Advanced Traveler Information System

Applications & Examples
Area of applications

- Freeway
- Highway
- Urban streets
Focus

• Travel time estimation and prediction
• Traffic concepts
• Travel time data collection
  – Sources:
    • Inductive loops
    • Floating car or probe vehicles
    • Cell phone signals
Travel time estimation and prediction

Estimation

Prediction

Known traffic conditions
Unknown traffic conditions

Instantaneous prediction
Short-term prediction
Long-term prediction

Past
Now
1 hour
Future time
Travel time pattern per day

- Rural Cars
- Business Day Trucks
- Through Trucks
- Urban Cars

Hour of Day

Percent of Daily Traffic
Describing Traffic

• Hypothesis:
  – Let’s consider one road lane of traffic
Typical 24-Hour Traffic Volume Distribution
I-82 West of Exit 122 (South of Tri-Cities)

From WSDOT 2003 Annual Traffic Report
Typical 24-Hour Traffic Volume Distribution
I-5 North of Exit 260 (Near Ferndale)

From WSDOT 2003 Annual Traffic Report
Modeling Traffic

- Traffic can be seen as:
  - Liquid?
  - Fluid?
  - Discrete events?
  - etc
Traffic concepts

- **Traffic Flux**
  - The equivalent hourly rate at which vehicles pass a point during a time period less than 1 hr.

- **Traffic Speed**
  - The distance traveled by a vehicle during a unit of time

- **Traffic Density**
  - The number of vehicles \( (n) \) occupying a given length \( (l) \) of a lane or roadway at a particular instant
Traffic Flow (q)

- Traffic Flux:

\[ q = \frac{n}{t} \]

- Where,
  - \( n \) is the number of vehicles passing a road segment at specific time \( t \)
- Units: vehicles/hour
- The flow in an hour is typically the volume
Traffic time space diagram microscopic approach

Distance

Time

Time headway

Space headway
Headway

Time Headway \( \bar{h} \) is the time (in seconds) between successive vehicles, as their front bumpers pass a given point.

\[
q = \frac{n}{\sum_{i=1}^{n} h_i} = \frac{1}{\bar{h}}
\]
Traffic speed

• Measuring traffic speed
  – Time mean speed (TMS)
    • Measured at a specific point
    • Average of instantaneous speeds
  – Space mean speed “u” (SMS)
    • Harmonic speed
    • Average speed of all vehicles in a specific road segment
Traffic speed

- Time mean speed

$$\bar{u}_i = \frac{1}{n} \sum_{i=1}^{n} v_i$$

- Measurement point

- $v = 10$ mph
- $v = 15$ mph
- $v = 7.5$ mph
Traffic speed

- Space mean speed

\[ u_s = \frac{n}{\sum_{i=1}^{n} \frac{1}{v_i}} = \frac{nl}{\sum_{i=1}^{n} t_i} = \frac{l}{\bar{t}} \]

\[ \bar{t} = \frac{1}{n} (t_1l_1 + t_2l_2 + \ldots + t_nl_n) \]
You are in a vehicle traveling a total of 10 kilometers.
- first 5 kilometer you travel at 40 km/h
- next 5 kilometer you travel at exactly 60 km/h

What is your time average speed?
What is your time average speed?

**Time per section:**
- 5 kilometers / 40 km/h = 7.5 minutes
- 5 kilometers / 60 km/h = 5 minutes

**Weighted average:**
\[
\text{weighted average} = \frac{40(7.5) + 60(5)}{7.5 + 5} = 48 \text{ km/h}
\]
• If you have 5 vehicles over a given 1 mile section take 1.0, 1.2, 1.5, 0.75 and 1.0 minutes respectively

• What is your space average speed?
What is your space average speed?

