Driving Automated Vehicles in Complex Conditions

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EiC IEEE Open Journal of Intelligent Transportation Systems

2009
Full professor (0.4) Driver Assistance Systems
University of Twente

2003
TNO, Researcher and program manager Intelligent Transport Systems

1991
PhD Queueing Models for communication systems
University of Twente

1986
BSc+MSc Applied Mathematics
University of Twente

1982

connected  electric  fair  safe
automated  sustainable  shared

empirics  ↔  modeling
individual  ↔  collective

Spatial and Transport Impacts of Automated Driving
Staying safe and sound!

Hello world from Delft!
POLL 1

We’ve harvested the low hanging fruit in the field of automated driving. For further progress we need to:

1. Make humans smarter about when to use automated driving and when not.
2. Intensify R&D into automated driving using AI and ubiquitous connectivity.
3. Invest in road infrastructure readiness for automated driving, physically and digitally.
If ever there was a hype....
<table>
<thead>
<tr>
<th>Level</th>
<th>Name</th>
<th>Dynamic Driving Task (DDT)</th>
<th>DDT Fallback</th>
<th>Operational Design Domain (ODD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sustained lateral and longitudinal vehicle motion control</td>
<td>Object and Event Detection and Response (OEDR)</td>
<td></td>
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</tbody>
</table>

Automated Driving System (ADS “System”) performs the entire DDT (while engaged)

- Level 3: Conditional Driving Automation
- Level 4: High Driving Automation
- Level 5: Full Driving Automation
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
Unravelling effects of cooperative adaptive cruise control deactivation on traffic flow characteristics at merging bottlenecks

Lin Xiao, Meng Wang, Wouter Schakel, Bart van Arem

Department of Transport Planning, Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, The Netherlands

- Sensor/V2V
  - Desired speed
  - Desired time gap
- Driver Perceptions
- Collision Warning System
  - (re)activation
- ACC/CACC Controller
  - Acceleration/Send Command
- Vehicle Model

- Driver Intervention
  - (remain) deactivation
- Human Driver Response
  - Acceleration Command

Car-Following Models
Perception
Decision-making
Actuation

8000 m
450 m
250 m
2500 m
3000 m

Lane 4
Lane 3
Lane 2
Lane 1

Spatial and Transport Impacts of Automated Driving
CACC benefits negligible at low MPR

CACC increases heterogeneity in fundamental diagram

Capacity drop prevails with CACC

Control transitions play significant role
Automated driving is (still) complex and challenging

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

A walk ascending the SAE levels?
AVs moving into deployment

**Appelscha**
How to maintain public transport in shrinking rural areas? EasyMile EZ10 on the bicycle lane.

**Container Exchange Route**
AVs connecting Maasvlakte 1 and Maasvlakte 2 in Port of Rotterdam

**Rivium ParkShuttle**
Without a steward inside the vehicle, in Rotterdam and Capelle a/d IJssel! Served over 6,000,000 paxs since 1999

**AV in Japan**
A case study conducted in regards to a demonstrator in Oku-Eigenji.

Over 100 shuttle experiments in the EU
Safety steward on board
Operational services very limited

**How to operate safely in shared space?**

Boersma et al, 2020, From Pilot to Implementation: What are Potential Deployments with Automated Vehicles in Public Transport Based on Knowledge Gained from Practice? TRB 100th Annual Meeting, paper TRBAM-21-00729
POLL 2

Humans either as driver, controller or supervisor remain the weak link in driving automated road vehicles.

1. We need to redefine automated driving as explainable and responsible.
2. We need less ‘drivers’ in the future, but those who are need to be highly skilled and certified.
3. Automated driving builds on an aging concept called ‘car driving’, we need radical new mobility solutions.
This keynote…

How can Automated Vehicles share the road with Vulnerable Road Users?

How can Automated Vehicles be controlled in a meaningful way?

