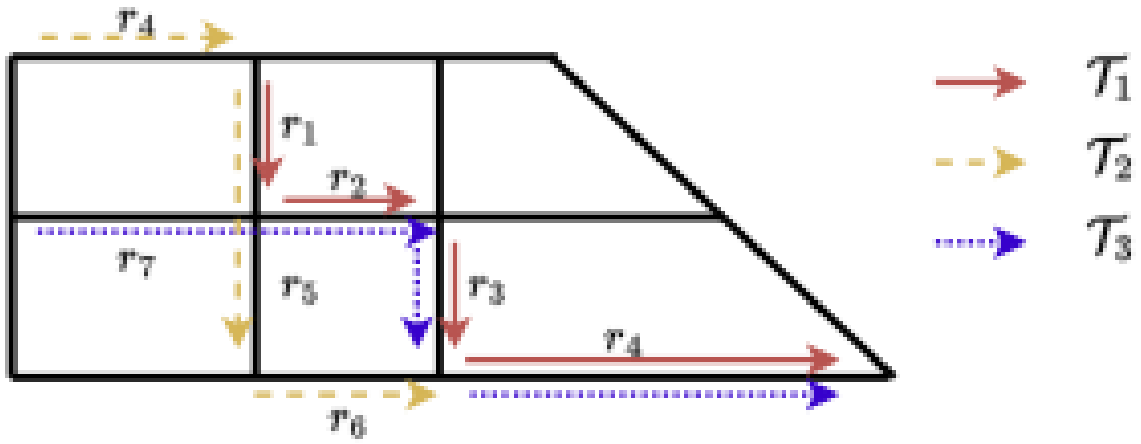


Graph representation

Problem formulation

Trip $\mathcal{T}_i$

GPS Records P^i → Road Segments V^i → Traveled Ratio R^i → Starting Time t^i → Travel Time y^i



