Development and Analysis of a Particle Model for Regional Traffic Interactions

Daily supervisors:
Dr. Havva Yoldaş, DIAM (Mathematical Physics), EEMCS
Dr. Irene Martínez Josemaría, Department of Transport & Planning, CEG

Problem Description

In transportation engineering, traffic models have been developed to describe the movement of vehicles as they approach their destinations within a network. These so-called bathtub models simplify the network to an undifferentiated movement area and the movement of vehicles is captured by the mean speed as a function of network level density. The speed of all vehicles is assumed the same based on the functional form of the Macroscopic Fundamental Diagram (MFD) which depends on the network. This approach captures essential complexities with lower computational costs (compared to traditional topology-based models) but assumes homogeneity in vehicle density and speed across the entire region modelled. In reality there may be some inhomogeneities within the region with slight speed variations and density variations.

Motivation: This project aims to address the inaccuracies arising from such assumptions by developing a more realistic particle model that considers spatial and temporal variations in vehicle density and speed.

Project goals

The assignment consists of:

- Literature study: Conduct a comprehensive review of existing bathtub models, focusing on both particle (agent-based) models and continuum models that utilize partial differential equations (PDEs) and ordinary differential equations (ODEs).
- Model development: Develop a particle model that accurately represents the interactions between travelers within a region. This model should incorporate spatial and temporal variations in density and speed.
- Mathematical Analysis: Perform a mathematical analysis to derive the corresponding PDE from the particle model by taking the appropriate limit. Study the analytical properties of the PDE, such as well-posedness, uniqueness, stability and/or long-time behaviour.
- Simulation and Validation: Develop a simulation-based framework to implement the particle model and the PDE in a suitable computational framework based on existing tools developed by the team. Simulate various traffic scenarios and validate the model. Quantify the benefits with respect traditional bathtub models that assume homogeneous densities.

Background

A student who has an affinity for working with both theoretical and applied aspects of mathematics and traffic engineering is ideal for this project. The student should possess strong analytical skills, experience with mathematical modeling, and proficiency in programming for simulation purposes.

References

[1] F. A. Chiarello and A. Tosin, Macroscopic limits of non-local kinetic descriptions of vehicular traffic, *Kinetic and Related Models*, 16(4): 540–564, 2023.

[2] M. di Francesco and M. D. Rosini, Rigorous derivation of nonlinear dcalar conservation laws from Follow-the-Leader type models via many particle limit, *Archive for Rational Mechanics and Analysis*, 217: 831–871, 2015.

[3] G. Dimarco, A. Tosin and M. Zanella, Kinetic derivation of Aw–Rascle–Zhang-Type traffic models with Driver-Assist Vehicles, *Journal of Statistical Physics*, 186 (17): 1–26, 2022.

[4] W.-L. Jin, Generalized bathtub model of network trip flows, *Transportation Research Part B: Methodological*, 136: 138–157, 2020.