Vehicle Trajectory Estimation from Probe Data

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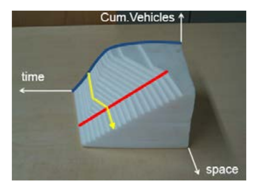
1. Theory（Kinematic Wave, Cumulative Curves and Variational Theory）

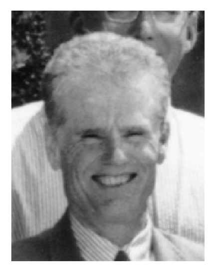
Kinematic Wave Theory first developed by Lighthill, Whitham and Richards in 1950s explains dynamic vehicle motions on the two-dimensional space of time and space (the Time-Space Diagram). In 1960s, Newell started to describe queue evolutions using the Cumulative Curves which has been conveniently used to understand time-dependent delay and the number of queued vehicles. Then, Newell proposed the three dimensional traffic flow representation that combines the time-space diagram with the cumulative curve. The three dimensional representation is a powerful tool to dynamically describe vehicle motions with queueing phenomena.

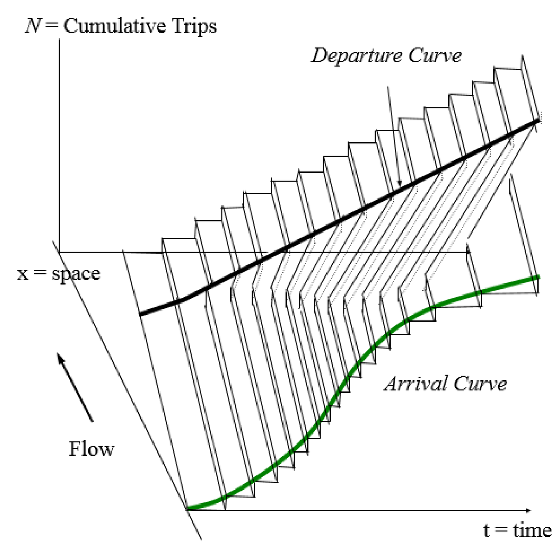
In 1993, Newell published a paper on the simplified kinematic wave theory, in which the theory was translated using forward and backward waves of cumulative curves to evaluate dynamic physical queue evolution. Furthermore, in 2005 Daganzo proposed an efficient calculation method of wave motions based on the Variational Theory, which this study employs to estimate trajectories of all running vehicles along a highway.