Example of travel time estimation

When y^i is missing, $q_i = (P^i, V^i, R^i, t^i)$

$\mathcal{D}$ set of trips with complete attributes

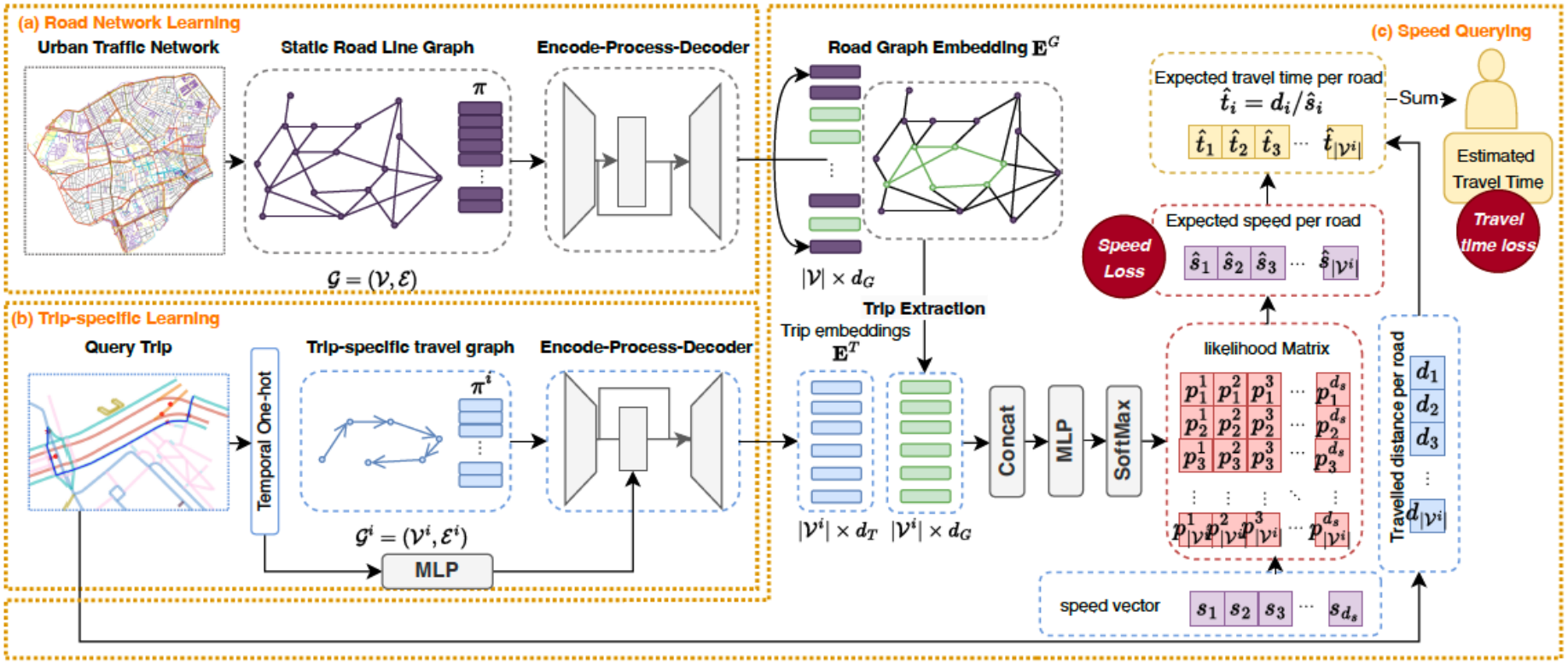
$\mathcal{G}$ Road network

$f(q_i|\mathcal{D}, \mathcal{G}) \rightarrow y^i$

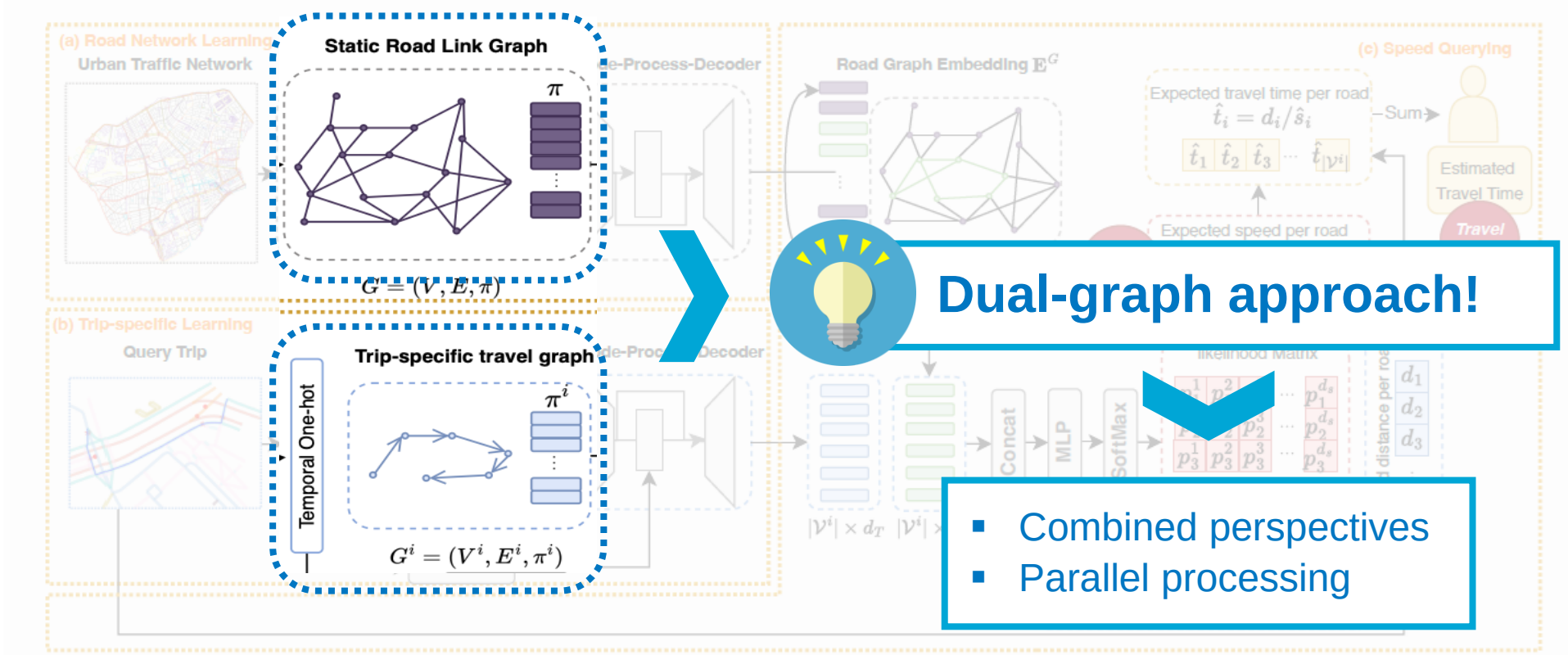
