Connected and Automated Trucks: What and When?

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Overview

• Automation 101 – terminology and classifications
• PATH background on connected and automated trucks
• Truck platooning – what it is and why it’s important
• Levels of truck automation and when they may happen
Automation Terminology Problems

• Common misleading, vague to wrong terms:
  – “driverless” – but generally they’re not!
  – “self-driving”
  – “autonomous” – 4 common usages, all different in meaning (and 3 are wrong!)

• Central issues to clarify:
  – Roles of driver and “the system” – levels of automation
  – Degree of connectedness and cooperation – V2V, I2V, V2I
  – Operational design domain
Levels of Automation - Classifications

*Driving automation systems* are categorized into levels based on:

1. Whether the driving automation system performs *either* longitudinal *or* lateral vehicle motion control.
2. Whether the driving automation system performs *both* longitudinal and lateral vehicle motion control simultaneously.
3. Whether the driving automation system *also* performs object and event detection and response.
4. Whether the driving automation system *also* performs fallback (fault recovery).
5. Whether the driving automation system can drive everywhere or is limited by an operational design domain (ODD).
Operational Design Domain (ODD)

- The specific conditions under which a given driving automation system is designed to function, including:
  - Roadway type
  - Traffic conditions and speed range
  - Geographic location (boundaries)
  - Weather and lighting conditions
  - Availability of necessary supporting infrastructure features
  - Condition of pavement markings and signage
  - (and potentially more...)
## Example Systems at Each Automation Level
(based on SAE J3016 - http://standards.sae.org/j3016_201609/)

<table>
<thead>
<tr>
<th>Level</th>
<th>Example Systems</th>
<th>Driver Roles</th>
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<tbody>
<tr>
<td>1</td>
<td>Adaptive Cruise Control OR Lane Keeping Assistance</td>
<td>Must drive other function and monitor driving environment</td>
</tr>
<tr>
<td>2</td>
<td>Adaptive Cruise Control AND Lane Keeping Assistance Traffic Jam Assist (Mercedes, Tesla, Infiniti, Volvo…) Parking with external supervision</td>
<td>Must monitor driving environment (system nags driver to try to ensure it)</td>
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<tr>
<td>3</td>
<td>Traffic Jam Pilot</td>
<td>May read a book, text, or web surf, but be prepared to intervene when needed</td>
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<tr>
<td>4</td>
<td>Highway driving pilot Closed campus “driverless” shuttle “Driverless” valet parking in garage</td>
<td>May sleep, and system can revert to minimum risk condition if needed</td>
</tr>
<tr>
<td>5</td>
<td>Ubiquitous automated taxi Ubiquitous car-share repositioning</td>
<td>Can operate anywhere with no drivers needed</td>
</tr>
</tbody>
</table>
Early PATH Research on CAV Trucks

Automatic steering control – 1998-2000

Two-truck platoon control – 2003
Why care about truck platooning?

- Significant energy savings from aerodynamic drafting
- More stable vehicle following dynamics, reducing traffic flow disturbances and saving additional energy and emissions
- Increased highway capacity and reduced congestion from improved traffic dynamics and shorter gaps
- *(Potential)* safety improvement
- *(When Level 3 automation becomes feasible)* Improvement in truck driving working conditions, with more diverse assignments for drivers on the road
- *(When Level 4 automation of follower trucks becomes feasible)* Reduced need for truck drivers on line haul
Enablers of Truck Platooning

• Adaptive cruise control (forward ranging sensor, plus engine, braking and transmission control) already available
• Fast, highly reliable V2V communication
• Informative driver-vehicle interface
• Reliable early detection of cut-in vehicles
• (For L2+) Lane position detection and automatic steering control
• (For L3+) Central supervision, I2V comm.
• (For L4) Extensive safety assurance + dedicated, segregated truck lanes (?)
L1 Truck Platooning State of the Art

Automated longitudinal control only

- Cooperative ACC as first step (pre-platoon)
  - V2V communication/coordination
  - Ad-hoc joining and leaving
  - Constant time-gap following

- L1 Platooning
  - Add coordination/supervision by leader
  - Extend to constant clearance distance gap and shorter distances

- Many research and development projects
- Peloton Technology planning 2-truck product release
- Major truck manufacturers considering it seriously, but no announcements yet
PATH/Volvo Truck CACC at 0.6 s Gap on Transport Canada’s Test Track (10/16)
PATH/Volvo Truck Platoon at 4 m Gap on Transport Canada’s Test Track (8/17)
PATH/Volvo Truck CACC, Including Response to Cut-in Vehicle
Fuel Savings per Truck at 110 km/h (65 mph)
Fuel Savings for Complete Platoon (Average) at 110 km/h (65 mph)
Traffic Impact Study for I-710 Corridor

- 15 miles, 21 on-ramps, 20 off-ramps
- 10% - 19% truck volume
- Morning off-peak (10-11 am) simulated northbound
- If all trucks can use CACC for close following:
  - Truck average speed +19%
  - Truck flows +2% -- +8%
  - LDV traffic unaffected
  - Trucks save ~2.5% of fuel (2% from traffic flow, 0.5% from aerodynamics)
L2 Truck Platooning State of the Art

L1 platooning + automatic steering control
  - Automatic steering likely necessary for shorter longitudinal gaps (visibility limitations)

• Multiple research projects have tested it, from CHAUFFEUR (1996-2004) to Konvoi, SARTRE, Energy ITS, etc.
• Some companies doing R&D on it (Daimler, Scania, Uber ATG, Waymo,...)
• Product releases?? Within a few years
L3 Truck Platooning State of the Art

L2 + driver can divert attention *temporarily* to other tasks, while remaining available to intervene when needed

- Follower truck driver could work as sales person or logistics manager *en route*

- Research needed on driver-vehicle interface to try to ensure driver availability when needed

- Remote supervision (by lead driver over V2V or central supervisor over I2V link) could be needed

- Passenger car applications likely to precede heavy trucks

- Product releases? ~5 years?
L4 Truck Platooning State of the Art

L3 + ability to ensure minimal risk condition without any human intervention (while operating within its specified Operational Design Domain – ODD)

- L4 platoon followers likely to be coupled behind a leader driven at L0, L1 or L2.
- Singapore requesting this now for a 10 km route connecting two container terminals
- Safety assurance state of the art not sufficient to support this level of automation for mixed traffic and highway-speed operations
- Likely to need segregated truck-only lanes or other special restrictions to simplify the ODD – like current port and mine applications
Potential Loss of Truck Driver Jobs?

- Starting from current shortage of drivers and aging driver population
- Any current truck driver will be able to retire, not go on unemployment
- Elimination of driver roles will take decades:
  - Safety assurance en route
  - Condition monitoring
  - Loading and unloading, load securement
  - Interfaces with shippers and receivers (pickup and delivery)
  - Managing the unexpected
- Add fleet turnover time