Building Knowledge from Real-Time Sensor Information
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Real-Time Transit Project Objectives

• Derive/Verify Transit System Artifacts from GPS Sensor Data
  • Route Geometries
  • Stop Locations
  • Schedules

• Monitor Transit Systems using GPS Sensor Data to Enable Integrated Real-Time Services
  • Real-Time Route Planning
  • Accurate Arrival Time Predictions
  • Passenger Service Alerts
  • Driver/Agency Notifications
  • Other Services

Create Better Transit Services through Enhanced Data Analytics and Methods
Real-Time Transit Project Overview

Transit Artifact Derivation

- Historic GPS Sensor Data
- Route Derivation
- Stop Derivation
- Schedule Derivation

Electronic Transit Sources

Transit Artifacts

Initialize Update

Real-Time Services

- Arrival Time Predictions
- Route Deviations
- Bus Bunching
- Schedule Deviations
- Real-Time Route Planner
- ...
Building Knowledge from GPS Sensor Data

Based on **Historic** GPS Sensor Data

- **Route Derivation**
  - Derive Route Geometries

Based on **Real-Time** GPS Sensor Data

- **Stop Derivation**
  - Derive Stop Locations along Routes

- **Schedule Derivation**
  - Derive Schedules at Stops along Routes

- **Arrival Time Predictions**
  - Predict Arrival Times for Vehicles at Stops along Routes
Route Derivation

• Spatial Clustering of GPS Locations
• Outlier Suppression of Low Density Clusters
• Route Formation through Spatial/Temporal Cluster Ordering
• Refine Cluster Accuracy by Aligning Clusters to Road Network
• Refine Route Accuracy by Adding Intersections
Stop Derivation

• Uses Supervised Machine Learning Model based on
  • Mini-Clusters at Stop Points
  • Speed
  • Heading
• Training Set (Patterns) Observed in the Real World
  • Transit Stops vs.
  • Stop Signals vs.
  • Stop Signs vs.
  • Combination
• Model Seeded with Training Set
• Artifacts Computed on Most Likely Match
  • Resulting in 90% Accuracy for Stop Derivation
Schedule Derivation

• Separate GPS Data by Weekday & Weekend

• Cluster GPS Data Temporally (by Time)

• Align Time Clusters with Stops

• Based on the Number of Transit Runs for each Route, for each Stop Compute
  • Mean Arrival Times
  • Standard Deviation (Variances) of Arrival Times
Real-Time Service: Arrival Time Prediction

- Uses Adaptive **Kalman** Filter
- Dynamic Weighting Between Historic & Real-Time Arrival Times based on
  - Historic Variances (from Derived Schedules)
  - Real-Time Variances (Estimated)
- Accuracy of Predictions On-Par or Better than Agency Arrival Time Services
Real-Time Service: Bus Bunching

• Bus Bunching occurs when Buses on a Route are too close
  − Bus Bunching leads to *irregular* service
  − *Closeness* is a function of the length of the route and the number of buses on the route at a given instance in time

• Regulate Service via Monitoring & Driver Notifications
Summary

• Artifact derivation from GPS/sensor data produces accurate Transit Models
  − Enables Route Planning for Agencies without Electronic Sources
  − Provides more up-to-date Models for Agencies with Electronic Sources

• Monitoring Transit Vehicles from GPS/sensor data enables Real-Time Services
  − Enables seamless integration of Real-Time Data & Services
  − Provides Services On-Par or Better than Agency-provided Services
  − Optimizes System efficiencies thus increasing Customer Satisfaction