03

Dual Graph-based neural networks for Bicycle travel time estimation

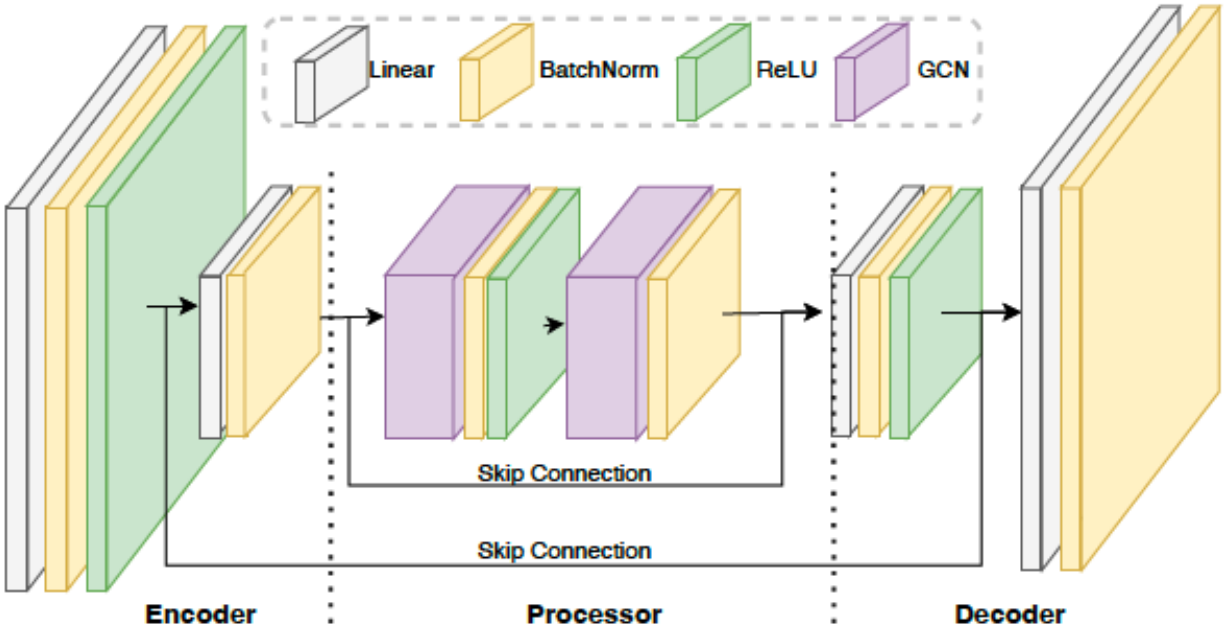
Our solution – DG4b



Our solution – DG4b



Encode-process-decode structure



Encode-process-decode structure

04

Real-world implementation

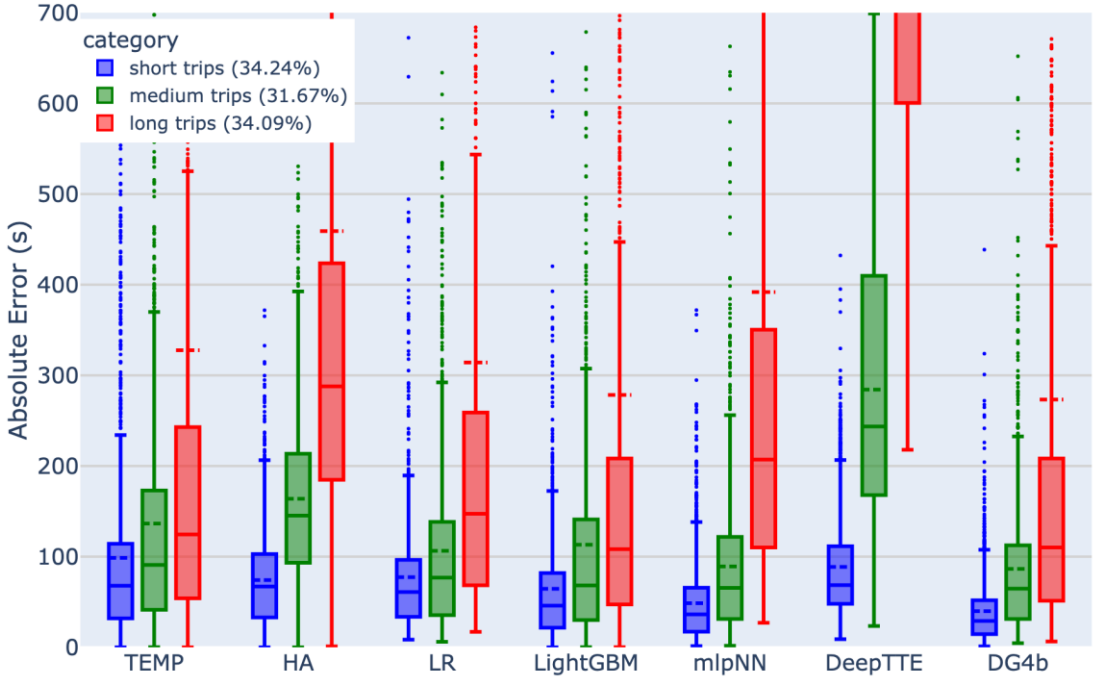