Lighthill




Newell

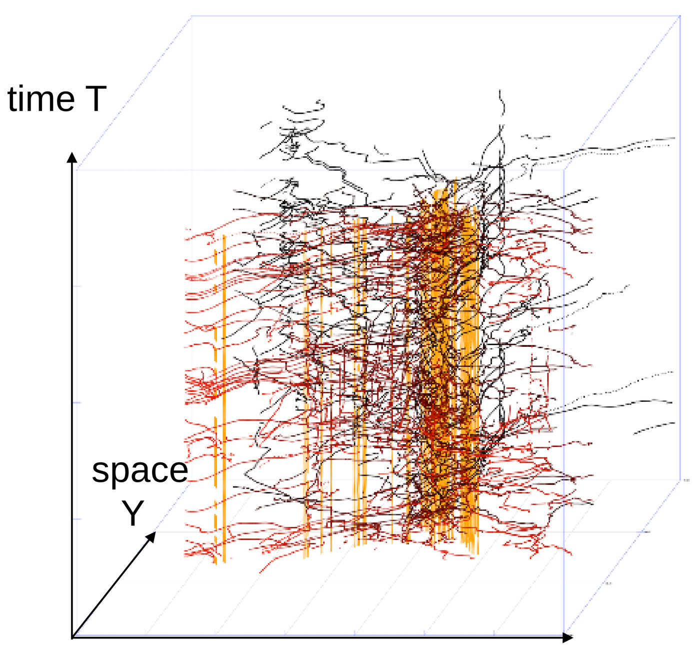

Daganzo



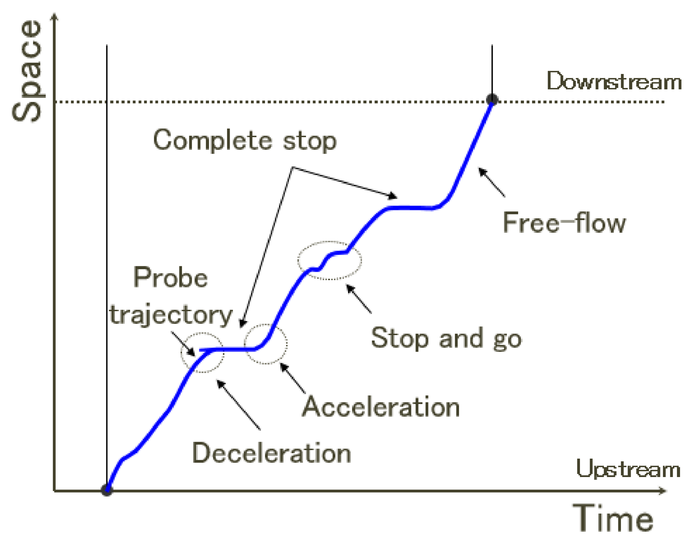
3D Flow Representation

2. Estimating Vehicle Trajectories using Probe and Detector Data

Probe Data

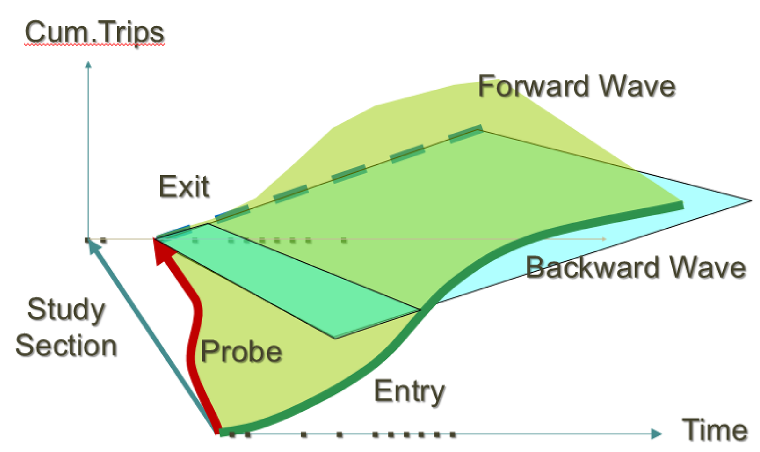


Probe data are generated from individual moving objects such as vehicles and pedestrians. A moving object carrying a GPS and a communication system send its location to a transport center at a certain time interval. The left-hand side figure shows trajectories of moving objects in a three dimensional space.



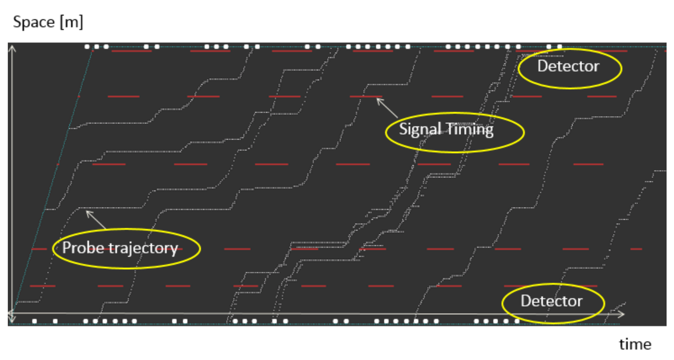
Rich probe data tell us their detailed motion.

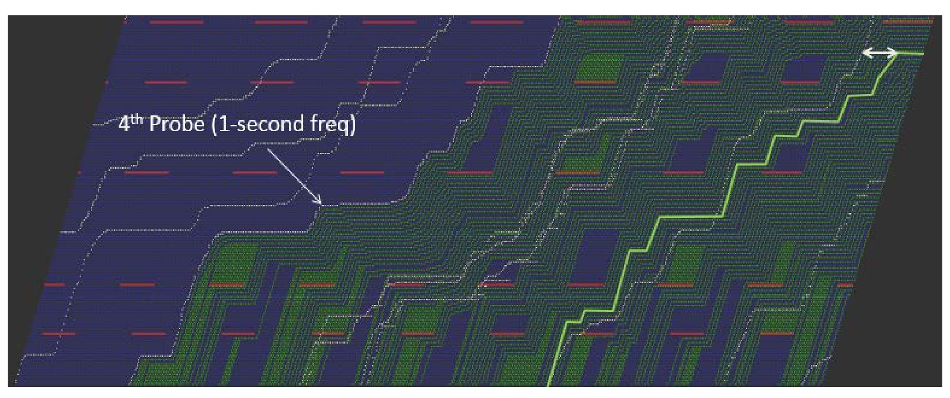
Forward and Backward Waves



Detector data at the entrance and exit of the section construct the cumulative curves at the locations and a probe trajectory adjust vertical heights of the curves. Then, the forward and backward waves draw the three dimensional surface as shown. Vehicle trajectories are estimated as contour lines on the surface.

