Arterial Traffic Estimation using GPS Cell Phone Data

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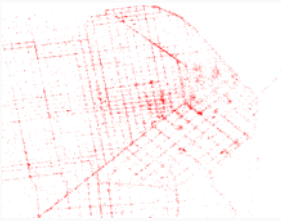
Arterial Traffic Estimation

• **Participatory sensing** in a privacy preserving environment: *Virtual Trip Lines* (VTLs) are virtual markers embedded in the memory of the phone. This sensing paradigm provides travel time measurements

• Discontinuous flow with high variability: we estimate the **probability distribution of traffic statistics** to provide accurate estimates with confidence intervals.

• Numerous parameters with important statistical variations (capacity supply and demand, pedestrian flows, variable signal timing…). Flow models are not appropriate for arterial traffic. We **learn the traffic patterns** from historical data to produce estimations and predictions in real time.

Raw Data



Processed Output

Parameter Estimation

• Transition matrix: probability of VTL pair *i* to be in state *s* given the state of the spatio-temporal neighbors

• Travel time probability distribution function of VTL pair *i* knowing that it is in state *s*.

EM algorithm

• **Initialization**:
  ⇒ Mixture model fiting to estimate the parameters of the conditional travel time distributions.
  ⇒ Maximum a posteriori state estimation and transition matrix estimation

• **E-step**: particle filter to estimate, for each VTL pair i and each time interval k, the expected value of the state and the expected state transitions.
  ⇒ Sampling Importance Resampling
  ⇒ Update the importance weights given the observations
  ⇒ Compute the effective number of particles
  ⇒ Resample using the transition probability matrix

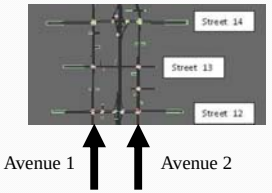
• **M-step**: Update of the transition matrix and conditional distribution parameters to maximize the expected complete log-likelihood

Experiment Design

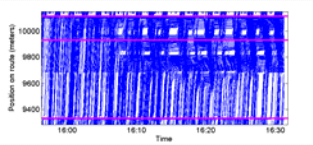
• Simulation data: Paramics software

• One simulation run used for training, another for validation

Simulation network:
The two north/south roads on either side of the freeway were the main roads of interest for our analysis



The figure below is a time/space plot of the vehicle trajectories on Avenue 1 in the northbound direction. There is heavy congestion later in the simulation.



Graphical Model

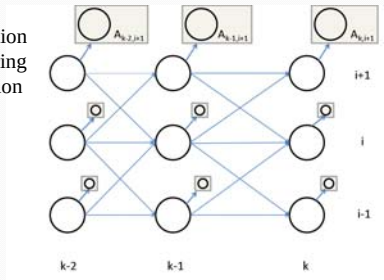
• Discrete value of traffic states for each link

• Spatio-temporal dependencies between the congestion states of the links

• Travel time distribution conditional on the state

• Variables:
  • Observations: travel time measurements
  • Hidden variables: congestion states

• Output:
  • Estimated travel time distribution
  • State estimation for map coloring
  • Predicted travel time distribution some time into the future.



Real-Time Estimation and Prediction

• Use the estimated transition probability matrix and conditional travel time distributions

• **Real time** estimation: use the *sparse* measurements available in real time to estimate traffic conditions on the whole network
  ⇒ E step of the algorithm with missing data and sparse measurement.

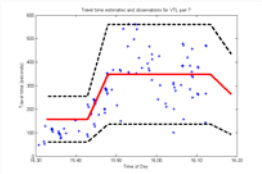
• **Prediction**: use the *past* data and estimation to forecast traffic statistics.
  ⇒ E step of the algorithm without evidence. Forward propagation using the transition probability matrix

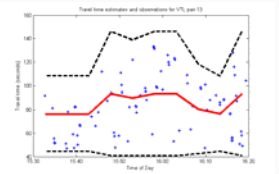
Update the parameters

• Run the **EM algorithm** in the background to update the parameters and account for traffic variations at a longer time scale.

Results

We trained the model assuming that each link of the road network had two states where each state has a Gaussian distribution of travel time along the link. We assumed a spatial dependency of one, meaning that each link is correlated with its neighboring links. The plots below are of the estimated travel time distribution on the validation test set for two links of the network. The normalized training and validation log likelihood scores were **XXXX** and **YYYY**, respectively.





Future Directions

The assumption of travel times following a Gaussian distribution is the main source of error in our model and travel times are not Gaussian. We also plan to investigate using more states to represent traffic.