AUTOMATED DRIVABILITY
A DIFFERENTIATED PICTURE ON THE SPATIAL DEPLOYMENT OF AUTOMATED VEHICLES

Aggelos Soteropoulos
future.lab, Institute for Transportation System Planning, Technical University of Vienna
OVERVIEW

I. Introduction

II. Framework for the Assessment of the Automated Drivability

III. Assessment of the Automated Drivability for the City of Vienna, Austria

IV. Discussion and Conclusions
I: INTRODUCTION
PUBLIC IMAGINATION OF AUTOMATED VEHICLES

• replacing the driver anywhere and under any conditions in which a normal human driver would be able to drive

Level 5
• Full Driving Automation
• unlimited Operational Design Domain (ODD)

NEAR FUTURE

• situations where the driver is replaced completely, i.e. not requiring driver interventions, only seem feasible in specific ODDs

Level 4
• High Driving Automation
• Limited ODD
OPERATIONAL DESIGN DOMAIN

• Conditions under which a given automated driving system (ADS) is designed to function
  • Geographical conditions
  • Environmental conditions
  • Roadway conditions
  • Traffic conditions
  • Temporal conditions

Complexity of ODD  Requirements of ADS
RELEVANCE OF DIFFERENT STREET SPACES

“Each new environment can bring new challenges and there can be complex intersections in cities like Paris, there is our Lombard Street in San Francisco and there are narrow streets in European towns.”

Drago Anguelov, Principal Scientist, Waymo

January 15, 2019 presentation at the MIT course “Deep Learning for Self-Driving Cars” in Cambridge, MA
RELEVANCE OF DIFFERENT STREET SPACES II

Spheres of causes for disengagments based on disengagement reports in California 2017

- **Infrastructure-related**
  - (bad visibility of road markings, unexpected obstacles, construction sites)
  - 12%

- **Vehicle-related (hard- & software)**
  - (system failures, misinterpretation of data)
  - 45%

- **Traffic environment**
  - (complex situations, unexpected behavior of other road users.)
  - 43%

Own analysis; N=1,550 disengagements
II: FRAMEWORK FOR THE ASSESSMENT OF AUTOMATED DRIVABILITY
STARTING POINT I

Automated Driving System

Perception Variability

Objects
- types,
- appearance
- pose

Scene configuration / object relationships
- occlusions,
- reflections,
- interactions

Environments
- roadway,
- time of day
- seasons

Human-Machine-Interaction/
User Interface

Perception & Cognition

Planning & Control
Automated Driving System

Urban Street Spaces

Traffic features
(e.g. function of the street, traffic volume)

Urban design characteristics
(e.g. character of the area, type and extent of the surrounding uses, specific street space situation)
AUTOMATED DRIVABILITY

Research Question: Which street spaces have a higher suitability for the functioning operation of automated driving systems (ADSs) from a technological-infrastructural point of view (without adaptation of infrastructure) and where are these located?

- Building on the logic of existing frameworks regarding walkability and bikebility

- Based on the combination of the challenges of ADSs with respect to their current technological state and consideration of different street spaces

- Development of components for the framework

- Deriving and calculating indicators for these components for the example of the city of Vienna, Austria
COMPONENTS OF THE FRAMEWORK

1. Perception & Cognition
2. Planning & Control
3. Human-Machine-Interaction/User Interface

Operational Design Domain
restrictions regarding:
- geographical area
- road type
- environment
- ...

Number of objects within the street space
(e.g. numerous road users, road markings, static object/barriers)
COMPONENTS OF THE FRAMEWORK

Operational Design Domain

- restrictions regarding:
  - geographical area
  - road type
  - environment
  - ...

Number of objects within the street space
(e.g. numerous road users, road markings, static object/barriers)

Diversity of objects within the street space
(e.g. different road users, road markings, traffic signs, traffic lights)

Perception & Cognition

Planning & Control

Human-Machine-Interaction/User Interface

restrictions regarding:
- geographical area
- road type
- environment
- …

Number of objects within the street space
(e.g. numerous road users, road markings, static object/barriers)

Diversity of objects within the street space
(e.g. different road users, road markings, traffic signs, traffic lights)
COMPONENTS OF THE FRAMEWORK

**Perception & Cognition**

Diversity of objects within the street space
(e.g. different road users, road markings, traffic signs, traffic lights)

Number of objects within the street space
(e.g. numerous road users, road markings, static objects/barriers)

**Planning & Control**

Permitted speed range
(e.g. less reaction time/time to respond for perception & cognition as well as for planning & control tasks at high speeds)

**Human-Machine-Interaction/ User Interface**

Operational Design Domain

restrictions regarding:
- geographical area
- road type
- environment
- …

**Operational Design Domain**

Number of objects within the street space
(e.g. numerous road users, road markings, static objects/barriers)

Diversity of objects within the street space
(e.g. different road users, road markings, traffic signs, traffic lights)

Permitted speed range
(e.g. less reaction time/time to respond for perception & cognition as well as for planning & control tasks at high speeds)

**Perception & Cognition**
COMPONENTS OF THE FRAMEWORK

Perception & Cognition

Planning & Control

Human-Machine-Interaction/ User Interface

Operational Design Domain

restrictions regarding:
- geographical area
- road type
- environment
- …

Stability of the ODD
(e.g. rapidly changing static barriers, rapidly changing weather and lighting conditions, construction works)

Permitted speed range
(e.g. less reaction time/ time to respond for perception & cognition as well as for planning & control tasks at high speeds)

