Predicting Traffic Load in Public Transportation Networks

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Context of the Research

Some Basic Facts:

- PhD study entitled “Supervision in Multimodal Transportation Systems”
- MExICo team, INRIA and LSV, CNRS & ENS de Cachan
- Corporation with IRT SystemX; project MIC
- From September 2013 until ~end of 2016

Major Contribution & Task:

- Stochastic hybrid automaton (SHA) model that can be used to forecast the passenger loads of a *multimodal transportation network* (TN)
- Supervision strategies for some use cases

TN in Perturbed Mode of Operation

Assumptions Made:

- Vehicles are parked or execute missions that in turn define fixed-route transportation services or dead headings
- Passengers can be grouped into a finite set of trip profiles defining paths in TN
- Passenger transfers spread perturbations across the different modes and lines

Operator or Authority of TN with a Particular Question on TN's Future Passenger Loads

Sample Question:

- Will the passenger load of the platform p in the station s exceed 200 passengers with a probability greater than 0.7 within the next 20 minutes?

Constraints:

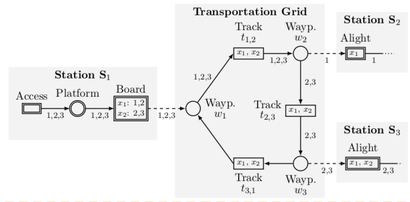
- Obtain forecast in time given reasonable computation constraints based on ...
- Exact knowledge of the vehicles' operational states
- Estimations for all passenger loads

Overview of SHA Model

- Every mode captures a particular state in TN's vehicle operation (which vehicle is stopped at whicht station, etc.)
- A set of decoupled (for every station one) Itô-stochastic balance equations defines the passenger flow dynamics in a particular mode
- Diffusion terms in balance equations capture uncertainty that comes along with every passenger arrival process associated with the passengers of a particular trip profile
- Deterministic-timed (arrival of a vehicle at a station upon its departure) and probabilistic passenger load-driven transitions (departure of a vehicle from a station) among a finite set of modes

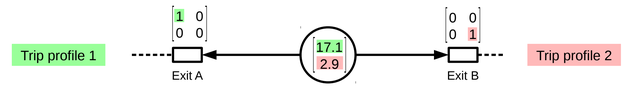
Infrastructure of TN in SHA

- Stations, transportation grids, and an interface between both (defining all passenger transfer possibilities) capture the infrastructure of TN
- The paths of all vehicle missions are unfolded in the SHA's infrastructure graph for the easy specification of the passengers' mission-aware trip profiles



Routing of Passenger Flows in Balance Equations

- Balance equations relate passenger load vectors via locally-defined (re-)routing matrices
- Every element of a passenger load vector gives the number of passengers w.r.t. a particular trip profile at a discrete point in a station or on-board a vehicle docked to that station
- Every passenger flow is a vector with a passenger load-dependent magnitude and is thus demand- and capacity-sensitive



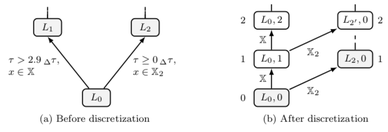
Forecasting Passenger Loads & Future Work

Problem:

- Probabilistic passenger load-driven mode transitions can occur at any time within uncountable time intervals

Workaround:

- Pinpoint all mode transition times to an equidistantly-spaced mesh → discretized mode graph that has to be computed time-layer by -layer (iterative propagation of prob. densities)



Future Work & Outlook

Efficient Implementation of Forecasting Algorithm:

- Compute compact discretized mode graph, which disregards everything that does not affect the forecast → fewer numerical integrations
- Decouple all passenger flows in balance equations for the numerical integration of the corresponding Fokker-Planck equations

Apply SHA Model to Different Forecasts:

- Forecast travel times
- Iterative search for bottlenecks without specification of particular target sets
- …

References & Related Links

Deterministic Hybrid Automaton Model:

- S. Haar and S. Theissing (2015). A hybrid-dynamical model for passenger-flow in transportation systems. In Proceedings of the 5th IFAC Conference on Analysis and Design of Hybrid Systems.

Stochastic Hybrid Automaton Model:

- S. Haar and S. Theissing (2016). Forecasting passenger loads in transportation networks. Submitted to a workshop.
- S. Haar and S. Theissing (2016). Predicting the Variability of Travelling Times in Transportation Systems. Submitted to a conference.

Research Abstract:

- http://www.lsv.ens-cachan.fr/~theissing/ResearchAbstract.pdf

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