Background -
Mobility Models and Simulation

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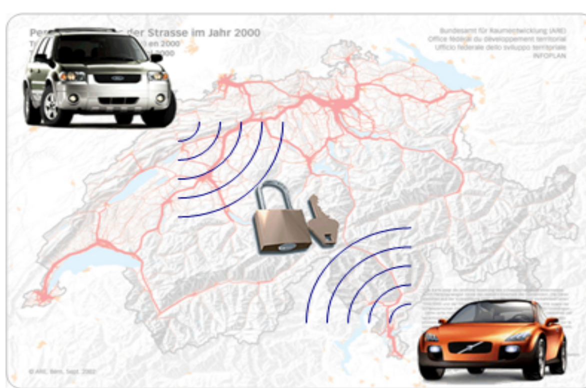
CS 795/895
Vehicular Networks

Background
Outline

- Traffic Monitoring
- Mobility Models
- Simulation



From EPFL research group

Vehicular Mobility

Unique Characteristics

- Acceleration and deceleration in the presence of other traffic
- Queuing at intersections
- Bursts caused by traffic lights
- Traffic congestion

Reference for Mobility Slides: Harri, Filali, Bonnet, “Mobility Models for Vehicular Ad Hoc Networks: A Survey and Taxonomy”, 2007.

Mobility Models

Macroscopic vs. Microscopic

- Macroscopic
  - models roads, traffic lights
  - defines traffic density, traffic flow, and initial vehicle distributions
- Microscopic
  - models the movement of each individual vehicle with respect to other vehicles

Mobility Models

Motion Constraints vs. Traffic Generator

- Motion Constraints
  - describes how each vehicle moves
  - macroscopic: roads, buildings
  - microscopic: neighboring vehicles
- Traffic Generator
  - generates different kinds of cars and deals with their interactions
  - macroscopic: models densities or flows
  - microscopic: inter-distances between cars, acceleration, braking

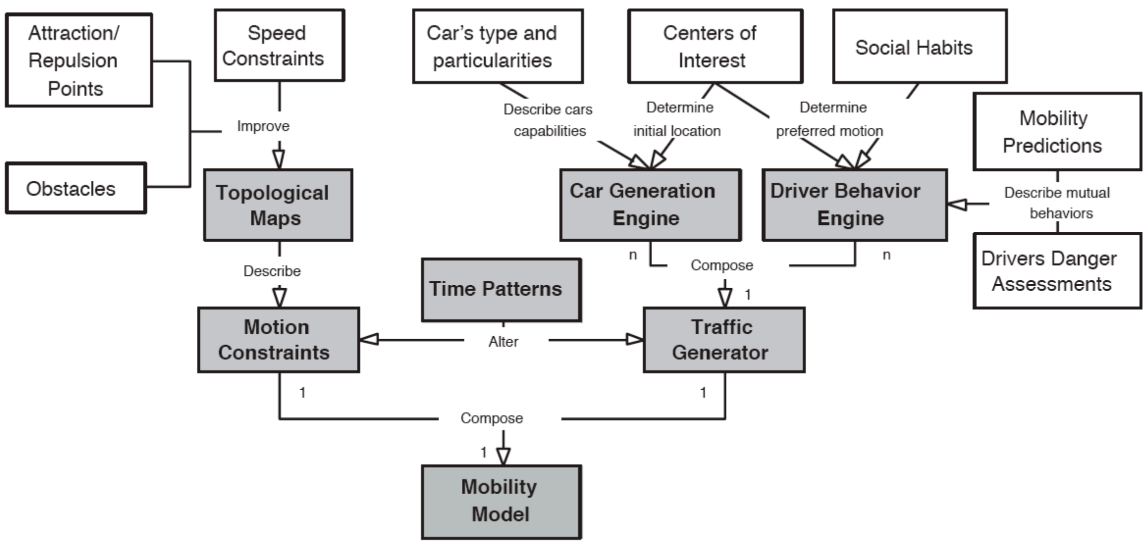
Mobility Models

Components

- Accurate and realistic topological maps
- Smooth deceleration and acceleration
- Obstacles
- Attraction points
- Simulation time
- Non-random distribution of vehicles
- Intelligent driving patterns

Mobility Models

Concept Map



Harri, Filali, Bonnet, "Mobility Models for Vehicular Ad Hoc Networks: A Survey and Taxonomy", 2007.