Baseline models

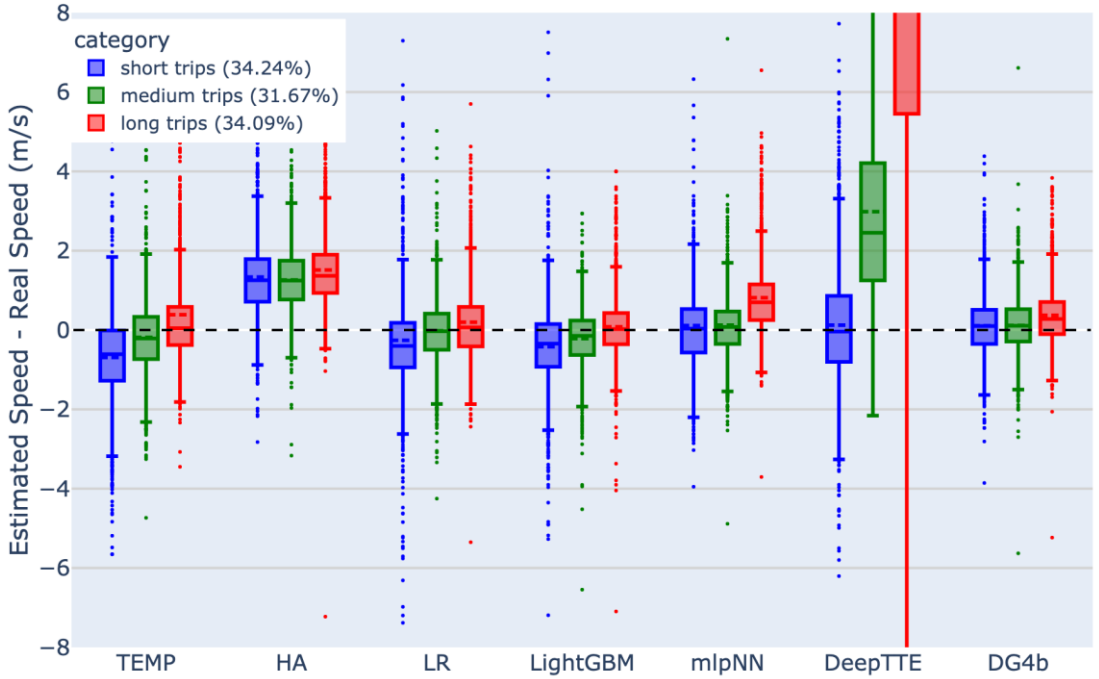
- HA: Historic Average
- TEMP: Temporally Weighted Neighbors
- LR: Linear Regression
- LightGBM: Light Gradient Boosting Machine
- mlpNN: Multi-Layer Perceptron Neural Network
- DeepTTE: Deep learning framework for Travel Time Estimation

