INTELLIGENT TRANSPORTATION SYSTEMS

Lecture 3  (22 Sep 2021)
Advanced Traffic Management System (ATMS)

Mozhgan Pourmoradnasseri, PhD
Economic Growth and High Rate of Urbanization in Recent Century

Congestion and its consequences; pressing issue of modern societies.

Problems such as economic impacts, greenhouse emissions, accidents, time spent, and health damages.
Solutions?

- More roads to accommodate more cars
- Use the full capacity of the current network to improve efficiency, decrease travel time and optimize routes.

Causes of urban traffic

- Bottlenecks are responsible for 40% of the overall traffic congestion
- traffic incidents with 25%,
- bad weather conditions with 15%,
- work zones with 10%, and
- poor traffic signal timing and special events with 5%.

ATMS aims to minimize traffic congestion and its negative effects.
Advanced Traffic Management Systems (ATMS) are composed of a set of applications and management tools to integrate communication, sensing, and processing technologies.

ATMS

- **Collect** traffic-related data from heterogeneous sources.
- **Aggregate** and **exploit** data in a cooperative manner in the Traffic Management Center (TMC), concentrated in a cloud or in a data center.
- **Extract** intelligent measures for **identifying** traffic hazards.
- **Controlling** traffic flow and consequently, increasing mobility efficiency, maintaining and improving **safety**.
ATMS Requirements

Traffic Information
- Sensors
- Communication
- Data Processing

Control Mechanisms
- Traffic Messages
- Traffic Lights
- Ramp Meters

Traffic Management Center
- Advanced Algorithms & Analytics
  - Traffic Assignment
  - Traffic Prediction
  - Decision Support
Traffic information is a unit for handling data collection and transmission from different data sources to understand traffic situations, manage the traffic, or avoid incidents based on data observation.
Methods to obtain traffic information

- Automatic
  - Point Detectors
  - Interval Detectors
- Manual
  - Survey
  - Manual Counting
Methods to obtain traffic information

Traffic Information

Automatic
- Point Detectors
- Interval Detectors

Manual
- Survey
- Manual Counting
- Tally sheets,
- Mechanical counting,
- Electronic counting boards
Methods to obtain traffic information

Traffic Information

Automatic
- Point Detectors
- Interval Detectors

Manual
- Survey
- Manual Counting

- Household surveys
- Roadside interviews
- Origin-Destination surveys

- Not feasible on a large scale
- Costly
Methods to obtain traffic information

- **Automatic**
  - Point Detectors
  - Interval Detectors

- **Manual**
  - Survey
  - Manual Counting

Point Detectors are located at fixed points of the street and record traffic information at these specific points.

- Costly, need periodic maintenance
- Replaced by video cameras
Methods to obtain traffic information

- Automatic
  - Point Detectors
  - Interval Detectors
    - Inductive loops
    - Floating cars or probe vehicles
      - GPS-based
      - Cellular-based
    - Automated vehicle identification

- Manual
  - Survey
  - Manual Counting
Traffic Monitoring Technologies: Inductive Loops

Inductive loops are electromagnetic detection systems that are based on alternating current to induce a magnetic field. It is used as a vehicle detection system for counting vehicles around intersections or approaching traffic lights.

The sensing of vehicles is performed by computing the change caused by the vehicle disturbing the loop magnetic field.
Traffic Monitoring Technologies: Inductive Loops

Functionalities:
- Counting and classifying vehicles.
- Velocity measurements.

Magnetic profiles of the selected vehicle classes:
1 – passenger vehicles, 2 – delivery vehicles,
3 – buses, 4 – heavy goods vehicles.

Traffic Monitoring Technologies: Cameras

Functionalities:
- Detecting and tracking moving objects
- Movement interpretation

Capable of:
- Adapt to dynamics of the real world
- Operate independently of human operators
- Easy to set up
- Performance in real-time
- Making decisions (AI)
Traffic Monitoring Technologies: Cameras

Some of the basic techniques:

- Model-based detection
- Region-based detection
- Active contour-based detection
- Feature-based detection
- Background subtraction
- Temporal differencing
- Optical flow
Traffic Monitoring Technologies: Cameras

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Recovering trajectories and models for a small number of vehicles

Weakness:

- Not reliable with geometric details
- Not realistic (hard to have all the designs of all the vehicles)

Traffic Monitoring Technologies: Cameras

Some of the basic techniques:

- Model-based detection
- **Region-based detection**
- Active contour-based detection
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Detect each vehicle blob using the cross-correlation function. Vehicle detection is based on a background substation.

