AI-relevant use cases in automotive engineering

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AI is already being used in cars today. Current and potential future use cases can illustrate how AI technology in automotive engineering can help make cars safer and more efficient. As a basis for this document the review of ENISA and JRC [1] was used together with results from internal BSI projects and discussions with partners from industry and research.

1 Context

1.1 Cooperative, connected and automated mobility (CCAM)

1.1.1 Automated Driving

Connected Autonomous Vehicles (CAVs) are expected to significantly improve road safety, traffic efficiency and comfort of driving, by helping the driver to take the right decisions and adapt in real-time to the traffic situation. According to SAE J3016 6 vehicle automation levels exist starting from 0 (no automation) to 5 (full automation). State-of-the-art is level 2 (partial automation) and level 3 vehicles will become available this year. In contrast to prospective vehicles with Autonomous Driving (AD) capabilities (levels 4 and 5), Level 2 automation is also termed Advanced Driver Assistance Systems (ADAS). ADAS is used as safety features that assist drivers in specific circumstances.

1.1.2 Data-Based Iterative Development Cycle

The complexity of CAVs requires an iterative development cycle which depends upon high quality and high quantity data that is updated regularly. One example is data from accident analyses.

1.1.3 Situatedness: Interaction with the Environment

Vehicles can increasingly interact and communicate with an environment that includes the road infrastructure (roads, tunnels, bridges, traffic signs), traffic management systems (smart city, navigation systems) and other road users.

1.2 Embedding: Relevant Software and Hardware Components

1.2.1 Hardware

The deployed hardware is used as a prerequisite for the automated vehicle operation.

1.2.1.1 Sensors

Sensors may be grouped as follows

- Proprioceptive, such as IMU, GNSS and Encoders (for position, velocity, acceleration, …)
- Exteroceptive, such as LiDAR, CCD Cameras, Radar, Microphone, Ultrasonic and Touch
- Virtual, such as inputs via communication channels or results of internal preprocessing, e.g. sensor fusion

1.2.1.2 Computing units and Network Technology

Computing may take place anywhere in between the edge, i.e. onboard the vehicle, and the cloud. Modules within the vehicle and other modules may communicate via different networking technologies (LAN, WLAN, 4G/5G, …).

1.2.1.3 Actuators

Relevant actuators include engines, steering systems, braking systems, light systems, sound systems and communication systems.

1.2.2 Software

Software systems in vehicles consist of multiple modules which interact with each other and with the hardware. Some of these modules are AI-based, other non-AI-based (or classical) IT modules.

1.2.2.1 Classical IT systems

In principal, classical IT systems (as well as symbolic AI systems) may be directly designed and their parameters adjusted by the human developer. Consequently, these systems are interpretable, traceable and their formal verification is, at least in principal, possible.

1.2.2.2 AI&ML as core enabling technologies

AI intelligence technology may be divided in connectionist AI and symbolic AI [5]: symbolic AI, such as decision trees, may be directly designed and interpreted by the developer whereas connectionist AI, such as neural networks, requires a complex lifecycle including a training phase where the model is trained using a machine learning (ML) algorithm and data. ML may be divided in supervised, unsupervised and reinforcement learning. Data quality and quantity is of paramount importance for the trained model. Since data acquisition is often resource intensive and might have legal implications, public databases for different use cases are the subject of discussion, e.g. scenario databases for autonomous driving, accident databases etc.
Generally, a multitude of applications may be powered by AI, e.g. computer vision (object recognition, segmentation, vehicle localization, object tracking), sequence modelling, automated planning (graph-based, deep reinforcement learning). In the automotive domain AI is mainly employed on the perception side, i.e. the processing of sensor information (e.g. scene understanding, scene flow estimation, scene representation) but also in planning (e.g. route planning, behavioral planning, motion / trajectory planning) and actuator control. AI may be used for automated driving functions as well as for infotainment, vehicle interior monitoring and human machine interactions.

Besides the opportunities offered by employing AI technology its usage also implies qualitatively new vulnerabilities [5], including poisoning attacks during training time, adversarial attacks during the inference phase and privacy attacks.

1.2.2.3 Hybrid Models

Classical IT, symbolic and connectionist AI (or in other words rule-based and data-driven algorithms) may be combined by hybrid models. These might e.g. integrate mathematical, physical, expert and world knowledge (e.g. accident data and formalization of guidelines) into AI models.