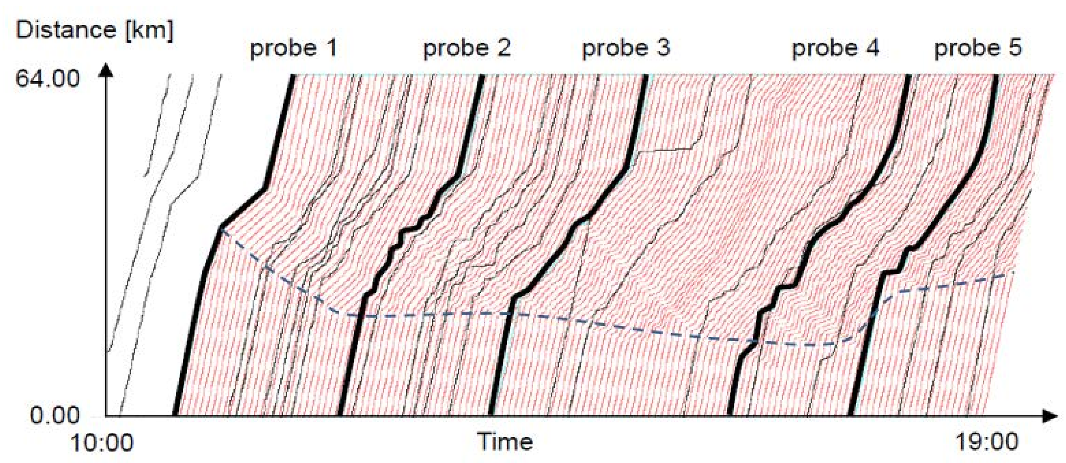
Application to an Arterial with Signalized Intersections





As shown in the left-hand side figure, the study section located in the center of Tokyo has 6 intersections. Passing times at the entrance and are measured by traffic detectors. Probe trajectories and signal timings (red bars) are observed manually in this study. The estimated trajectories are shown in the right-hand side figure (alternative blue and green lines). The estimate well agrees with the observed probe trajectory.

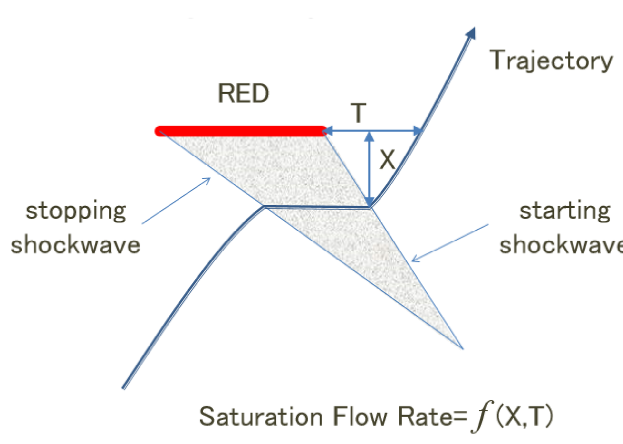
Application to an Intercity Motorway



The application is made at a congested section in the southbound of Tohoku expressway with a 64-km long section from 10:00 to 19:00. Five probe trajectories and detector data at the entrance and exit are used to estimate trajectories of all running vehicles. The estimated trajectories agrees with the observed and the queue length is well evaluated.

3. Extensions

Traffic monitoring in the center of Ishinomaki just after the Great East Japan earthquake using probe data.



Estimation of Delay and Saturation Flow Rate using a Probe Trajectory

Research Extensions

1. Real time traffic monitoring just after a natural disaster
Just after a natural disaster, real time traffic monitoring is needed to support safe evacuation. Data fusion technique using several possible data such as probe, detector, twitter, camera image, web data has to be developed.

2. Advanced signal control utilizing probe data
Using probe trajectory data, it may be possible to estimate key variables for traffic signal control: saturation flow rate, traffic delay and traffic demand, etc.

3. Incident detection and delay prediction
Since probe trajectories are directly influenced by incidents on a highway, they can be used to detect them and also to evaluate the impacts such as delay due to the incidents.