SimRa data

- Data source: crowdsourced Berlin bicycle dataset collected via a mobile app
- Time span: June 2019 – January 2025
- Data size: 22,270 trips
- Road network size: 47,896 nodes and 150,172 edges

Performance comparison with baseline models

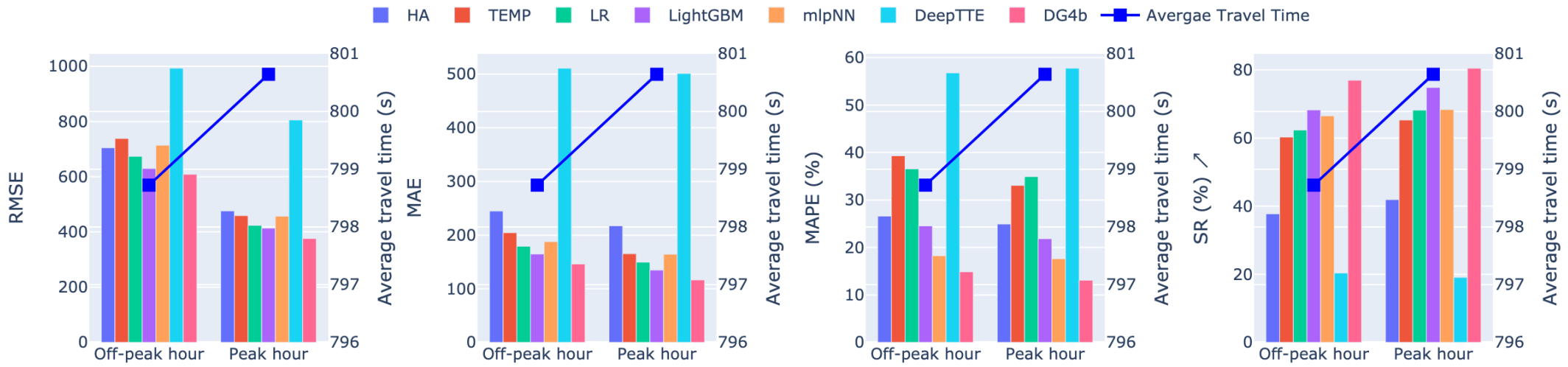




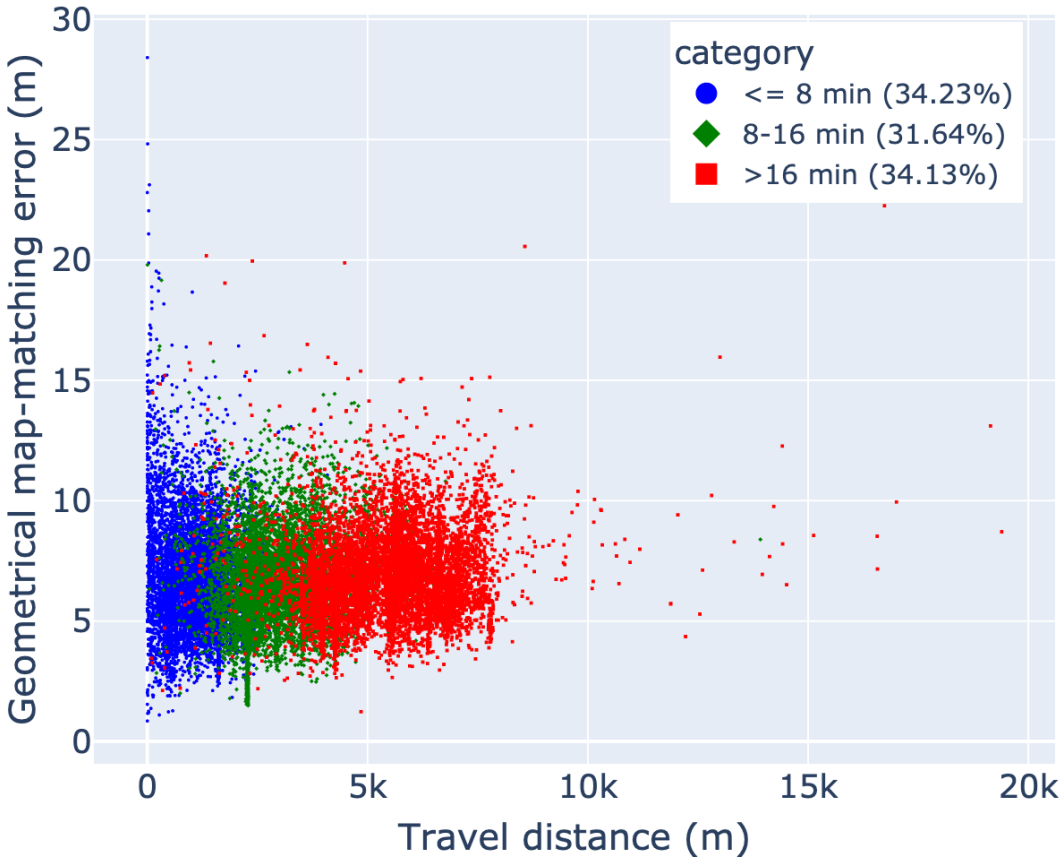
Short trips (<=8min), medium trips (8-16min), long trips (>16 min)

