Vehicular mobility in a large scale urban environment

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Outline

- Motivation
- Tools
- Trace generation
- Resulting trace
- Connectivity analysis
- Conclusions and future work
Motivation

- Networking solutions for vehicular environments require **car mobility information**
  - **Cellular networks**
    - Infrastructure planning
    - Resource allocation
    - Hand-off management
    - Green networking
  - **Autonomous networks** (e.g., DSRC-based)
    - Roadside infrastructure planning (V2I communication)
    - Protocol design and performance evaluation (V2I + V2V)
Motivation

- Trivial solution: collect and use real-world traffic data
- Possible sources
  - **Transportation** departments (vehicular mobility only)
    - Time: 3:30pm
      - Road ID: 29834AC
      - Coords: (x,y) (x,y)
      - In-flow: 26 veh/min
      - Out-flow: 10 veh/min
  - **Telecom service** providers (vehicular + pedestrian mobility)
    - Time: 5:50pm
      - User ID: 063149***
      - Cell ID: ladoua_01
      - Previous cell ID: villeurbanne_06
      - Network: 3G

- However, real-world mobility traces are **not publicly available**
- Public security, privacy, industrial competition, expensive access
Resort to **synthetic traces** of vehicular mobility

State-of-art mobility traces freely available

- **Canton of Zurich** (CS Dept., ETH Zurich, Switzerland)
- **Downtown Zurich** (Telecom Dept., ETH Zurich, Switzerland)
- **Downtown Turin** (CS Dept., Politecnico di Torino, Italy)
Motivation

However existing traces have major limitations

<table>
<thead>
<tr>
<th>Datasets</th>
<th>Canton of Zurich</th>
<th>Downtown Zurich</th>
<th>Downtown Turin</th>
<th>Koln</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Area</strong></td>
<td>10000 km²</td>
<td>12 km²</td>
<td>20 km²</td>
<td>400km²</td>
</tr>
<tr>
<td><strong>Road topology</strong></td>
<td>Highways + major roads</td>
<td>Major + minor roads</td>
<td>Major + minor roads</td>
<td>Highways + major + minor roads</td>
</tr>
<tr>
<td><strong>Trace length</strong></td>
<td>24 hours</td>
<td>20 minutes</td>
<td>1 hour</td>
<td>24 hours</td>
</tr>
<tr>
<td><strong>Microscopic simulation</strong></td>
<td>Low detail (MMTS)</td>
<td>Medium detail (GMSF)</td>
<td>High detail (SUMO)</td>
<td>High detail (SUMO)</td>
</tr>
<tr>
<td><strong>O/D matrix</strong></td>
<td>Low detail</td>
<td>Low detail</td>
<td>Observation</td>
<td>Survey</td>
</tr>
</tbody>
</table>
Trace generation tools

- Required components
  - Realistic road topology
    - Accurate map of street layout including road properties
  - Microscopic simulator
    - Representation of individual driving behavior
  - Macroscopic model
    - Identification of trips travelled by drivers
      - Traffic demand: origin-destination (O/D) matrix
      - Traffic assignment: route calculation
Trace generation tools

Required components

- Realistic road topology ➔ OpenStreetMap
  - Accurate map of street layout including road properties

- Microscopic simulator ➔ SUMO
  - Representation of individual driving behavior

Macroscopic model

- Identification of trips travelled by drivers
  - Traffic demand: origin-destination (O/D) matrix ➔ TAPAS
  - Traffic assignment: route calculation ➔ Gawron’s algorithm
OpenStreetMap

- World map database
- Open-source
- **Road topology quality** closely matches that of Google Maps, Mappy
- Includes additional information
  - Traffic lights, AOI, buildings
- Dedicated editing tools
  - Osmosis: database information filtering
  - JOSM: road information editing
Simulation of Urban Mobility

- Microscopic **vehicular mobility simulator**
  - Open-source
  - Imports different maps formats
    - OSM, GDF, US Census TIGER database

- Featured models
  - Krauss’ **car-following model**
    - Controls driver acceleration/deceleration based on car-to-car distance and velocity
  - Krajzewicz’s **lane-changing model**
    - Overtaking decisions
Travel and Activity Pattern Simulation

- Macroscopic traffic flow dataset
  - Provided by Institute of Transportation Systems at the German Aerospace center (ITS-DLR)
  - 24-hour O/D matrix of a typical day in Koln, Germany

- Based on TAPAS methodology
  - Exploits a survey by German Federal Statistical Office
    - 30,700 daily activity reports
    - 7000 households
    - 1.2 million trips
Integrating the tools as they are leads to a plain unusable trace.

- Pervasive traffic congestion early in the simulation
- Impossibility to recover from above condition
Repairing all flaws provides expected road traffic behavior.

Realistic speed and travel time.
Resulting trace

Live traffic comparison: our trace vs. ViaMichelin

ViaMichelin – 5pm

Koln trace – 5pm
Connectivity analysis

- Impact of car traffic realism on **vehicular network connectivity**
  - Comparison with canton of Zurich trace (only large-scale trace available)
  - Metrics: clustering and degree distribution

- Realism of **Zurich trace**
  - Incomplete road topology
  - Low microscopic detail (queuing approach)
  - Approximate macroscopic model

![Graph showing vehicular traffic comparison between Koln and Zurich over time](image-url)
Connectivity analysis

- Cluster analysis
  - Many more clusters
  - Clusters are much smaller in size
  - No giant components

- Degree distribution
  - 60% vehicles have less than 5 neighbors

- Significantly reduced connectivity w.r.t. Zurich trace
Conclusions

- Large-scale vehicular mobility trace
  - 400 km² around the city of Koln, Germany
  - 24 hours of car traffic, involving 700,000 trips
  - Generated with state-of-art tools
  - Closely matches live traffic

- Comparison with existing traces
  - Simplistic macroscopic and microscopic modeling results in exceedingly good network connectivity
  - Using current traces may cause over-optimistic protocol performance evaluation

- Availability: last week of November
EURECOM’s OpenAirInterface (LTE Emulator) uses Koln vehicular mobility through SUMO.

Demo in bell labs Open days 2012

http://www.openairinterface.org

Mobility Simulator

LTE Emulator

SUMO w Koln Vehicular mobility

OMG

OpenAirInterface
Future direction

- Further mobility analysis using Voronoi tessellations
- Mobility prediction on macroscopic flows
- Exploit the signal propagation in outdoor urban environment using WiPLAN
Thank you

Question?
Appendix 1: Gawron’s algorithm

- Simple **iterative process** for better route calculation which is more knowledgeable about congestion

- Traffic Equilibrium requires **repeated simulations**

Traffic distribution within the network under different simulations is shown in the graph. The graph illustrates the number of vehicles over time, indicating the traffic equilibrium and iterations. The graph shows that traffic equilibrium is achieved after multiple iterations, with vehicle counts stabilizing after iteration 35.
Appendix 2: Few more results

Vehicles activities during simulation

- Traveling
- Ended
- Waiting

Time (h):
- 6am
- 7am
- 8am
- 9am
- 10am

Vehicles (x 1000):
- 0
- 5
- 10
- 15
- 20
- 25
- 30

Time (h):
- 3am
- 6am
- 9am
- 12am
Trace generation

- Traffic demand
  - Restricting the dataset to **car traffic**
  - Reduction of bursts of vehicle in-flow to the simulation

- **Highway traffic** is introduced
Wrong restrictions
OSM conversion
- Un-built road
- Complex junctions