How can Automated Vehicles enable (re-) design of smart and sustainable cities?
Should I stop or should I cross?
Ajzen Theory of Planned Behaviour for VRU AV interaction

Public space

Nuñez Velasco (2019)
Findings

- Motion cues of vehicles are the most important factors (speed, distance)
- Little difference between response to automated and regular vehicles
- Trust and high perceived behavioral control lead to more and faster crossing
- Intention cues (eHMI) potentially useful
- Long term adaptation to exposure to automated vehicles uncertain


This keynote…

How can Automated Vehicles share the road with Vulnerable Road Users?

How can Automated Vehicles be controlled in a meaningful way?

How can Automated Vehicles enable (re-) design of smart and sustainable cities?
Meaningful human control of automated driving systems

... so much more than robot-dilemmas
Responsibility gaps of AI and networked systems

Human controllers

... can lose track of their role in the control chain,
... ending up not being able to effectively steer the system in the desired direction
... though remaining, technically speaking, “in-the-loop”, and possibly legally liable for it.
Toward Meaningful Human Control

The system (human operators, operated devices, infrastructures...) should be able to co-vary its behavior with the relevant reasons of the relevant human agent(s) for carrying out X or omitting X

There is at least one human agent in the system design history or use context who can appreciate the capabilities of the system and her own role as target of potential moral consequences for the system’s behaviour

Tracking by proximal scale of reasoning
Tracing taxonomy

MHC

Tracing

- Knowledge and Capacity
  - Knowledge of the system
  - Capacity/Ability to...

- Training
  - Experience
    - Active
    - Passive

- Traffic events
  - Regular
  - Irregular

- Plans
  - Coordinated decisions/intentions
  - Simple decisions
  - Driver traits/attributes
  - Driver state

- Manoeuvre (Tactical)
  - Controlled/conscious action patterns
  - Automatic/subconscious action patterns

- Operations (Proximal)

Moral awareness
(as potential target)

Knowledge of Moral Standards

Benchmark values

Role
- Recognition of own role
- Moral authority

Description/definition (of role)

Responsibility

Influence (on others)

Legal

Moral

Values

Rule & regulations

Spacial and Transport Impacts of Automated Driving

TU Delft
Operationalisation of Meaningful Human Control

Overtaking strategy
- Lateral distance from cyclist
- Overtaking speed

A crash can occur because cyclist lateral position is not fully predictable

Repeated simulation with updated parameters of overtaking strategy

Iteratively building capability and experience
# crashes decreases

Know capability increases  
Duration improves  
Deciding faster
Contributions

- Abstract concept made applicable in practice
- Demonstrates ways that MHC can be considered in vehicle and infrastructure design
- Demonstrates an approach to evaluate the extent of MHC
- Demonstrates potential policy influence on MHC
This keynote...

How can Automated Vehicles share the road with Vulnerable Road Users?

How can Automated Vehicles be controlled in a meaningful way?

How can Automated Vehicles enable (re-)design of smart and sustainable cities?
How can Automated Vehicles enable (re-)design of smart and sustainable cities?

Hollestelle et al (in preparation), *From urban design to transport demand patterns: An integrated approach to study the spatial impacts of automated driving in urbanized regions*
Province of Utrecht
## Scenarios

<table>
<thead>
<tr>
<th>Scenario 1: Transformation of the mobility system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Only shared automated vehicles (taxi-bots) on the roads (Level 5). High capacity gains in regional and urban road networks. It's so convenient that all conventional PT disappears. Good travel comfort and experience. Value of Travel Time (VOTT) decreasing.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 2: Growth on private AVs with great experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automated driving develops to full automation everywhere but only as a private mode of transport (Level 5). Technology allows vehicles to drive empty to park at specific outside parking areas. Traveling in a private AV is a great experience. Public transport is the same as today's. VOTT in cars decreases</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 3: Constrained usage of private AVs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automated driving is level 4 so only full automation in regional networks (no city centers). Capacity only increases on that part of the network. It does not deliver the comfort that was expected at the outset. Parking is the same as today. VOTT decreases but not as much.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 4: Decline of the mobility system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automated driving becomes Level 5 but it does not lead to capacity increases. No real effect on the comfort. No public transport any more. Everyone using private AVs. VOTT the same as today.</td>
</tr>
</tbody>
</table>

