FORECASTING OF TRAFFIC JAMS CAUSED BY ADVERSE WEATHER

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Objectives

- **Problem:** How to forecast formation and characteristics of traffic jams caused by adverse weather?
- **Example:** Evolution of traffic jam on road section with increased slipperiness or fog.
- **Source of information:** Forecasted traffic flow at critical road sector and appropriate speed limit determined from road weather conditions.
- **Mathematical tool:** Hybrid system comprised of: input traffic flow, road capacity and jam estimators.
- **Goal:** To develop an intelligent unit for traffic information providers and road operators.
Prediction of traffic flow rate (normal driving conditions)

*Basis:* Prediction is performed by a non-parametric statistical model using previously recorded time series of flow rate.

![Traffic Flow Rate Graph](image)

**Correlation coefficient (flow rate) ~97%**

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- ... orig
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Prediction of traffic jam

Intelligent unit

*Basis:* Hybrid system comprised of: input traffic flow, road capacity and jam estimators

Prediction of road weather conditions

*Basis:* Prediction is performed by a non-parametric statistical model using previously recorded road weather data.

- slipperiness
- stopping distance
- fog formation

The fog formation is predicted from previous records of:
- concentration of particulate matter $PM_{10}$
- wind velocity $W$
- humidity $H$
- temperature $T$

Recorded road weather data - [www.sris.nu](http://www.sris.nu)

Predicted and actual slipperiness $X$
Estimation of speed limit

- A proper speed limit on wet road is obtained by equalizing stopping distances at normal and wet conditions:
  \[ x_{st1} = x_{st2} \] - black arrow

Due to decay of \( \mu(v) \) the stopping distance is increased:
\[ x_{st} = x_{react} + x_{break} \approx \tau v + \exp(0.7 v/c) \frac{v^2}{2 \mu_o g} \]

- A proper speed limit at decreased visibility is obtained by equalizing stopping and visibility distance:
  \[ x_{st2} = x_{vis} \] - blue arrow

Speed limit determines the road capacity \( Q_{max} \).
Estimation of jam length

- When the input flow surpasses the road capacity: $Q_{in} > Q_{max}$, a jam starts to evolve.
- The number of cars in jam is estimated by the integral: $\Delta N = \int (Q_{in} - Q_{max}) dt$.
- The time that a car coming to the jam spends to pass it is estimated by: $T_J = \Delta N / Q_{max}$.
- The jam length can be estimated by this time and velocity of the car: $L = T_J \times v_c$. 

![Flow versus time](image1.png)

![Number of cars in jam](image2.png)
Determination of traffic jam characteristics

Description by field equations

- Velocity adaptation law:
  \[ \frac{\partial v}{\partial t} + v \frac{\partial v}{\partial x} = \frac{v_e(\rho) - v}{T} ; \]
- Relaxation time: \( T \approx 3\tau \)
- Continuity equation:
  \[ \frac{\partial \rho}{\partial t} + \frac{\partial \rho v}{\partial x} = I(x, t) \]
- Traffic source term:
  \[ I(x, t) = Q(t)\delta(x, t) \quad ; \quad Q(t) \text{ is forecast} \]

Numerical treatment

- Cell dimensions: \( \Delta x = \lambda ; \Delta t = 0.1\tau \)
- Intervals: \( 0 < x < 0.5\text{km} ; 0 < t < 1\text{h} \)
- Initial and boundary conditions:
  \( \rho = 0 ; v = 0. \)
- Source term specified by the predicted flow rate \( Q \) centered at rush hour: \( t = 0.5\text{h} \).
- Transition to non-dimensional variables:
  \( t/\tau ; x/\lambda ; v \tau/\lambda ; \rho \lambda ; Q\tau \)

Macro-modeling based on fundamental diagram of flow and continuity equation. Boundary condition is determined by the predicted flow.
Example of the disturbed region

- **Position**: $0.2 \text{km} < x < 0.4 \text{km}$
- **Reduced speed**: $0.5 \, v_o$

Dependence of the velocity reduction factor $B$ on $x$.

Field distributions
Traffic flow field

Parameters: $v_o=130 \, \text{km/h}$; $Q_{\text{max}}=1875 \, \text{veh/h}$
Example of the disturbed region

Field distributions

Parameters: $v_o=130$ km/h ; $Q_{max}=1875$ veh/h
Conclusions

• Information on traffic jams is vital for road users.
• Forecasting of traffic jams provides support for traffic information center and road services.
• We have shown that in spite of rather complex, non-linear, and stochastic character of traffic flow, it is possible to model the evolution of traffic jam at a disturbed region based upon the forecasted input flow and the proper speed limit that corresponds to driving conditions in severe weather.
• The next step is to transfer predicted data directly to drivers (e.g. over mobile phones).
References


• I. Grabec, F. Švegl, *Forecasting of traffic flow at a high-way bottleneck*, Proc. ISEP 2011, Ljubljana, SI

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Thank you for your attention!

Kiitos
mielenkiinnosta!
Variables used in PM10 modeling

- Wind Velocity
- Humidity
- Temperature
- Concentration PM10 Air Quality
Statistical variables

- **Basic variables:**
  - $r$: distance between cars, $\rho=1/r$: density of cars
  - $\nu$: mean velocity,
  - $\nu e(\rho)$: equilibrium velocity
  - $Q=\rho \nu$: flow rate

- **Parameters and reference variables:**
  - $\lambda \sim 5m$: car length, $r - \lambda$: clear spacing
  - $\tau \sim 1s$: reaction time
  - $u = C \lambda/\tau$: characteristic velocity; $C \sim 3$
  - $r = \lambda + \tau w$: proper distance
  - $w = (r - \lambda) / \tau$: proper velocity
Fundamental diagram of traffic

**VELOCITY VERSUS DENSITY**

- Model 130 km/h
- Model 110 km/h
- Model 60 km/h
- Exper 110 km/h

**FLOW VERSUS DENSITY**

- Model 130 km/h
- Model 110 km/h
- Model 60 km/h
- Exper 110 km/h
Micro-dynamic modeling of traffic jam evolution

Micro-dynamic model stems from driving rules and predictor of traffic flow.

Micro-model is not convenient for application.

The goal: Macro-modeling based on fundamental diagram of flow and continuity equation. Boundary condition is determined by the predicted flow.