Number of objects within the street space
(e.g. numerous road users, road markings, static object/ barriers)

Diversity of objects within the street space
(e.g. different road users, road markings, traffic signs, traffic lights)

restrictions regarding:
- geographical area
- road type
- environment
- …

Number of objects within the street space
(e.g. numerous road users, road markings, static object/ barriers)

Diversity of objects within the street space
(e.g. different road users, road markings, traffic signs, traffic lights)
COMPONENTS OF THE FRAMEWORK

Perception & Cognition

Human-Machine-Interaction/ User Interface

Planning & Control

Operational Design Domain

Diversity of objects within the street space (e.g. different road users, road markings, traffic signs, traffic lights)

Number of objects within the street space (e.g. numerous road users, road markings, static object/ barriers)

Condition and Configuration of the road infrastructure (e.g. bad condition/ non-existence of road markings, traffic signs, traffic lights, potholes, existing intersection type, weaving area)

Stability of the ODD (e.g. rapidly changing static barriers, rapidly changing weather and lighting conditions, construction works)

Permitted speed range (e.g. less reaction time/ time to respond for perception & cognition as well as for planning & control tasks at high speeds)

Number of objects within the street space (e.g. numerous road users, road markings, static object/ barriers)

Diversity of objects within the street space (e.g. different road users, road markings, traffic signs, traffic lights)

restrictions regarding:
- geographical area
- road type
- environment
- …
III: ASSESSMENT OF THE AUTOMATED DRIVABILITY FOR THE CITY OF VIENNA, AUSTRIA
DERIVATION AND CALCULATION OF INDICATORS

• Data from Austrian road network and city of Vienna

• Spatial reference = <=100m street links of road network approved for motorized traffic

• Indicators selection based on relevance and data availability, pearson correlation to test correlations among the variety of possible indicators to guide selection

• 13 indicators derived for the components of the framework

• Indicators calculation and additive integration to an integrated Automated Drivability Index (ADX) using GIS
<table>
<thead>
<tr>
<th>Indicator</th>
<th>Criteria type</th>
<th>Number of objects within the street space</th>
<th>Diversity of objects within the street space</th>
<th>Permitted speed range</th>
<th>Stability of the ODD</th>
<th>Condition and shape of the street infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average number of traffic lanes of road(way)</td>
<td>indirect</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>(✓)</td>
</tr>
<tr>
<td>Number of traffic lights</td>
<td>indirect</td>
<td>✓</td>
<td>(✓)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of forbidden legal access for road(way) for pedestrians and cyclists</td>
<td>direct</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of pedestrian crossings</td>
<td>indirect</td>
<td>(✓)</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of pedestrian or encounter zone</td>
<td>indirect</td>
<td>(✓)</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of bicycle infrastructure on road(way)</td>
<td>indirect</td>
<td>(✓)</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of tram tracks on road(way)</td>
<td>indirect</td>
<td>(✓)</td>
<td>✓</td>
<td></td>
<td></td>
<td>(✓)</td>
</tr>
<tr>
<td>Average maximum speed of road(way)s</td>
<td>direct</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Number of bushes in the road space</td>
<td>direct</td>
<td>(✓)</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Average width of road(way)s</td>
<td>direct</td>
<td>(✓)</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Frequency of different types of road surfaces</td>
<td>direct</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Number of three or more arm intersections</td>
<td>direct</td>
<td>(✓)</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Dominant type of residential area</td>
<td>direct</td>
<td>(✓)</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>
AUTOMATED DRIVABILITY INDEX: VIENNA

Suitability of street spaces for the functioning use of automated driving systems

Data sources: gip.gv.at, City of Vienna
IV: DISCUSSION AND CONCLUSIONS
LIMITATIONS

• Further indicators (and data) needed to increase the accuracy of the estimated ADX values (especially on condition of infrastructure, also digital infrastructure)

• not incorporating dynamic indicators such as change of traffic volumes throughout the day, change of weather conditions, existence of construction works yet

• Indicators integration by addition of values (multiplication or weights for respective indicators could also be used)

→ future work!
CONCLUSIONS I

• Cities do not represent homogeneous spaces for the use of AVs

• Results are detailing the complexity of driving urban street spaces for ADSs at a yet unprecedented level

• Disperse urban areas in the outskirts tend to have an advantage over older, mostly more complex city quarters in the centre, in the latter AVs only seem feasible in case of:
  - Major adjustments to the street space (physical infrastructure)
  - Speed reduction (compared to the current state)
  - Retrofitting support due to digital infrastructure

• Possible shift in location favourability through accessibility with AVs
CONCLUSIONS II

• Relevant for policy markers to develop concepts and strategies using different L4 use cases in line with current and future urban policy goals with regard to specific adjustments (infrastructural, speed) which might be needed in specific areas at least in the near feature - support of level 4 islands (European Commission 2017)
EXAMPLE: FREIGHT TRANSPORT – PORT OF VIENNA AND HIGHWAY 4

Port Vienna

Highway 4

low suitability

based on Mitteregger 2019
CONCLUSIONS II

• Relevant for policy markers to develop concepts and strategies using different use cases in line with current and future urban policy goals with regard to specific adjustments (infrastructural, speed) which might be needed in specific areas at least in the near feature - support of level 4 islands (European Commission 2017)

• Relevant for companies to get an overview of the complexity of street spaces in a city – where can/should I deploy my system/ tests with regard to what I want to test?
FURTHER INFORMATION


www.avenue21.city