Platoon System Architecture

Wireless Communication Network

CACC – Collaborative adaptive cruise control
ACC – Adaptive cruise control
CC – Cruise control

Collaborative Adaptive Cruise Control

• How to jointly minimize fuel consumption for a platoon of vehicles?
  o Keep small relative distances or close to individual optimal trajectories?
  o Uphill and downhill segments; heavy and light vehicles

Dynamics of vehicle i depend on distance $d_{i-1,i}$ to vehicle i-1:

$$\frac{dv_i}{dt} = \frac{d}{dt} \left( F_{\text{eng}}(\delta_i, \omega_i) - F_{\text{tire}}(v_i) - F_{\text{wind}}(v_i, d_{i-1,i}) - F_{\text{friction}}(x_i) - F_{\text{prop}}(x_i) \right)$$

Alam et al., 2013
Hilly roads generate platoon disturbances

May impose fuel-inefficient braking commands

Compensated by feedforward communication of road topology and vehicle commands

Alam, 2014
Functional Architecture for Goods Transport

Outline

- Introduction
- Architecture for fuel-optimized goods transport
- Cruise control for vehicle platoons
- Optimized transport planner
- Humans in the loop
- Conclusions
When and where to create platoons?

**Goal:** Maximize total amount of platooning with limited intervention in vehicle speed and route

Heavy-duty vehicle traffic without platooning

Platoon merge and split

Merge and split platoons at highway intersections

Only vehicles that are relatively close in space and time platoon
Distributed optimization of platooning

Heavy-duty vehicle traffic without platooning

With platooning

Predictive control decisions at road intersections on whether it is beneficial for a vehicle to catch up another vehicle at next intersection

Larson et al., 2013

Numerical evaluations

- German road network with 300 trucks
- Random starting points and destinations
- 500 experiments

Fuel saved vs total no of vehicles

2-5% deployment enough for substantial benefit
Feasibility Study Based on Real Truck Data

- Position snapshot May 14 2013
- 7,634 Scania trucks
- 500,000 km² in Europe

- 875 long-haulage trucks over European region
- Trucks close in time and space (<r m) could adjust speed to platoon and then save 10% fuel during platooning
- Benefits:
  - r = 0.2 km: 78 trucks platooned, 0.16% savings
  - r = 1 km: 241 trucks platooned, 0.38% savings
  - r = 5 km: 778 trucks platooned, 1.2% savings

Spontaneous vs Coordinated Platooning

- Paths of 1,773 trucks
- Trucks within 100 m from another truck

Larson et al., 2013
Liang et al., 2014
Spontaneous vs **Coordinated** Platooning

Adjust truck departure times

Coordinated departure times enable much more platooning

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Stockholm-Zwolle 24/7 Testing

- Real-time fleet management
- Platooning in real traffic
- Fuel reductions and safety
- Driver acceptance
- Public acceptance

Scania Transport Lab
Internal haulage company
20 trucks, 360,000 km/year
75 trailers, 92% loaded
65 drivers, 40 h work/week

How willing are drivers to manually platoon?

- Jan-Apr 2013 experimental evaluation
- Drivers in the loop with advanced ACC (radar etc)
- Encouraged but not enforced to platoon
- Notable fuel reductions

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Conclusions

• CPS architecture for goods transportation
  – High-level optimization and scheduling of transport
  – Low-level control and coordination of truck platoons

• Centralized vs decentralized computing
  – Global vs local objectives: Who owns the performance metric?
  – Computing vs communication costs: When to do it in the Cloud?
  – Safety-critical systems: How guarantee real-time communications?

• Large-scale testing and evaluations

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