Graph Neural Networks for Traffic Flow Prediction under Network Reconfiguration

Project Description

Traffic flow prediction is immensely important in modern transportation systems. Importantly, accurate data allows various agents and decision makers to take optimal decisions. In recent years, much research has focused on temporal prediction to forecast how traffic changes over time.

However, an equally important question is to understand what happens to flow when the road network changes. Access to such information can be pivotal in the case of accidents or when redesigning the road network from a city-planning perspective. How will traffic adapt if we add a bridge, close a road, or change the capacity of an intersection? Traditional methods in transportation planning require origin–destination (OD) demand data and computationally heavy traffic assignment solvers to answer such questions. However, OD data is often unavailable, costly to estimate, or unreliable.

This thesis explores a new direction: using Graph Neural Networks (GNNs) to rapidly predict stationary traffic flows in road networks under structural changes, without relying on OD information. A key application for this tool would be planning of infrastructure projects, e.g., new bridges or bypasses. Moreover, since such a method might be faster than conventional ones, it could be included in outer loops to efficiently predict Braess paradox. This is a phenomena that causes some road links to be detrimental to overall travel times in the grid. Paradoxically, travel times might be reduced by identifying Braessian links and removing them.

Tasks

The candidate(s) will explore the capability of graph neural networks to predict the effect of changes in the road network to the traffic flow. As a key assumption, we will work without OD pairs, and instead try to directly predict counterfactual link flows from actual ones. The idea is also that the obtained method will be orders of magnitude faster than conventional solvers.

Concretely, the candidate(s) will:

- Conduct a literature review on GNNs for flow prediction in traffic, power grids, and fluids.
- Develop and implement a GNN model that predicts link flows from network structure and attributes.
- Train and evaluate the model on benchmark road networks with simulated ground truth from traffic assignment solvers.
- Test generalization to counterfactual network modifications (adding/removing/modifying links, changing speed limits).

Additionally, the project is flexible, and the student(s) will have a large autonomy in pursuing their own directions. Possible examples include:

- Augmenting the model with physics (e.g., flow conservation laws), to preserve the soundness of the obtained solution.
- Benchmarking on real (non-simulated) datasets.
- Investigating how to predict Braess paradox.
- Exploring deeper connections to game theory.

Who should apply?

We are looking for one or two motivated candidates with a strong background in computer science, applied mathematics, physics, data science & AI, systems & control or similar subjects. A high interest in machine learning and programming is a requirement. Experience with GNNs is desirable. Additionally, some knowledge in mathematical programming is meriting but not required.

What we offer

- Supervision by researchers in transportation systems and graph machine learning.
- Access to computing resources.
- A scientifically exciting project with high publication potential (conference or journal).
- A chance to contribute to next-generation tools for sustainable mobility planning.

Practical Information

The start date is flexible, but intended to be sometime during January/February of 2026. The main supervisor is Filip Rydin (department of Electrical Engineering) and the project will also be co-supervised by Alvin Combrink (Electrical Engineering) and Sten Elling Tingstad Jacobsen (Volvo Cars and Electrical Engineering).

To apply, send an email to `filipry@chalmers.se` (cc Alvin and Sten Elling) with a short CV and grades transcript. Applications will be reviewed on a rolling basis.