Driving with Automation

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INTRODUCING VOLVO CARS
SEAMLESS INTERFACE FOR SELF-DRIVING CARS

http://www.volvocars.com/intl/about/our-innovation-brands/intellisafe/intellisafe-autopilot/drive-me/real-life
<table>
<thead>
<tr>
<th>Level</th>
<th>Name</th>
<th>Narrative definition</th>
<th>DDT</th>
<th>OEDR</th>
<th>DDT fallback</th>
<th>ODD</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Driving Automation</td>
<td>The performance by the driver of the entire DDT, even when enhanced by active safety systems.</td>
<td>Driver</td>
<td>Driver</td>
<td>Driver</td>
<td>n/a</td>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance</td>
<td>The sustained and ODD-specific execution by a driving automation system of either the lateral or the longitudinal vehicle motion control subtask of the DDT (but not both simultaneously) with the expectation that the driver performs the remainder of the DDT.</td>
<td>Driver and System</td>
<td>Driver</td>
<td>Driver</td>
<td>Limited</td>
</tr>
<tr>
<td>2</td>
<td>Partial Driving Automation</td>
<td>The sustained and ODD-specific execution by a driving automation system of both the lateral and longitudinal vehicle motion control subtasks of the DDT with the expectation that the driver completes the OEDR subtask and supervises the driving automation system.</td>
<td>System</td>
<td>Driver</td>
<td>Driver</td>
<td>Limited</td>
</tr>
<tr>
<td></td>
<td><strong>ADS (“System”) performs the entire DDT (while engaged)</strong></td>
<td></td>
<td><strong>System</strong></td>
<td><strong>System</strong></td>
<td><strong>Fallback-ready user (becomes the driver during fallback)</strong></td>
<td><strong>Limited</strong></td>
</tr>
<tr>
<td>3</td>
<td>Conditional Driving Automation</td>
<td>The sustained and ODD-specific performance by an ADS of the entire DDT with the expectation that the DDT fallback-ready user is receptive to ADS-issued requests to intervene, as well as to DDT performance-relevant system failures in other vehicle systems, and will respond appropriately.</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Limited</td>
</tr>
<tr>
<td>4</td>
<td>High Driving Automation</td>
<td>The sustained and ODD-specific performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene.</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Limited</td>
</tr>
<tr>
<td>5</td>
<td>Full Driving Automation</td>
<td>The sustained and unconditional (i.e., not ODD-specific) performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene.</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Unlimited</td>
</tr>
</tbody>
</table>
Automated driving

Driver assistance/ Partial automation

Driver needs to be able to intervene at all times

Automated parking, autocruise

Conditional/ High automation

Vehicle in control in special conditions

Taxibots, platooning, automated highways

Comfort, efficiency, safety, costs

Mode choice, location choice, urban and transport planning
Fundamental changes in driving behaviour

- Driver in control
- Vehicle in control
  Driver supervision

Workload, driving performance, attention, situation awareness, risk compensation, Driver Vehicle Interface, acceptance, mode transition, purchase and use
Human behaviour during highly automated platooning

Heikoope et al. (2016), Effects of platooning on signal-detection performance, workload, and stress: A driving simulator study, Applied Ergonomics
Driving Behaviour in Control Transitions between Adaptive Cruise Control and Manual Driving

35 km motorway

BMW 5 with Full Range ACC
23 participants

observations 10 s before, 10 s after, each authority transition at 1 Hz
Deactivation by brake: speed drops 10 km/h in 4 s
Distance headway increases 5 m in 2s

Deactivation by gas pedal: speed increase 6 km/h in 5 s
Distance headway increases 1.5 m in 1s

Factors attributing to deactivation:
- On ramps, expected cut-ins,
- Approaching slower vehicles

Varotto, et al (2017), Resuming manual control or not? Modelling choices of control transition in full-range adaptive cruise control, Transportation Research Record
Current ACC systems maintain longer headways than human drivers

Drivers reduce lane changing when using ACC – staying in left or right most lane

ACC users rate pleasure at 8 on a 1-10 scale
  Full range ACC scores higher
  Clumsy technology decreases pleasure

