Cars and road traffic
Introduction on traffic flow

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Introduction: traffic simulation models

- Traffic jams: €1,5 bil/yr
- Capacity 3-5% too low
- Ex-ante testing of measures
- Zones 80 km/h:
  - Average speed check leads to different lane usage
  - Lower capacity
  - Models incorrect

New communication allows to coordinate traffic control
Outline

- Explanation on scales
- Microscopic: motorway modelling
- Macroscopic: patterns
- Networks: a new aspect
Scales

- Microscopic: vehicle level
  www.traffic-simulation.de

- Macroscopic: link level
  www.traffic-states.com

- New level: network level
  http://victorknoop.eu/research/networktransmissionmodel/
Question

Traffic lights reduce the inflow of vehicles to the freeway. Why does this reduce the average delay?

A) Drivers keep shorter distances if they have not queued yet
B) In a specific time, cars on the freeway cover more distance than cars on the onramp
C) There are less cars delayed on the onramp
Microscopic description
Car-following model

- Description of acceleration (or speed, or position?) of vehicle i as function of leader(s) parameters.
- \( a_i = \ldots \) or \( v_i = \ldots \) or \( x_i = \ldots \)

- **2 minutes: build your own car-following model**
Newell simple car-following model

1. Translate the trajectory in time
2. Translate the trajectory in space
   => $X_{i+1}(t+\tau) = x_i(t) - x_0$
Newell simple car-following model

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\[ X_{i+1}(t+\tau) = x_i(t) - x_0 \]
Relation microscopic-macroscopic

1. Translate the trajectory in time
2. Translate the trajectory in space

\[ K_j = \frac{1}{x_0} \]
Impact of microscopic actions
Innovation 1: combine speed & lane

Motorway traffic simulation model

Couple acceleration and lane choice
Innovation 2: action points

- Up to now: continuous adaptation acceleration
- In Veni: acceleration changes at action points (together with lane)
Innovation 3: Leaving space for others

- State-of-the-art:
  One chooses its lane and the rest follows
- Model proposal:
  “Negotiate” on the space
Observations and calibration

- Individual vehicle data
  - 55 linked cameras (Rijkwaterstaat/TNO)
  - Helicopter: follow vehicle (nieuwe techniek)
- Driving simulator
  - Several test persons (required?)
  - Vary only one variable

=> Calibration of the model
Apply on test case: average speed check

- Commercial simulation models require calibration
- Test: calculate effect without calibration (ex ante!)
- Compare to other models
Where is underused road capacity

- Right lane heavily underused
- ITS measures to improve this
- Speed limit (and speed check) changes behavior
Where is underused road capacity
Calibration

• Step 1: find action points (longitudinal/lateral)
  Difficulty: lane changes considered, but not performed

• Step 2: determine cost for all paths
  Running costs: acceleration, gain in time, not behind truck, lane change
  End costs: end speed, final lane, leader/follower
  Difficulty: not all individual costs are being observed

• Step 3: Model choice process
  Difficulty: every one is different, risk assessment?
Preliminary results

- How to quantify (and prove) correlation?
Questions...

• Could you describe your driving decisions?

• And are you willing to join experiments?
Macroscopic description
Stable and unstable parts

- What do you expect on this road?
Boomerang effect
What could we see?

- temporary acceptance (or occurrence!) of small headways
- Jam starts inside or downstream bottleneck and moves upstream
- Also note instability of congested flow
Capacity and capacity drop

- One law and one relationship in modelling
Fundamental diagram

Flow = density * speed

Flow q (veh/h)

1 veh / 1.5 s

85 km/h

150 veh/km/lane

Density k (veh/km)
Now, the real world

- Stochasticity
- (and capacity drop)

Capacity drop!

free flow capacity is higher than congested capacity

Inverse-lambda fundamental diagram
Intermezzo: calculate delays

• Consider cumulative curves, i.e. how many cars passed ($N$)?