Classes of Mobility Models

- Synthetic models
  - based on mathematical models
- Survey-based models
  - extracted from surveys (commute times, driving speeds, etc)
- Trace-based models
  - generated from real mobility traces
- Simulator-based models
  - extracted from detailed traffic simulator

Synthetic Models

- Stochastic models
  - purely random motion
- Traffic stream models
  - flow-based
- Car following models
  - movement depends on car ahead
- Queue models
  - roads are FIFO queues, cars are clients
- Behavioral models
  - movement depends on behavioral rules

Survey-based Models

- US Dept of Labor has statistics on US workers' behavior
  - commuting time
  - lunch time
  - travel distance

- Example: UDel Mobility Model
  - simulates arrival times at work, lunch times, breaks/errands

Trace-based Models

- Extrapolate generic movement models from traces
  - hard to find patterns not explicitly found in traces
- Several approaches to measuring general mobile networks (CRAWDAD project)
  - mainly human movement
- Traces are often very specific to what was being measured

Simulator-based Models

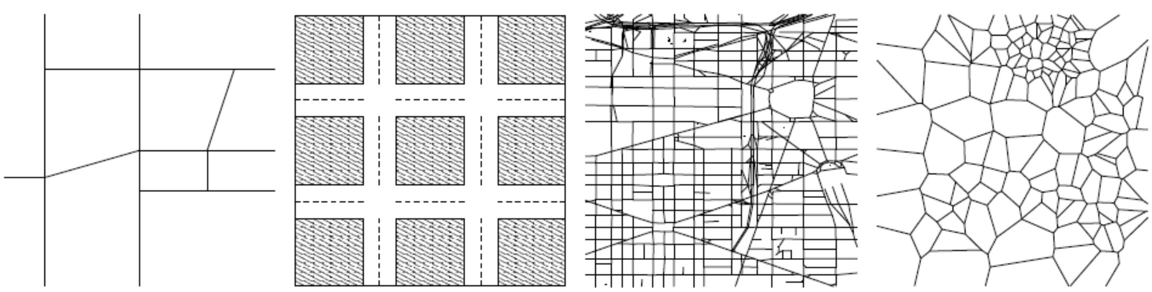
- Simulators developed for traffic engineering
  - PARAMICS, CORSIM, VISSIM, TRANSIMS
- Simulators are complex, many parameters, high level of detail, commercial (expensive)

Components

Macro-mobility

- Topology
  - user-defined, random, maps, multi-lane
- Initial and Destination Position
  - random, random-restricted, attraction/ repulsion points
- Trip Generation
  - random between two points, activity sequence
- Path Computation
  - algorithm to generate the path
- Velocity
  - uniform, smooth, road-dependent

Road Topologies



(a) User-defined topology

(b) Manhattan-grid map topology

(c) TIGER map topology

(d) Clustered Voronoi

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Components

Micro-mobility

- Mobility pattern
  - car following models
- Lane changing
  - need for lane changing
  - possibility of lane changing
  - trajectory of lane changing
- Intersections

Car Following Models

- GHR models
- Psychophysical models
- Collision Avoidance (CA) models

Car Following Models
GHR Models

- General Motors (GM) model is an example
- Based on the idea that a driver's acceleration is proportional to the deviation from a set following distance
- Parameters are difficult to set and validate, so not used much anymore

Car Following Models
Psychophysical Models

- Based on the idea that drivers can initially determine that they are approaching a vehicle based on the perceived change in size of the vehicle

Car Following Models

Collision Avoidance (CA) Models

- Also called safety distance models
- Examples are Gipps and Intelligent Driver Model (IDM)
- Basic idea is that there is a safe following distance and cars will not come closer than this distance
  - decision to accelerate or brake depends on the distance from the car immediately ahead
- Models are widely used in simulation

IDM Parameters

- Desired velocity when driving on a free road, v_0
- Desired safety time headway when following other vehicles, T
- Acceleration in everyday traffic, a
- Comfortable braking deceleration in everyday traffic, b
- Minimum bumper-to-bumper distance, s_0
- Acceleration exponent, δ

IDM

Standard Parameters

Parameter	Car Value	Truck Value	Remarks
desired velocity, v_0	120 km/h	80 km/h	adapt velocity for city traffic, leave others alone
time headway, T	1.5 s	1.7 s	realistic values vary between 0.8 - 2 s
min gap, s_0	2.0 m	2.0 m	traffic stopped, also at red traffic lights
accel, a	0.3 m/s^2	0.3 m/s^2	realistic values are 1-2 m/s^2, low values enhance formation of stop-and-go traffic
decel, b	3.0 m/s^2	2.0 m/s^2	realistic values are 1-2 m/s^2, high values enhance formation of stop-and-go traffic

Intersection Mgmt

IDM-IM

- Developed by Fiore *et al.* (2007) [FHF +07]
- Models both intersections with stop signs and those with traffic lights
- Only acts on the first vehicle (car following)

IDM-IM

- Stop Sign
  - Decelerates based on distance to intersection and gap between center of intersection and stopping point
  - No other cars, vehicle proceeds
  - Wait for turn based on first-arrived, first-passed and right-hand rule
- Traffic Light
  - Informed about state of light
  - If green, vehicle maintains its current speed
  - If red, car decelerates (similar to stop sign)
  - Takes care of red-to-green and green-to red changes