1.2.3 Interconnectivity / Interaction between Software- and Hardware-Modules

The interaction of software and hardware modules may have significant impact on the behavior of the system.

1.3 Auditing of AI-based components and AI-based systems

Trustworthy AI requires regulation and auditability of AI modules and AI systems [3,4]. Relatively abstract, domain overarching requirements are e.g. formulated in the European AI act [2] but its operationalization requires concretization for relevant domains and use cases. Specific sectors have their own characteristics and requirements that need to be enabled and developed. In the automotive sector, dedicated AI systems are needed based on automotive use cases. So far practically applicable technical requirements, audit methods and audit tools are not yet sufficiently available and further research and development is required. A constant and transnational discussion is necessary to keep up with the technical development.

2 Use Cases / Applications

AI technology may in principle be employed in use cases ranging from perception to planning to actuation. Due to its limited auditability AI technology is currently predominantly employed in perception, less in planning and even less in actuation. Actuation must always be explainable, and conform to law and local rules. Decision making should be deterministic. Therefore, extensive use of AI/ML and especially end to end learning systems such as neural networks directly connecting sensors and actuators are currently prohibitive.

2.1 Infrastructure and Support Functionality

2.1.1 Accident Analysis

To provide a public, augmented, and highly detailed research database of traffic accidents for diverse regions based on real boundary conditions of the regional road traffic accident statistics and database contents based on AI model results using available in-depth accident data.

2.1.2 Detection, Prediction, Prevention and Management of Incidents

AI can be used for active safety systems, especially in perception. AI methods can also be used to detect hazardous situations in tunnels more quickly and reliably and thus prevent or better manage incidents.

2.1.3 Traffic Flow Management

Traffic flow management and pavement deterioration analysis using data like weather conditions, air quality conditions, surface and subsurface characteristics and performance, geometric data, age and type of pavement, connection function. Traffic flow can be optimized through data-driven approaches such as traffic data or vehicle data, thus reducing fuel consumption and emissions.

2.1.4 Predictive Maintenance

For vehicle and infrastructure components AI technology may be employed for predictive maintenance. It is possible to predict when a vehicle component will need to be replaced to anticipate an expected defect. Another example is pavement deterioration analysis where e.g. supervised learning may be used for a prediction of the deflection of the street and unsupervised learning for clustering of the structural state of the roadway (good, excellent …).

2.2 Automated Driving

Automated driving functions may be categorized into high level functions and low-level functions whereby low-level functions subserve and enable high level functions.

2.2.1 High Level Functions

High level functions may be categorized as generic, ADAS specific and AD specific:

2.2.1.1 Generic

- Collision avoidance
- Rain/grip level
- Virtual sensor replacements
- Driver / passenger interaction
- Voice control
- Global navigation / Path planning
- User interaction: Explanation of decision by ADAS / AD components

2.2.1.2 ADAS specific

- Adaptive cruise control
- Blind spot monitoring
- Traffic sign recognition
- Wrong-way warning
- Driver drowsiness detection
- Lane keeping assistant
- Lane changing assistant
- Lane leaving warning
- Parking assistant
- High beam assistant
- Safe exit assistant
- Emergency brake assistant
- Night vision assistant
- Environmental sound detection

2.2.1.3 AD specific

- Priority map-based localization
- Road user detection
- Road elements detection
- Free space detection
- Rule-based decision-making
- Automated valet parking

- Cooperative intelligent transport systems
- Behavior prediction
- Local path planning
- User interaction: Emergency take over by driver

2.2.2 Low Level Functions

- Detection of
  - roads
  - lanes
  - moving agents
  - Traffic signs
  - Stationary obstacles
- Traffic jam recognition
- Markings recognition
- Tracking of objects
- Sound event recognition
- Localization
- Occupancy maps
- Routing
- Behavior planning
- Motion planning
- Trajectory execution

3 Literature

[1] ENISA / JRC: Cybersecurity challenges in the uptake of artificial intelligence in autonomous driving (2021)
[2] European Commission: Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL LAYING DOWN HARMONISED RULES ON ARTIFICIAL INTELLIGENCE (ARTIFICIAL INTELLIGENCE ACT), 2021, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0206
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