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
- Known traffic conditions
- Unknown traffic conditions

Prediction
- Instantaneous prediction
- Short-term prediction
- Long-term prediction

Past
Now
1 hour
Future time

Travel time
Travel time pattern per day

The graph shows the percent of daily traffic by hour of day for different types of vehicles:
- Rural Cars
- Business Day Trucks
- Through Trucks
- Urban Cars

The x-axis represents the hour of the day, while the y-axis shows the percent of daily traffic.

Key points:
- Rural Cars have a peak around 9 AM.
- Business Day Trucks have a peak around 9 AM, followed by another peak around 17 PM.
- Through Trucks have a steady pattern with minor peaks.
- Urban Cars have a broad peak around 9 AM.

The graph illustrates the variation in traffic patterns throughout the day for different vehicle categories.
Describing Traffic

• Case:
  – Let’s consider one road lane of traffic
Describing Traffic

- Time Space analysis
Traffic time space diagram
microscopic approach
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
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

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

\( v = 10 \text{ mph} \)
\( v = 15 \text{ mph} \)
\( v = 7.5 \text{ mph} \)
Traffic speed

• Space mean speed

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

\[ \bar{t} = \frac{1}{n} \left( t_1 l_1 + t_2 l_2 + \ldots + t_n l_n \right) \]
• 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 = \( \frac{40(7.5) + 60(5)}{7.5 + 5} \) = 48 km/h
• If you have 5 vehicles over a given 1 kilometer 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, $q_{\text{max}}$
- Mean free flow speed, $u_f$
- Optimal speed, $u_o$
- Speed is the slope. $u = \frac{q}{k}$
- Uncongested flow
- Congested flow
- Optimal density, $k_o$
- Jam density, $k_j$
Fundamental diagram of traffic flow (SMS vs. density & SMS vs. flow)

- SMS vs. density
  - Density
  - SMS
  - $u_f$
  - $k_j$
  - Uncongested flow
  - Congested flow

- SMS vs. flow
  - Flow
  - $q_{max}$
  - SMS
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 > δ
- E.g., δ = 1

![Diagram of matched taxi trajectories, detected landmarks, and a landmark graph.]

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

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

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

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

\[
\text{WAE}(i; S^{xc}) = \frac{|S^{xc}_1(i)|}{|S^{xc}|} \text{Ent}(S^{xc}_1(i)) + \frac{|S^{xc}_2(i)|}{|S^{xc}|} \text{Ent}(S^{xc}_2(i))
\]

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

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

(a) Travel time distribution

(b) Cumulative frequency

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