Graph Neural Networks for Traffic Flow Prediction under Network Reconfiguration

Project Description

Traffic flow prediction plays a central role in modern transportation systems, since accurate flow estimates allow planners and operators to make well-informed decisions. In recent years, much research has focused on the temporal problem of forecasting how traffic evolves over time.

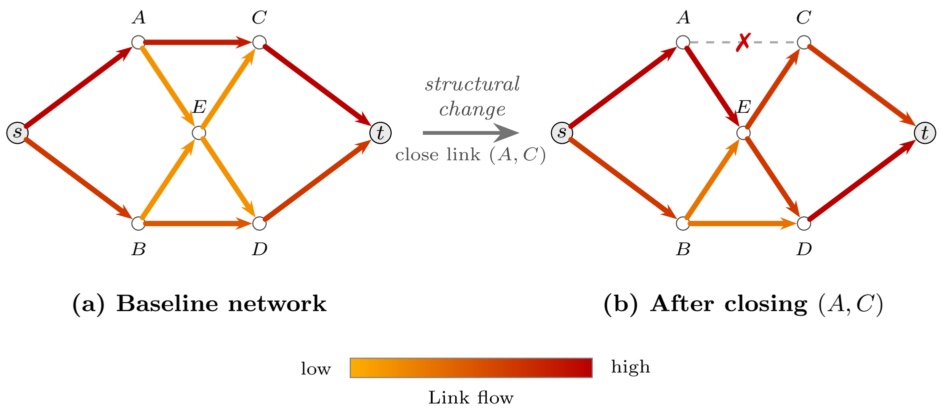
However, an equally important yet understudied question is how flow responds when the road network itself changes. Answers to this question are pivotal both for reacting to disruptions, such as accidents or road closures, and for long-term city planning. How will traffic redistribute if we add a bridge, close a road, or alter the capacity of an intersection? Traditional transportation-planning methods answer such questions through traffic assignment, but this requires origin–destination (OD) demand data together with computationally heavy equilibrium solvers. In practice, OD data is often unavailable, costly to estimate, or unreliable, which limits how readily these methods can be applied.

This thesis explores a different direction: using Graph Neural Networks (GNNs) to rapidly predict stationary traffic flows in road networks under structural changes, without relying on OD information. A natural application is the planning of infrastructure projects such as new bridges or bypasses, where many candidate configurations must be evaluated quickly. Because a learned model can be substantially faster than conventional solvers, it could also be embedded in an outer optimization loop, for instance to detect the Braess paradox, the counterintuitive phenomenon in which adding a road link increases overall travel times. Identifying and removing Braessian links can, paradoxically, reduce congestion across the network. For applications of this kind, it is essential to account for incomplete information and prediction uncertainty. The method should therefore handle heterogeneous inputs and provide reliable uncertainty estimates to support transportation planning.

Tasks

The candidate(s) will build upon a master's thesis conducted last year for the OD-free flow-to-flow problem. They will develop/extend the method along several axes:

- Integrate Bayesian uncertainty estimation alongside the point-estimates. This would yield crucial uncertainty quantification for decision-makers.
- Enable partial OD-input as well as partial traffic flow information.
- Apply the methodology for several downstream tasks, such as Braess paradox prediction.
- Validate the method on real data in realistic setups.
- Investigate generalization across different road networks, network reconfigurations and demand distributions.
- Improve the physical and equilibrium consistency of the predictions.



(a) Baseline network **(b) After closing** (A, C)

Figure 1: The OD-free flow-to-flow task. Given a road network and its link flows, the model predicts how flow redistributes under a structural change to the network.

The ultimate goal is to obtain a thoroughly validated method that can be used in realistic setups with incomplete heterogenous data.

Moreover, depending on the interest of the candidate(s), several directions could be explored, including:

- Investigating deeper connections to game theory.
- Building a working product-ready prototype.
- Accounting for heterogenous traffic, non-stationary redistribution or induced travel demand.

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 2027. The supervisors are Filip Rydin (department of Electrical Engineering) and Xinwei Wu (department of Electrical Engineering).

To apply, send an email to `filipry@chalmers.se` and `wuxin@chalmers.se` with a short CV and grades transcript. Applications will be reviewed on a rolling basis.