LECTURE 4:
TRAFFIC MONITORING SYSTEMS

(TECHNOLOGY AND SENSORS)

INTELLIGENT TRANSPORTATION SYSTEMS:

Amnir Hadachi, PhD.
hadachi@ut.ee

Fall 2020
TRAFFIC MONITORING SYSTEMS
(Technology)

- Inductive loops
- Cameras
- Lidar and lasers
- Radar
- GPS
- Mobile network data
DEFINITION 4.1: Inductive Loops

Inductive loops are electromagnetic detection system that are based on alternating current to induce and electric current. It used as vehicle detection systems for counting vehicle around intersection or approaching traffic lights.
TRAFFIC MONITORING SYSTEMS

(INDUCTIVE LOOP)
The inductance signal decreases when a car pass through the loop.

$$T = t_{on}$$

$$T = t_{off}$$
TRAFFIC MONITORING SYSTEMS
(INDUCTIVE LOOP)

FUNCTIONALITY 4.1:
Loops can measure:

• Occupancy
  - Percentage of time loop is occupied per interval
• Volume
  - Vehicle per interval
How can we get speed from loops:

\[ s = \frac{EVL}{t_o} \]

- \( s \) = speed (m/sec)
- \( EVL \) = effective vehicle length (m)
- \( t_o \) = occupancy time (s)

\( EVL \sim \) (vehicle length + detector length)
### Estimating Speed:

The speed estimation formula is given by:

\[ s = \frac{N}{T \times O \times g} \times 3600 \text{ sec/hr} \]

- **s** = speed (km/hr)
- **N** = number of vehicles in the observation interval
- **T** = observation interval (s)
- **O** = percentage of time the loop is occupied by vehicles during the observation interval (occupancy)
- **g** = speed estimation parameter

To convert percentage to decimal, use:

\[ g = \frac{1000 \text{ m/km}}{EVL \times 100} \]

100 converts percent to decimal.
TRAFFIC MONITORING SYSTEMS
(CAMERAS)

Source: Panasonic
TRAFFIC MONITORING SYSTEMS
(CAMERAS)

FUNCTIONALITY 4.2:
• Detecting and tracking moving objects
• Movement interpretation

WHY
- Minimise the user interaction, the cost and the time.
- Reduce traffic jams, accidents, monitor the safety of our roads.
TRAFFIC MONITORING SYSTEMS
(CAMERAS)

OBJECTIVES:

- Having the capability of:
  - Adapt to dynamics of the real world
  - Operate independently of human operators
  - Easy to set up
  - Performance in real time
  - Making decision (AI)
TRAFFIC MONITORING SYSTEMS
(CAMERAS)

LIST 4.1: Some of the basic techniques

• Model based detection
• Region based detection
• Active contour based detection
• Feature based detection
• Background subtraction
• Temporal differencing
• Optical flow
EXAMPLES 4.1: Model based detection

Recovering trajectories and models for small number of vehicle

Weakness:
Not reliable with geometric details
Not realistic (hard to have all the designs of all the vehicles)
EXAMPLES 4.2: Region based detection

Detect each vehicle blob using cross correlation function
Vehicle detection is based on background substation

Weakness:
Traffic jams and occlusion can be an easy obstacle for the detection.

Potential segmentation problem
EXAMPLES 4.3: Active contour (aka snake)

Detection is based on active contour approach
Computational complexity is less compared to region based method
Objects are represented in bounding contour

Weakness:
The detection is reliable in occlusion cases.
TRAFFIC MONITORING SYSTEMS
(CAMERAS)

EXAMPLES 4.4: Feature based detection

Focus on detecting sub-feature present on the vehicle

The performance relies on the motion
EXAMPLES 4.5: Background subtraction

Frames comparison to the reference frame

Weekness:
Sensitive to background changes
Suitable for static environment
EXAMPLES 4.6: Temporal differencing

Intensity check in chronological frames

Weekness:
Difficult to extract all relevant features
Number frame affect the performance
TRAFFIC MONITORING SYSTEMS
(CAMERAS)

EXAMPLES 4.6: Optical flow

Flow vectors of moving object

Weekness:
Too slow for real time application
TRAFFIC MONITORING SYSTEMS
(RADAR)

FUNCTIONALITY 4.3:

- Detecting the speed of vehicles on the road.
- Detecting moving object.
TRAFFIC MONITORING SYSTEMS

(RADAR)

EXAMPLES 4.6:

Radar

Characteristics:
- Horizontal range
- Bearing angles (vertical)
- Brightness indicate strength of the return

Source: TI’s mmWave sensors
TRAFFIC MONITORING SYSTEMS
(LIDAR)

FUNCTIONALITY 4.4:

• Measuring distance based on illuminating the target with laser light.
• Applications:
  - Mapping
  - Localisation
  - Simultaneous localisation and mapping
TRAFFIC MONITORING SYSTEMS
(LIDAR)

Mapping

Source: Ouster - highway drive
TRAFFIC MONITORING SYSTEMS
(LIDAR)

SLAM : Simultaneous localisation and Mapping
FUNCTIONALITY 4.4:

- GPS satellites are at high orbits
- Total 31 satellites
- Several ones are related every year.
TRAFFIC MONITORING SYSTEMS
(GPS)

FUNCTIONALITY 4.4:

- GPS satellites are at high orbits
- Total 31 satellites operational
- Several ones are related every year.
TRAFFIC MONITORING SYSTEMS

(Satellite)

Original GPS data

Clarified GPS data
TRAFFIC MONITORING SYSTEMS
(MOBILE DATA)

DATA:
- Mobile Network Data
- Mobile Phone Data

Flow pattern analyzed against GPS drive data and adjustments made to pattern model.

Overlaid on Navigation quality GIS.

Iterative process creates sample observer to observe flow patterns.
TRAFFIC MONITORING SYSTEMS
(MOBILE NETWORK DATA)

Handover event

GPS data

Location area derived from location module
TRAFFIC MONITORING SYSTEMS
(MOBILE NETWORK DATA)
TRAFFIC MONITORING SYSTEMS
(MOBILE PHONE DATA)

GPS VS Mobile phone data
Comparison between GPS data and Mobile Phone Data
TRAFFIC MONITORING SYSTEMS
(MOBILE NETWORK DATA)

Case Study: Detecting movement episode in mobile network data

Detect if the location was a:
- Move
- Stay
- Jump
Traffic Monitoring Systems
(Mobile Network Data)

Idea: Switching Kalman filter

\[
\begin{align*}
z_{t+1} &= Fz_t + r_t \\
y_{t+1} &= Hz_{t+1} + r_t
\end{align*}
\]

Hidden variables: $z_{t+1}$
Observation variables: $y_{t+1}$
Transition matrix between different states: $F$
Observation matrix: $H$
Noise: $r_t$
Switching Kalman Filter:

$$x_{t+1} = x_t + v_t \Delta \tau + q_t$$

$$v_{t+1} = v_t + q_t$$

Location $$x_t$$ and velocity $$v_t$$ as hidden variables

$$z_t = \begin{pmatrix} x_t \\ v_t \end{pmatrix}$$

Every different models (Move Stay and Jump) are defined through the transition matrix F.
TRAFFIC MONITORING SYSTEMS
(MOBILE NETWORK DATA)
THANK YOU FOR YOUR ATTENTION

— Intelligent Transportation Systems - MTAT.08.040 - Lecture 4