- DG4b outperforms baseline models, especially for short trips (more complicated).
- DeepTTE performs the worst -> limitation of directly apply car traffic methods on bicycles.

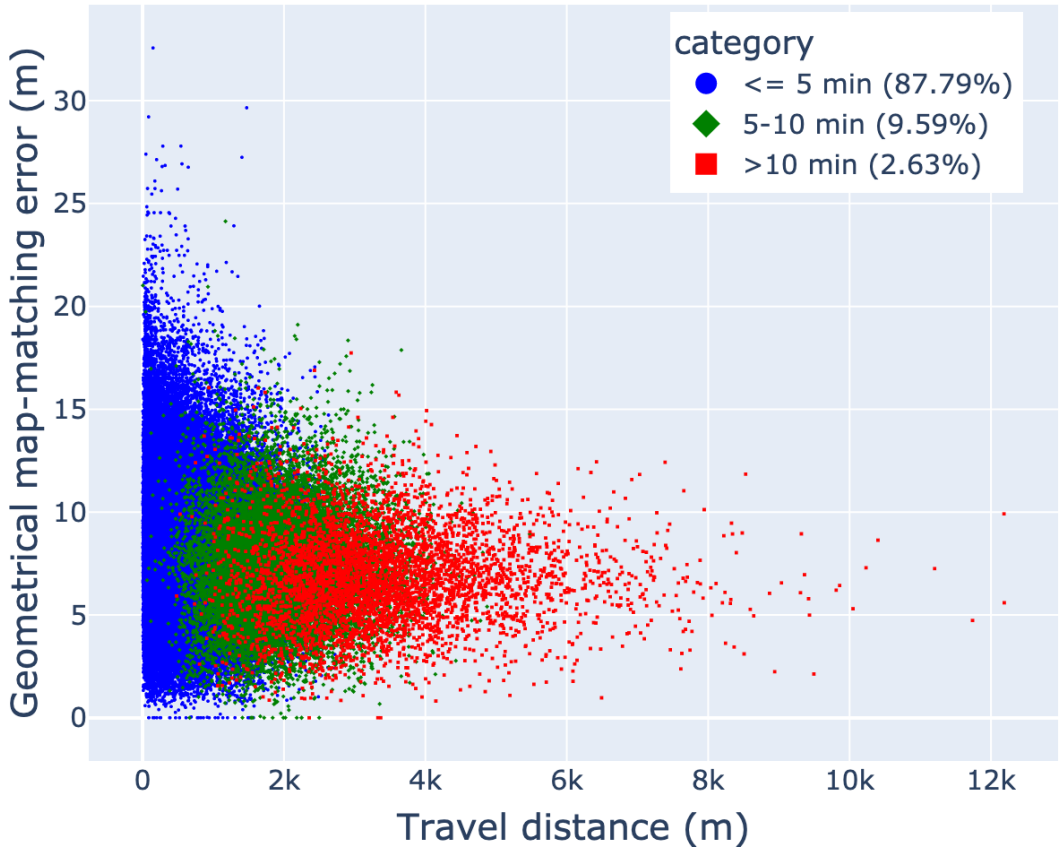
Peak vs off-peak hour performance



Generality on a Dutch dataset



German SimRa dataset

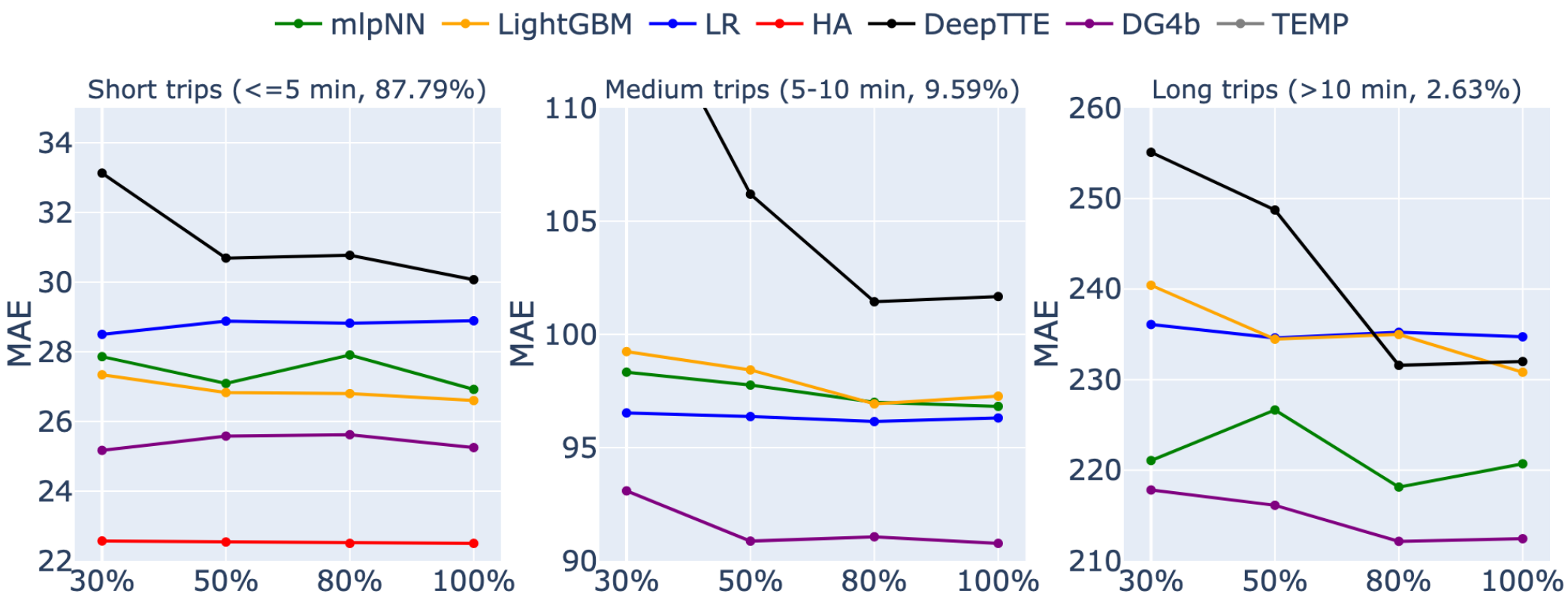


Dutch Talking Bike dataset

Dutch dataset has more trips, but also more data bias and errors.

Generality on a Dutch dataset

If we keep only 30%, 50%, 80%, and 100% of short trips in the training dataset…



Key takeaways

- Estimating bicycle travel time is hindered by limited and low-quality real-world data.
- Car-based models are not suitable for bicycle travel time estimation due to different dynamics and constraints.
- We introduce DG4b, a dual-graph neural network that combines road infrastructure perspective and specific-trip perspective.
- DG4b outperforms baseline models on two real-world datasets: German SimRa and Dutch Talking Bike.

Thanks for your attention!

Ting Gao

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