ACC more likely to be bought by high-income males

Schakel et al (2017), Driving Characteristics and Adaptive Cruise Control, IEEE ITS Magazine
Driver aspects

- Automated Vehicles will lead to different vehicle behaviour
- Authority transitions relevant but hardly studied
- Situation awareness decreases with prolonged automated driving
- Current ACC headways larger than human headway
- Decrease in lane change when driving with ACC
Potential impacts on traffic

- Solve traffic jams by increased outflow
- Prevent traffic jams by better stability
- Increased throughput by smaller headways
- Decreased throughput by larger headways
- Decreased stability by lack of anticipation

Less congestion delay

Increased risk of congestion

Non connected, high penetration rate
A20: bottleneck motorway, no more space to expand

3+2 cross weaving

Short on-ramp

How can AVs relieve congestion here?
A20 congestion S112 on ramp

RSU: triggers at high flows on right lane; suggests courtesy yielding and anticipatory lane changing

ACC: more agile response; switched off by RSU

<table>
<thead>
<tr>
<th>Scenario</th>
<th>(l)ccomp (%)</th>
<th>q_{th} (veh/h)</th>
<th>pACC (%)</th>
<th>Avg. TT change (%)</th>
<th>Delay change (%)</th>
<th>Vehicle-kilometres change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base case</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Only-ACC</td>
<td>-</td>
<td>-</td>
<td>40</td>
<td>-4.5</td>
<td>-18.3</td>
<td>+2.7</td>
</tr>
<tr>
<td>Only-RSU</td>
<td>80</td>
<td>1200</td>
<td>-</td>
<td>-19.5</td>
<td>-72.6</td>
<td>+2.3</td>
</tr>
<tr>
<td>Combined</td>
<td>80</td>
<td>1200</td>
<td>40</td>
<td>-7</td>
<td>-27.5</td>
<td>+2.4</td>
</tr>
</tbody>
</table>

Sideris (2016)
• Current ACC increases congestion
• New/improved ACC start reducing congestion at 10% penetration rate
• CACC strongly reduces congestion

Note: (C)ACC modelled as ‘special’ drivers
Huisman (2016)
Managing traffic with Connected Variable Speed Limits and ACC

- Traffic control is still necessary with presence of IVs, particularly at low penetration rate;
- Although IV changes traffic flow characteristics, the VSL algorithm works well with presence of IVs;
- Connected traffic control and vehicle control bring extra benefits in improving traffic efficiency;
- Redesign of traffic control systems taking into account the changed flow characteristics may lead to further improvement.

High Performance Vehicle Streams with active CACC string clustering

Full processes of CACC string operation

Roadway Capacity of Traffic with CACC Strings

Vehicle Clustering Strategy
Managed Lane Strategy
I2V Strategy

Market Penetration
CACC Dedicated Lane Scenario
Traffic Bottleneck Scenario

Lin Xiao
Cooperative automated driving strategies for efficient traffic operations near on-ramp bottlenecks

Better control algorithms
• Relieve traffic congestion,
• improve traffic safety,
• reduce pollution.

Mixed AV and manual traffic.
Different penetration rates
Different traffic scenarios
Traffic flow simulation

Na Chen
Will Automated Driving improve traffic flow efficiency?

- Potential impacts of current ACC systems negative because of long headways
  - Need for more capable ACC
- Cooperative ACC can improve traffic flow efficiency
- Special attention needed for bottlenecks and authority transitions
- Statement about doubling roadway capacity are far from reality
Driving with automation…

- SAE L1-2 commercially available
  - SAE L3-4 with OEDR at system in R&D stage
- Mental underload, reduced situation awareness
  - More than ever, automation needs to be safer than driver
- Current ACC have longer headways than human drivers
  - Better ACC or CACC needed to avoid increase of congestion
- New focus: lane changing and manoeuvering
  - Especially at roadway bottlenecks
- Simulation models widely available
  - Are authority transitions included
- Public data about driving with automation scarce
  - Data sets to be published in journals