ADVANCED TRAVELER INFORMATION SYSTEMS
(ATIS)

DEFINITION 3.1: ATIS
Advanced Traveler Information Systems are considered the core service of intelligent transportation systems and their main role is to support travellers in planning their journey efficiently in order to define their route, estimate travel time and avoid traffic congestions. Therefore, ATIS provides two types of information such as:

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

- Dynamic information
  - Schedules
  - Weather conditions
  - Closed roads
  - ETAs
  - Etc,
ADVANCED TRAVELER INFORMATION SYSTEMS (ATIS)

FUNCTIONS 3.1: ATIS operational roles:

- Static and real-time traffic information
- Weather information
- Real-time information about public transport
- Parking information
ADVANCED TRAVELER INFORMATION SYSTEMS
(TRAVEL TIME ESTIMATION AND PREDICTION)

Estimation

- Known traffic conditions
  - Past
  - Now

Prediction

- Instantaneous prediction
  - Travel time
- Short-term prediction
  - Travel time
- Long-term prediction
  - Travel time
  - 1 hour
  - Future time
ADVANCED TRAVELER INFORMATION SYSTEMS
(TRAVEL TIME ESTIMATION AND PREDICTION)

DEFINITION 3.2: Travel time
Travel time is a specified period of time spent in traveling from a specific origin to a destination.

DEFINITION 3.3: Travel time estimation as offline application
In broadest sense it is about evaluating the time needed to travel from any origin $O$ to any destination $D$ using historical data.

DEFINITION 3.4: Travel time prediction
Travel time prediction is about forecasting the travel time from unknown traffic conditions.
ADVANCED TRAVELER INFORMATION SYSTEMS
(TRAVEL TIME PATTERN PER DAY)
Let’s consider one road line of traffic with one intersection and one exit.
Platooning or flocking is a method for driving a group of vehicles together.
DEFINITION 3.6: Time headway

Time headway is the time difference between two successive vehicles at a cross given point.

DEFINITION 3.7: Space headway

Space headway is the distance separating two successive vehicles at a cross given point.
DEFINITION 3.8: Traffic flow
Traffic flow is the equivalent hourly rate at which vehicles pass a point during a time period less than 1 hour.

DEFINITION 3.9: Traffic density
Traffic density is the number of vehicles $n$ occupying a given length $L$ of a lane or roadway at a particular instant.

DEFINITION 3.10: Traffic speed
Traffic speed is the distance travelled by a vehicle during a unit of time.
ADVANCED TRAVELER INFORMATION SYSTEMS
(DESCRIBING TRAFFIC)

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
Time Headway $\bar{h}$

\[
q = \frac{n}{\sum_{i=1}^{n} h_i} = \frac{1}{\bar{h}}
\]
ADVANCED TRAVELER INFORMATION SYSTEMS
(DESCRIBING TRAFFIC)

Measuring Traffic speed:

**DEFINITION 3.11:** Space mean speed (SMS)

Space mean speed is the distance traveled divided by an average travel time. It is an harmonic speed and it average speed of all the vehicles in a specific road segment.

**DEFINITION 3.12:** Time mean speed (TMS)

Time mean speed is an average of individual vehicle speed and it is measured at a specific point.
ADVANCED TRAVELER INFORMATION SYSTEMS
(DESCRIBING TRAFFIC)

Time Mean Speed:

\[ \bar{u}_i = \frac{1}{n} \sum_{i=1}^{n} v_i \]
ADVANCED TRAVELER INFORMATION SYSTEMS
(DESCRIBING TRAFFIC)

Space Mean Speed:

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

\[ \bar{t} = \frac{1}{n} \left( t_1 l_1 + t_2 l_2 + \ldots + t_n l_n \right) \]
EXERCISE 3.1: TMS

- You are in a vehicle traveling a total of 10 kilometres.
  - first 5 kilometre you travel at 40 km/h
  - next 5 kilometre 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 \text{ km/h}
EXERCISE 3.2: SMS

- If you have 5 vehicles over a given 1 kilometre section take 1.0, 1.2, 1.5, 0.75 and 1.0 minutes respectively.