Hollestelle et al (in preparation), From urban design to transport demand patterns: An integrated approach to study the spatial impacts of automated driving in urbanized regions
### Parameters for the scenarios

<table>
<thead>
<tr>
<th>Category</th>
<th>Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Induced travel</strong></td>
<td></td>
</tr>
<tr>
<td>For road travel by new user groups</td>
<td>Transformation: All public transport transferred to cars on the road network</td>
</tr>
<tr>
<td>By empty ride allocation to pick-up other passengers</td>
<td>Transformation: +20%</td>
</tr>
<tr>
<td>By empty ride allocation to designated parking zones</td>
<td>Transformation: N/A</td>
</tr>
<tr>
<td><strong>Traffic efficiency</strong></td>
<td></td>
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<tr>
<td>Outer-urban roads</td>
<td>Transformation: +100%</td>
</tr>
<tr>
<td>Inner-urban roads</td>
<td>Transformation: +50%</td>
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<tr>
<td>Intersection delay factor</td>
<td>Transformation: All 0.1</td>
</tr>
<tr>
<td><strong>Travel cost factors</strong></td>
<td></td>
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<tr>
<td>Value of time (all purposes)</td>
<td>Transformation: -35%</td>
</tr>
<tr>
<td>Scenario</td>
<td>Mean travel time [min:sec]</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------------------------</td>
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<tr>
<td>0. (Base)</td>
<td>11:48 (ref.)</td>
</tr>
<tr>
<td>1. Transformation</td>
<td>14:43 (+24%)</td>
</tr>
<tr>
<td>2. Growth</td>
<td>19:24 (+64%)</td>
</tr>
<tr>
<td>3. Constraint</td>
<td>11:35 (-1.9%)</td>
</tr>
<tr>
<td>4. Decline</td>
<td>20:00 (+69.5%)</td>
</tr>
</tbody>
</table>
Spatial classification
Spatial transformation potential

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Centre-urban</th>
<th>Outer-centre</th>
<th>Green-urban</th>
<th>Centre-village</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Centre-urban plus</td>
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<td>2. Centre-urban</td>
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<td>3. Centre-small urban</td>
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<td>4. Urban pre-war compact</td>
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<td>5. Urban post-war ground floor</td>
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<tr>
<td>6. Small-urban</td>
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<tr>
<td>7. Green-urban</td>
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<tr>
<td>8. Green-small urban</td>
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<tr>
<td>9. Centre-village</td>
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<tr>
<td>10. Village</td>
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<tr>
<td>11. Rural</td>
<td></td>
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</tbody>
</table>

**Transformation potential:**
- high
- medium
- low
- none
Spatial quality premium house price, based on research by design at (residential) street (0,2) and (arterial) road level (0,8); +5% if street can be made greener, -5% if demand increases too much;
TIGRIS Land use transport interaction model

transformation

sprawl

growth

concentration

constraint

decline

Legend
change in household density compared to base scenario at 2100
-200 to -100
-100 to -50
-50 to -10
0 to 10
10 to 50
50 to 100
100 to 150
150 to 200
200 or above
POLL 3

Problems on sustainable and affordable housing for a growing population or more pressing than automating driving.

1. We need to redesign our cities, ban human driving and allow low speed automated driving in connection to personal and freight mobility hubs.

2. We need automated super highways to connect new dwellings to existing conurbations.

3. Shared electric vehicles that are easy to drive are key to future urban mobility. Why automate?
Progressive deployment of Automated Driving taking place, but less fast as (some) expected.

Automated Vehicles and humans need to learn how to operate safely in shared space.

Automated Driving can support Urban Transformation in combination with public transport, zero-emission vehicles, cycling and new mobility modes.

New methods and models for impact assessment needed to study the fundamental changes in impacts at high levels of automation.

THANK YOU!