Advanced Traffic Management System (cont.)

Advanced Traveler Information System (ATIS)
Main variables to visualize a traffic stream:

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**Density** is the number of vehicles per unit length of the roadway (vehicles per kilometer).
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\[
v_s = \frac{n}{\sum_{i=1}^{n} \left(1/v_i\right)} = \frac{nl}{\sum_{i=1}^{n} t_i} = \frac{l}{t}
\]
Exercise;

You are in a vehicle traveling a total of 10 kilometers.

- first 5 kilometers you travel at 40 km/h
- next 5 kilometers you travel at exactly 60 km/h

What is your average speed?
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Time per section:
5 kilometers / 40 km/h = 7.5 minutes
5 kilometers / 60 km/h = 5 minutes

weighted average = (40(7.5) + 60(5))/(7.5 + 5) = 48 km/h
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Suppose you have five vehicles over a given 1-kilometer section. It takes 1.0, 1.2, 1.5, 0.75, and 1.0 minutes respectively, to travel the section for the cars.

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Average travel time $\frac{5.45}{5} = 1.09$ minutes $= 0.0182$ hours.
Therefore, average speed over that distance $\frac{1 \text{ km}}{0.0182 \text{ hours}} = 55.05 \text{ km/h}$. 
Fundamental diagram of traffic flow (flow vs. density)

Free flow speed

Optimal speed

speed \( v = \frac{\delta q}{\delta k} \)
ATMS Example; Real-time merging traffic control
$N = \#\text{veh}$

$q_{cap}$: 1000 veh/h
\(N = \#\text{veh}\)

If \(N > N_{cr}\) then the capacity drop is observed.
Another scenario: Install traffic control here.
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Merging traffic: $M \rightarrow \mu$ lanes.

1. Merging of two highways.
2. Merging of on-ramps into mainstream.
3. Toll plaza infrastructure.
4. Freeway work zones.
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Merging traffic control helps to restore the capacity flow.
Control Devices in Merging Areas

- Traffic lights (with appropriate switching)
- Physical barriers (toll plaza)
- Variable speed limits
- Emerging vehicle-to-infrastructure technologies
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Control Algorithm:

- Feedback control for exit flow regulation:
  \[ q_k = q_{k-1} + K_R (\dot{o} - o_{k-1}), \quad k = 1, 2, \ldots \]
- Distribution of entering flow per lane
- Translation of control decision
Bay Bridge Toll Plaza (San Francisco)

20 lanes

5 lanes

Traffic Lights

Detectors

Merging Control

No Control

Toll Plaza
Bay Bridge Toll Plaza (San Francisco)

Variable speed limit (VSL) as a tool for traffic management

- Applied in Germany, US, UK, Netherlands, Finland,...
- Sometimes in peak hours set the speed limit to 20-30 km/h
- Impact on improving road traffic safety and congestion

Systematic studies about the effectiveness of VSL on traffic flow are limited.
Variable speed limit (VSL) as a tool for traffic management

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There are still open questions:
- Can we achieve higher capacity for highways with VSL?
- Can VSL increase the capacity of highways?
- Does VSL provide a more stable condition?

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Feedback Structure for VSL and ramp metering
Advanced Traveler Information System

Advanced Traveler Information Systems are considered the core service of intelligent transportation systems. Their central role is to support travelers in efficiently planning their journey to define their route, estimate travel time, and avoid traffic congestion.
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ATIS provides two types of information:

- **Static information**
  - Geographic data of stopped vehicles
  - Transport schedules
  - Etc

- **Dynamic information**
  - Schedules
  - Weather conditions
  - Closed roads
  - ETAs
  - Etc
ATIS operational roles:

1. Static and real-time traffic information
2. Weather information
3. Real-time information about public transport
4. Parking information
Case Study:
Microsoft Research Asia T-Drive Project

Smart driving direction system leveraging the intelligence of experienced drivers.
Taxi trajectories contain the information of both human knowledge of experienced drivers and traffic patterns by sensing traffic flows on road surfaces.

Check here for more!

Given a user query with a start point $q_s$, a destination $q_d$ and a departure time $t_d$, find the fastest route $R$ in a dynamic road network which is learned from a trajectory archive.
1. GPS-equipped taxis are used as mobile sensors probing the traffic rhythm of a city.
2. A cloud is built to aggregate and mine the information from these taxis, and other sources like web maps and weather forecasts. The mined knowledge includes the intelligence of taxi drivers in choosing driving directions and traffic patterns on road surfaces.
3. The knowledge in the cloud is used in turn to serve Internet users and ordinary drivers.
4. A mobile client, typically running in a user’s GPS phone, accepts a user’s query, communicates with the cloud, and presents the result to the user. The mobile client gradually learns a user’s driving behavior.
Challenges:

1. **Intelligence modeling.** Maybe no taxi trajectory for the selected OD by the user.
2. **Data sparseness and coverage.** Not many taxis in all road segments to estimate speed patterns.
3. **Low sampling-rate problem.** To save energy and communication loads, taxis usually report on their locations in a very low frequency, like 2-5 minutes per point. So, uncertainty increases.
Methodology

1. landmark graph building
2. Travel time estimation
3. Two-stage routing.
Methodology

1. **Landmark graph building**
   - Models the intelligence of taxi drivers based on the taxi trajectories and reduces the online computation of route-finding.
   - GPS trajectories → sequence of road segments.
   - Top traveled road segments are detected as landmarks.
   - Edges are formed based on trajectory archive and a frequency threshold.

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A) Matched taxi trajectories  B) Detected landmarks  C) A landmark graph

(a) $k=500$  
(b) $k=4000$
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3. Two-stage routing.

- The travel time of a landmark edge
  - varies in time of day
  - distributions of different edges, change differently over time.

- Clustering
  - V-clustering: the travel times of transitions of a landmark edge clustered into several categories based on the variance of these transitions' travel times.
  - VE-clustering: automatically learn a proper time partition for each landmark edge.
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1. Based on driver behavior (if exists), an optimist index $\alpha$ is determined. If $\alpha = 0.9$ means a person usually drives as fast as the top 10%.

2. Time-dependent fastest path between each pair of $m$ nearest landmarks to origin and destination is calculated.

3. Finds in the real road network a detailed fastest route that sequentially passes the landmarks of a rough route by dynamic programming.
Results

- 60-70% of the routes suggested by the method are faster than Bing and Google Maps.
- Over 50% of the routes are 20+% faster than Bing and Google.
- On average, it saves 5 minutes per 30 minutes driving trip.

Figure 21: An example of searching areas
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More efficient:
1) The landmark graph is a small subset of the original road network;
2) the rough route has specified the key directions, hence, reduces the searching area;
3) the detailed route between two consecutive landmarks can be computed in parallel.

Figure 21: An example of searching areas