- What is your space mean 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

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

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

• Unit of density is vehicles per kilometre (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
ADVANCED TRAVELER INFORMATION SYSTEMS
(DESCRIBING TRAFFIC)

Fundamental diagram of traffic flow (SMS vs. density & SMS vs. flow)
EXAMPLES AND CASE STUDIES
ADVANCED TRAVELER INFORMATION SYSTEMS (ATIS)

EXAMPLE 3.1: Traveler information system

ATIS systems based on service-oriented architecture for Public Road Transport(*)

[| CORPORATE SERVICES MODULE (CSM) | USER SERVICES MODULE (USM) |
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<tbody>
<tr>
<td>Location system</td>
<td>SOA</td>
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<td>Payment system</td>
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<td>Control system</td>
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[| TRANSPORT INFRASTRUCTURE MODULE (TIM) |
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<td>CAMERAS</td>
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<td>ONBOARD COMPUTER</td>
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<td>COMMUNICATION</td>
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SUMMARY 3.1:

Services operations:

- Service initialisation and resource execution (start-up)
- Service advertisement and their availability
- Service execution
EXAMPLE 3.2:

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
ADVANCED TRAVELER INFORMATION SYSTEMS

OBJECTIVES AND CHALLENGES:

Objective:
  • Provide the fastest path to a destination at given departure time.

Challenges:
  • Intelligent Modelling
  • Data sparseness
  • Low-sampling rate of trajectories

Traffic patterns

System Intelligence

Data sparseness

Low-sampling-rate
ADVANCED TRAVELER INFORMATION SYSTEMS

METHODOLOGY

Pre-processing

Travel time estimation

Routing

Building landmark

Time-dependent landmark

A Time-dependent Landmark Graph

Rough Routing

Taxi Trajectories

Refined Routing

A Road Network

Refined Routing
ADVANCED TRAVELER INFORMATION SYSTEMS

Major steps in the approach adopted:

STEP 1: PREPROCESSING

STEP 2: BUILDING LANDMARK GRAPHS

STEP 3: TRAVEL TIME ESTIMATION

STEP 4: TWO-STAGE ROUTING

RESULTS

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

- Map-matching
  - Map a GPS point to a road segment
ADVANCED TRAVELER INFORMATION SYSTEMS

Major steps in the approach adopted:

**STEP 1: PREPROCESSING**

**STEP 2: BUILDING LANDMARK GRAPHS**

**STEP 3: TRAVEL TIME ESTIMATION**

**STEP 4: TWO-STAGE ROUTING**

**RESULTS**

- **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 showing A) Matched taxi trajectories, B) Detected landmarks, and C) A landmark graph.](image-url)
Major steps in the approach adopted:

**STEP 1: PREPROCESSING**

- 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

**STEP 2: BUILDING LANDMARK GRAPHS**

**STEP 3: TRAVEL TIME ESTIMATION**

**STEP 4: TWO-STAGE ROUTING**

**RESULTS**
Major steps in the approach adopted:

STEP 1: PREPROCESSING

STEP 2: BUILDING LANDMARK GRAPHS

STEP 3: TRAVEL TIME ESTIMATION

STEP 4: TWO-STAGE ROUTING

RESULTS

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

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

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

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

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

\[
\Delta E(i) = \text{Ent}(S^\text{cl}) - \text{WAE}(i; S^\text{cl})
\]

\[
\text{Ent}(S^\text{cl}) = \sum_{r=1}^P p_r \log(p_r)
\]
Major steps in the approach adopted:

**STEP 1: PREPROCESSING**

**STEP 2: BUILDING LANDMARK GRAPHS**

**STEP 3: TRAVEL TIME ESTIMATION**

**STEP 4: TWO-STAGE ROUTING**

**RESULTS**

- **Rough routing**
  - Search a landmark graph for a rough route
  - Based on a user query
  - Applying time dependent algorithm
Major steps in the approach adopted:

**STEP 1: PREPROCESSING**

**STEP 2: BUILDING LANDMARK GRAPHS**

**STEP 3: TRAVEL TIME ESTIMATION**

**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**
ADVANCED TRAVELER INFORMATION SYSTEMS

Major steps in the approach adopted:

STEP 1: PREPROCESSING

STEP 2: BUILDING LANDMARK GRAPHS

STEP 3: TRAVEL TIME ESTIMATION

STEP 4: TWO-STAGE ROUTING

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
THANK YOU FOR YOUR ATTENTION

— Intelligent Transportation Systems - MTAT.08.040 - Lecture 3