Average travel time

\[ \frac{5.45}{5} = 1.09 \text{ minutes} = 0.0182 \text{ hours} \]

Therefore, average speed *over that distance*

\[ 1 \text{ km}/0.0182 \text{ hours} = 55.05 \text{ km/h} \]
Traffic density

- Traffic density

\[ k = \frac{n}{l} = \frac{q}{u_s} \]

- Unit of density is vehicles per kilometer (v/km).
Fundamental diagram of traffic flow (flow vs. density)

- Optimal flow or capacity, $q_{\text{max}}$
- Optimal density, $k_o$
- Jam density, $k_j$
- Mean free flow speed, $u_f$
- Optimal speed, $u_o$

Flow ($q$) vs. Density ($k$)

Uncongested flow

Speed is the slope. $u = q/k$

Congested flow
Fundamental diagram of traffic flow (SMS vs. density & SMS vs. flow)
Case study example: Microsoft Research Asia T-Drive project

[*] Jing Yuan, Yu Zheng, Chengyang Zhang, Xing Xie, Guanzhong Sun, and Yan Huang, "T-Drive: Enhancing Driving Directions with Taxi Drivers' Intelligence", Knowledge and Data Engineering, IEEE Transactions on (Volume:25 , Issue: 1 ), 2013
Motivation

- Using Taxi drivers
- Taxis are equipped with GPS
Challenges we are faced

- Data sparseness
- Low-sampling-rate
Methodology

Pre-processing

Building landmark

Travel time estimation

Time-dependent landmark

Routing

A Time-dependent Landmark Graph

Taxi Trajectories

A Road Network

Rough Routing

Refined Routing
Step 1: Pre-processing

- **Shortest path**
  - Find out possible routing
  - Get the effective routing

- **Map-matching**
  - map a GPS point to a road segment
Step 2: Building landmark graphs

Detecting landmarks
- A landmark is a frequently-traversed road segment
- Top k road segments, e.g. k=4

Establishing landmark edges
- Number of transitions between two landmark edges > \( \delta \)
- E.g., \( \delta = 1 \)

A) Matched taxi trajectories  
B) Detected landmarks  
C) A landmark graph
Step 3: Travel time estimation

The travel time of an landmark edge
- Varies in time of day
- is not a Gaussian distribution
- Looks like a set of clusters

A time-based single valued function is not a good choice
- Data sparseness
- Loss information related to drivers
- Different landmark edges have different time-variant patterns
- Cannot use a predefined time splits

VE-Clustering
- Clustering samples according to variance
- Split the time line in terms of entropy
Step 3: Travel time estimation

**V-Clustering**
- Sort the transitions by their travel times
- Find the best split points on Y axis in a binary-recursive way

\[
WAV(i; L) = \frac{|L_1(i)|}{|L|} \text{Var}(L_1(i)) + \frac{|L_2(i)|}{|L|} \text{Var}(L_2(i))
\]

\[
\Delta V(i) = \text{Var}(L) - WAV(i; L).
\]

**E-clustering**
- Represent a transition with a cluster ID
- Find the best split points on X axis iteratively

\[
WAE(i; S^{xc}) = \frac{|S^{xc}(i)|}{|S^{xc}|} \text{Ent}(S^{xc}(i)) + \frac{|S^{xc}(i)|}{|S^{xc}|} \text{Ent}(S^{xc}(i))
\]

\[
\Delta E(i) = \text{Ent}(S^{xc}) - WAE(i; S^{xc}). \quad \text{Ent}(S^{xc}) = - \sum_{i=1}^{m} p_i \log(p_i)
\]
Step 4: Two-stage routing

- Rough routing
  - Search a landmark graph for a rough route
  - Based on a user query
  - Applying time dependent algorithm

![Graphs and Diagrams](image)

(a) Travel time distribution  (b) Cumulative frequency
Step 4: Two-stage routing

- **Refined routing**
  - Find out the fastest path connecting the consecutive landmarks
  - Can use speed constraints
  - Dynamic programming
    - Very efficient
      - Smaller search spaces
      - Computed in parallel
Results

• More effective
  • 60-70% of the routes suggested by our method are faster than Bing and Google Maps.
  • Over 50% of the routes are 20+% faster than Bing and Google.
  • On average, we save 5 minutes per 30 minutes driving trip.

• More efficient
• More functional