Lane Changing

IDM-LC

- Developed by Fiore *et al.* (2007) [FHF+07]
- Extends IDM-IM
- Possibility of vehicle to change lane and overtake another vehicle
- Uses MOBIL overtaking model
  - allows vehicle to change lanes if change minimizes the overall braking of vehicles
  - includes a politeness factor

Background
Outline

- Traffic Monitoring
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From EPFL research group

Simulation

- Because it's expensive and hard to equip lots of real cars and run tests, we mainly use simulation
- Components for VANET sim
  - vehicular traffic (mobility models, maps, etc)
  - networking

VANET Simulation
Approaches

- Separate
  - use vehicular traffic generator to generate movement traces
  - feed traces to network simulator (ns-2, QualNet, etc)
  - advantages: little development needed, good tools available
  - disadvantages: no feedback between tools
- Combined, or Federated
  - one tool combines mobility model and network simulator
  - advantages: investigate how network communication affects traffic movement
  - disadvantages: not many good tools available (yet)

Generating Mobility Traces

- Realistic traffic simulators
  - PARAMICS, CORSIM, VISSIM, TRANSIMS
  - macroscopic and microscopic
  - commercial
  - designed for traffic analysis rather than generation of movement traces

Generating Mobility Traces

- IMPORTANT
  - random mobility models (Manhattan model)
  - car-following model
  - http://nile.usc.edu/important/
- MONARCH
  - extract road topologies from TIGER/Line database
  - no micro-mobility support
  - simple random waypoint model
  - http://www.monarch.cs.rice.edu/

Generating Mobility Traces

- SUMO
  - car following model
  - parsers for TIGER/Line, Arcview, VISSIM
  - doesn't output traces
  - http://sumo.sourceforge.net/
- MOVE
  - parser for SUMO
  - generates traces for ns-2 or QualNet
  - http://www.csie.ncku.edu.tw/~klan/move/

Generating Mobility Traces

- Smart AHS
  - generates trajectories of vehicles driving according to validated models on realistic road networks
  - lacks complete topology modeling
  - http://path.berkeley.edu/smart-ahs/
- CARISMA
  - proprietary tool developed by BMW
  - Krauss' car following model
  - stop sign intersection management
  - imports real maps from ESRI (not publicly available)
  - has been interlinked with ns-2
  - no lane changing or complex intersection management

Generating Mobility Traces

- STRAW
  - written for JiST/SWANS (network simulator)
  - uses urban topologies from TIGER/Line
  - intersection management with traffic lights and stop signs
  - contains mobility constraints as well as a traffic generator engine
  - includes implementations of several networking protocols
  - http://www.aqualab.cs.northwestern.edu/projects/STRAW/

Generating Mobility Traces

- CanuMobiSim
  - can use real topologies from Geographical Data Files (GDF)
  - many mobility models implemented
  - generate traces for ns-2 and GloMoSim
  - implements Fluid Traffic Model (adjusts speed given vehicles' local density) or IDM
  - complex traffic generator implements basic source-destination paths or using attraction points
  - extended version includes radio propagation information
  - http://canu.informatik.uni-stuttgart.de/mobisim/

Generating Mobility Traces

- VanetMobiSim
  - motions patterns for urban and highway environments have been validated
  - compared traces obtained with that from CORSIM
  - spatial distributions, speed distributions, traffic shock waves generated were similar
  - models car-to-car and car-to-infrastructure interactions
  - can use GDF or TIGER/Line topologies
  - random source-destination or activity-based trips
  - Dijkstra shortest-path, road-speed shortest path, or density-based shortest path
  - generates traces for various network simulators
  - http://vanet.eurecom.fr/

Mobility Models and Network Simulators

- Once mobility trace generated, it's fed to the network simulator
- What if network messages result in different driving decisions?
  - detour message?
- There's no way to model the new mobility

Mobility Models and Network Simulators

- There are some that integrate mobility and networking
- Example: MoVes
  - generates mobility traces
  - contains a basic network simulator
    - lacks routing protocols
- Major limitation of embedded approach is poor quality of network simulation

Mobility Models and Network Simulators

- Federated Simulations Development Kit (FDK)
  - federated CORSIM with QualNet
  - direct interaction between the two
  - but, CORSIM is complex
  - http://www.cc.gatech.edu/computing/pads/fdk.html

Mobility Models and Network Simulators

- UC Davis
  - federated SWANS and a synthetic traffic model
  - based on Nagel and Schreckenberg model
  - includes lane changing
  - http://wwwcsif.cs.ucdavis.edu/~VGrid/
- AutoMesh
  - random macro-movement
  - IDM
  - can't reproduce non-uniform distribution of positions and speed usually experienced in urban area
  - radio propagation model is very detailed, using 3D maps

Mobility Models and Network Simulators

- TraNS
  - federating SUMO and ns-2
  - TraNS will be extended to work with SWANS
  - http://trans.epfl.ch/

- MSIE
  - similar to TraNS, but using VISSIM instead of SUMO
  - VISSIM is commercial