Platoon of SAE level-2 automated vehicles on public roads: setup, traffic interactions, and stability

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V.L. Knoop, M. Wang (TU Delft)
I. Wilmink, D.M. Hoedemaeker (TNO)
Mark Maaskant (Prodrive training)
Evert-Jeen van der Meer (AON)

Victor L. Knoop PhD
TU Delft (Transport & Planning)
v.l.knoop@tudelft.nl

Abstract

Automation in vehicles increases. Currently, SAE level 2 vehicles are on the market, allowing to drive hands and feet off on freeways. There is a need to study the effect of increasing numbers of automated vehicles on the road. In particular, how these vehicles react following each other (in a platoon) is unknown. This paper discusses how an experiment with a platoon of automated vehicles on the public road can be set up. For this, interaction with other vehicles is important.
We conducted a field operational test of 465 km on Dutch freeways. We qualitatively analyze the platoon stability (or string stability) of current ACC systems. The first vehicle has a relatively constant speed, but minor changes in speed are amplified and the 7th vehicle has large speed changes. This is uncomfortable, fuel inefficient, and sometimes even unsafe: the lowest speed was 40 km/h in otherwise free flow traffic on the freeway.

Aims

- Vehicles of SAE-level of automation 2: adaptive cruise control & lane centering; "hands off" driving is possible
- How should can one organise a test of a platoon of automated vehicles on the public road?
- Can the vehicles drive as a platoon on the freeways
- What are string stability effects of a platoon of SAE-level 2 vehicles?

Vehicles

- 7 vehicles, several types, year 2017
  - Tesla Model S
  - Mercedes E-class (2x)
  - BMW 5 series (3x)
  - Audi A4
- Most advanced ADAS packages, including adaptive cruise control, lane center control
- Data logged from OEM sensors (via CAN) and additional sensors for study:
  - 8 cameras per vehicle: driver and traffic
  - Mobil eye stereo camera
  - GPS
  - Accelerations

Organization

- Wide consortium, including ministry and road authority
- Stay in one lane: left lane prevents influences of ramps
- Exemption from speed limit (+ 10 km/h as cruising speed) to prevent blocking and right-hand overtaking
- Trained drivers (long term users of car)
- Co-pilot by advanced driving trainers
- Co-pilots discussed required movements
- Radio-contact via co-pilots
- Advisor driving behind platoon

Route

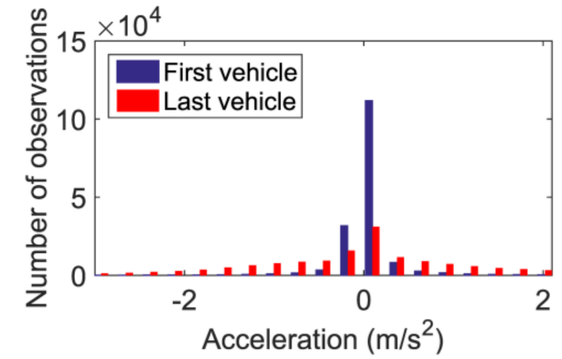
- 465 km multi-lane freeway
- > 95% driving at ACC (estimate)
- >75% as platoon (estimate)

Other users

- Netherlands driving: short headways (often <1 s)
- Shortest headway setting too long to prevent cut-in
- Speed should be >10 km/h over speed limit to prevent holding traffic
- Some overtaking at the right
- No intentional "experimenting" by other vehicles

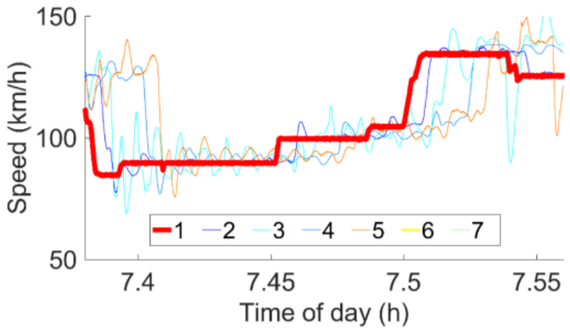
Safety and stability

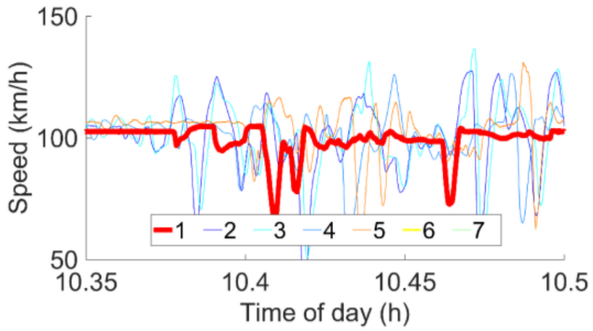
- Lead vehicle at constant speed, last vehicle high speed fluctuations and accelerations
- Experience first vehicle: "Comfortable". Last vehicle uncomfortable
- Fuel consumption based on speeds (so corrected for vehicle differences): 15.2 liter for first vehicle 45 liter for last vehicle



Platoon lane changing

- Coordinated lane changing was developed to keep platoon together
- Various strategies for various movements
- General:
  - first vehicle lane change
  - speed change, limiting speed in one lane, holding traffic or increase speed to catch up or create gaps
  - next vehicle changes lane
  - etc.





Conclusions

- Speeds of 10 km/h above speed limit do not prevent overtaking at the right.
- Other vehicles will merge into platoon, even with shortest headway settings.
- ACC can be used for a large part of the time and works as comfort tool.
- ACC does not work for platoons.
- Accelerations amplify in the platoon, to dangerous values for longer platoons.

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