Weakness:

- Traffic jams and occlusion can be easy obstacles for detection.
Traffic Monitoring Technologies: Cameras

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- Model-based detection
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Objects are represented in bounding contours and keeping updated dynamically. Computational complexity is less compared to region-based method.

Weakness:

- The detection is unreliable in occlusion cases.
Traffic Monitoring Technologies: Cameras

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Focus on detecting sub-features present on the vehicles.
The performance relies on the motion and addition of common motion constraints.
Traffic Monitoring Technologies: Cameras

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Frames are compared to a reference background frame, pixel by pixel.

Weakness:

- Sensitive to background changes
- Suitable for a static environment.
Traffic Monitoring Technologies: Cameras

Some of the basic techniques:
- Model-based detection
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- Optical flow

Identifies the intensity changes of moving objects, by checking consecutive frames.

Weakness:
- Difficult to extract all relevant features
- Number frame affect the performance
Traffic Monitoring Technologies: Cameras

Some of the basic techniques:

- Model-based detection
- Region-based detection
- Active contour-based detection
- Feature based detection
- Background subtraction
- Temporal differencing
- **Optical flow**

Identifies the characteristics of the flow vector of the moving objects over time.

Weakness:

- Too slow for real-time application

Reference: [https://nanonets.com/blog/optical-flow/](https://nanonets.com/blog/optical-flow/)
Traffic Monitoring Technologies: RADAR

Functionalities:

- Detecting the speed of vehicles on the road.
- Detecting moving objects.

Check [this video](#), for the ADAS application.
In mid-1990s, researchers began to explore the possibility of obtaining trip data from GPS data. Combined with a web-based diary system or a Geographic Information System (GIS), gives additional and confirmation information of transportation modes and trip purposes.

Average speed on the track is symbolized with a rainbow color scale.

Traffic Monitoring Technologies: Cellular DATA

- Increasingly informative database, collected by the mobile operators for billing purposes.
- Each time a mobile terminal is used for a call or for sending an SMS, the operator records the call features, including the timestamp, the base station's identifier to which the user is connected, and quantitative data (call duration, volume of data exchanged).
Traffic assignment

The traffic assignment problem is about determining the traffic flows per road segment or link to a given road network.

The major aims of traffic assignment procedures are:
1. Estimating the traffic volume of network links
2. Estimating the cost of the trip between the zones
3. Determining the trip pattern and identifying congested links

These models determine the flow on each link and capture the interaction between demand and supply.
Traffic Assignment; Techniques

- **Network loading model**
  - The network loading model or traffic flow component explains how the traffic is distributed within our road network. The performance is usually measured using travel time.

- **Trip matrix (Origin-Destination Matrix)**
  - OD-matrix is about any movement for performing a task that started from a specific origin to a particular destination.
    - Static OD-matrix
    - Dynamic OD-matrix

- **Travel choice principle**
  - The travel choice principle points out how the travelers choose their routes, departure time, mode of transportation, and destination.
Active traffic management (ATM) is the ability to dynamically manage recurrent and non-recurrent congestion based on prevailing and predicted traffic conditions.

- **Dynamic speed limits**: the dynamic change in speed limits based on road, traffic, and weather conditions.
- **Adaptive ramp metering**: the dynamic adjustment of traffic signals at ramp entrances to proactively manage vehicle flow from local-access roads.
- **Adaptive traffic signal control**: the optimization of signal timing plans based on prevailing conditions to increase throughput along an arterial.

Reference: https://ops.fhwa.dot.gov/atdm/approaches/atm.htm
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- Heterogeneous data integration;
  - tracking, managing, and identifying the high number of devices that will be involved in such integration.
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- Traffic condition representation and hazards identification;
  - how to converge different information into a single traffic condition representation? How to identify hazards in real-time? Which information have more impact on the traffic?
ATMS Future Challenges?

- Heterogeneous data integration;
  - tracking, managing, and identifying the high number of devices that will be involved in such integration.

- Data management and big data issues;
  - provide sophisticated mechanisms to fuse, aggregate, and exploit data to deal with different data types provided from heterogeneous sources.

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- Alternative route guidance;
  - how to provide a full scenario overview about the traffic condition to every vehicle to enable them to compute an efficient route without overloading the network.
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- Security and privacy;
  - in addition to inherent security problems in cloud computing, personal data and tracking people and vehicles.