LEVELS OF DRIVING AUTOMATION FOR ON-ROAD VEHICLES

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OUTLINE

› SAE levels of automation – very brief overview

› Example automation system
  › Classification according to SAE level

› Yet another example automation system
  › And again its SAE level classification

› Moving to a higher automation level

› Conclusion
SAE LEVELS OF AUTOMATION

- Society of Automotive Engineers (SAE) issued standard J3016, January 2014
  - 6 levels of driving automation: 0 – 5
    - 0: no automation
    - 5: full automation

- Corresponds to levels defined by Germany Federal Highway Research Institute (BASt)

- Roughly corresponds to National Highway Traffic Safety Administration (NHTSA) definitions (May 2013)
EXAMPLE: CACC

- Automated short-distance vehicle-following by longitudinal automation
- Increasing road capacity (time gap ≈ 0.3 s)
- Decreasing fuel consumption (trucks: 5 – 20 %)

Control objectives
- Vehicle following
  - $d_i \rightarrow d_{r,i}$
  - desired distance: $d_{r,i} = r + hv_i$
- String stability
  - Attenuation of the effect of disturbances over the vehicle string
CONTROL SYSTEM ARCHITECTURE

- Layered architecture
  - Supervisory layer
  - Control layer
  - Perception / information layer

- Vehicle equipped with low-level controllers
  - Acceleration
  - Steering
VEHICLE CONTROL SYSTEM
CACC AUTOMATION LEVEL?

- Basically, four questions need to be answered to establish the automation level:

1. Longitudinal and lateral automation?
   - No, only longitudinal.

2. Who or what monitors the system?
   - That would be the driver.

3. Fall-back in case of system failure?
   - That would be the driver too.

4. Can I use it on all types of roads?
   - Well, you can try, but it’s not designed for urban situations.
# SAE Automation Level

<table>
<thead>
<tr>
<th>SAE level</th>
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<th>Monitoring</th>
<th>Fall-back</th>
<th>Driving scenarios</th>
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<tbody>
<tr>
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<td>1</td>
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<td>Human driver and system</td>
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<tr>
<td>2</td>
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<td>Conditional automation</td>
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<tr>
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EXAMPLE 2: COOPERATIVE MANEUVERING
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MOVING TOWARDS LEVEL 3

Monitoring

“The activities and/or automated routines that accomplish comprehensive object and event detection, recognition, classification, and response preparation, as needed to competently perform the dynamic driving task.”

Meaning: system should warn the driver if the operational envelope is likely to be abandoned (e.g., a component failure occurs, or decreased object tracking reliability).

Hence, a rather complex system of sensors, sensor fusion, and object tracking is required to reliably monitor the system performance.
MOVING TOWARDS LEVEL 4

Fall-back

“The automated driving system covers all aspects of the dynamic driving task, even if a human driver fails to respond appropriately to a request to intervene.”

Requires mechanisms for

Fail-safety

The property that, in the event of failure, no harm is caused, or at least a minimum of harm, to other devices or danger to personnel.

Graceful degradation

The property that enables a system to continue operating properly in the event of the failure of (or one or more faults within) some of its components. If its operating quality decreases at all, the decrease is proportional to the severity of the failure (graceful degradation).
MOVING TOWARDS LEVEL 4 (CNT’D)

Graceful degradation example: “safety checker”
- Based on quality of object detection (i.e., the specific sensors that detect the preceding vehicle), the desired distance will be automatically enlarged, such that a safe distance is obtained.

Safety checker modes
- Detection without wireless communication (i.e., only on-board sensor(s)): maximum distance
- Detection with wireless communication (possibly with on-board sensor(s)):
  - Preceding vehicle manually driven: medium distance
  - Preceding vehicle controlled (CC/ACC/CACC): smallest distance

Biggest question: which distance is actually “safe”? 
- Prediction of other traffic participants’ behavior
- Trade-off between safety and throughput
CONCLUSION

- Reliable perception and prediction is key to automation level ≥ 3
  - Level 3 automation requires (at least) measures for reliability of object detection
  - Level 4 automation requires mechanism for fail-safety/fault-tolerance which ultimately require traffic prediction

- This is easier for ‘closed’ traffic systems, i.e., no manually driven vehicles

- There’s still a trade-off between safety and traffic efficiency
  - “Automation makes traffic safer ...” is not necessarily true
  - “… because 90% of traffic accidents are caused by human failure” is misleading
THANK YOU FOR YOUR ATTENTION