• Restrictions for curve

$$\frac{dN}{dt} = ?$$
Intermezzo: calculate delays

- One for demand (Nin) and one for outflow (Nout)
Intermezzo: calculate delays

- One for demand ($N_{in}$) and one for outflow ($N_{out}$)
Intermezzo: calculate delays

- Total delay:
  - sum (integral) of delays over all vehicles
  - Sum (integral) van alle queues over all times
Effect ramp metering

- No ramp metering: queuing
- After queue:
  lower capacity => lower outflow => more delay

Ramp metering

No ramp metering
Ramp metering

- Avoid capacity drop at motorways

Restriction:
Queuing at underlying road network cannot exceed the available space
Ramp metering: avoid congestion

(a) TDI gebaseerd op feedback control

(b) TDI gebaseerd op feedforward control

ALINEA algorithm (in NL)

RWS algorithm (in NL)
Network Fundamental Diagram
Fundamental diagram

- Network Fundamental Diagram
- Average fundamental diagram for an area

Density

Fig: (Geroliminis and Daganzo)
Simple road

- Road with bottleneck
- What happens to the outflow

![Diagram of a simple road with a bottleneck](image)

\[ q \]

\[ u \]

\[ i \]

\[ t \]
Not so simple road

- www.traffic-simulation.de
- Origins and destinations everywhere
- Increased demand => jams
Network Fundamental Diagram

- What happens to the flow if the density increases?
Many other applications - desks
Now: simulation models for NFD

Network Transmission Model
A dynamic traffic model at network level

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Abstract
New IT techniques allow communication and coordination between traffic measures. To best use this, one needs to coordinate over longer distances. Optimization of the measures is not possible using traditional microscopic or macroscopic simulation models. The Network Fundamental Diagram (NFD) describes the relation between flow and density on a network level. This paper introduces a traffic model which uses this relationship, representing traffic and traffic dynamics at a high spatial scale. The model shown to work on an example network. The model can be used to predict the effect of routing information or perimeter control.

Supply & demand
- Supply and demand are based on the NFD.
- Demand is the same as the NFD for all densities. This is contrary to the cell transmission model where demand stays high for overcritical situations. However, in networks gridlocks can occur.
- Supply is, similar to the cell transmission model, at capacity at under critical accumulation and follows the NFD for higher accumulations. Supply reduction is essential for blocking back.

Simulation scheme
- Accumulation
- Total demand
- Edge capacities
- Demand per destination
- Supply per cell
- Routing
- Flow = \min(\text{demand}, \text{supply})
- If supply is restrictive: assignment to cells proportional to demands
- Accumulation per destination

Background
Introduction
- Modern IT techniques allow for coordination of traffic management measures.
- Larger areas need a longer time horizon for the traffic optimization
- Microscopic and macroscopic simulation programs are too slow for large area and long simulation times

The Network fundamental diagram describes the relationship between accumulation (average density) and the (unrestricted) outflow out of the network

Vehicle level

Link level

(Sub-)network level

Case study
Control measures
- Dynamic route guidance
  - based on speeds in areas
  - variable update times
- Gating
  - Limit inflow such that accumulation stays under critical accumulation
  - Vary the traffic areas where gating is applied

Results
- Gridlocks prevented
- Considerable decrease of delay

Next steps
- Calibrate for a real world network
- Implement in a model predictive control framework

Conclusions
We propose a model that describes the traffic dynamics on a network level scale. The base elements are the subnetworks, and the flows from one subnetwork to another are calculated using the proposed scheme. The model accounts for blocking back from downstream as well as internal gridlocks within a cell.
A case study showed how the model can be for traffic control (gating and routing). We used feedback controllers to optimize the traffic stream, but given the limited computation steps the model can also be used in a model predictive control framework.
Practical implementation Amsterdam
Coordination of ramp metering

• Delay between access and measurements => To many cars in network
• Banace between spillback and flows => limit inflow upstream
Field test

• Coordinate ramp metering
• Limit upstream

• How much to allow from which ramp?
Network measurements

- Use of ramp metering limited
- More buffer space by coordination with underlying road network
- Maximum queue length per traffic light
Questions

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