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AUTONOMOUS DRIVING ARCHITECTURE (ADA)

Enabling Intelligent, Automated, and Connected Vehicles and Transportation

Authored by

Autonomous Driving Working Group

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AUTONOMOUS DRIVING ARCHITECTURE

ABSTRACT

As the automotive industry continues its rapid evolution toward autonomy, this document describes a prototypical Autonomous Driving Architecture (ADA) along with a promising application ecosystem. It comprehensively explores fundamental components within ADA, ranging from hardware and software stack layers to regulatory and ethical considerations.

- Trends and challenges: The document sets the stage by detailing prevailing trends shaping autonomous driving. It navigates challenges encountered in transformation, encompassing safety imperatives, regulatory complexities, cybersecurity concerns, and societal readiness.
- ADA: A focal point of the discussion, ADA delineates the hierarchical layers comprising hardware, software stack layers, infrastructure, services, and application interfaces. By proscribing their interplay, ADA's modular and scalable framework will promote the evolution of autonomous driving systems.
- Applications: Venturing into practical uses, the document explores diverse applications fostered by ADA's ecosystem, from immersive in-vehicle experiences to revolutionizing mobility.
- Innovative technologies: At the forefront of innovation, emerging technologies such as artificial intelligence and vehicle-to-everything (V2X) communication are considered as enablers for autonomous driving and smart cars.
- Regulatory and ethical considerations: The document navigates the regulatory terrain governing autonomous vehicles, such as safety standards, certification protocols, and legal frameworks.

In essence, this document offers a holistic view of ADA and its ecosystem, illuminating its vast potential and the challenges ahead in realizing the vision of autonomous mobility.

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1. INTRODUCTION

Smart cars, like the proliferation of other digital products, will reshape the landscape of the global automotive and transportation industry into a new era of software-defined vehicles (SDVs). The automotive industry is undergoing an innovation process akin to the replacement of feature phones with smartphones. This transformation encompasses various aspects, including the shift from internal combustion engines to electric motors as the primary powertrain, the evolution from manual driving to autonomous driving, and the transition from individual car ownership and driving to embracing safe, convenient, and cost-effective travel services.

The new transportation industry integrates the automotive, IT, communication, transportation, and energy sectors. It has the potential to lead to a reversal of current leading companies and countries, resulting in a massive transfer and reconfiguration. This marks the crown of the global fourth industrial revolution.

At the same time, the software for smart cars encompasses a range of modern software, including real-time embedded firmware, cloud computing software, consumer software, simulation software, AI algorithms, and large-scale multi-agent collaborative system software. The complexity and criticality of smart car software underscore the imperative need to ensure the utmost safety, security, and reliability. The ramifications of software failures extend far beyond mere inconvenience, potentially posing life-threatening consequences, necessitating the adoption of advanced software engineering and testing methodologies to ensure rigorous validation.

This document targets declarations of ADA in the technologies, applications, and related issues. Its scope and methodology range from trends, layers, applications, and innovations to regulatory and ethical issues, consisting of software, hardware, data, AI (including deep learning models and large-scale models), applications, safety/security, laws, and social factors, etc.

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2. TRENDS AND CHALLENGES OF THE AUTOMOTIVE AND TRANSPORTATION INDUSTRY

The automotive and transportation industry stands amid a transformative era where rapid technological advancements, evolving consumer preferences, and global challenges are reshaping the landscape. Technological innovations, such as autonomous vehicles, are redefining traditional notions of mobility. Connectivity and data-driven insights are revolutionizing the way vehicles operate and interact with their surroundings. The emergence of autonomous and intelligent vehicles, smart infrastructure, and the integration of digital platforms are reshaping business models and operational processes. Adapting to these technological disruptions while ensuring safety, security, and regulatory compliance poses a formidable challenge for industry stakeholders.

As the world embarks on this journey into the future, it becomes imperative to comprehensively examine the major trends and challenges that define the trajectory of this crucial sector.

2.1. TRENDS

The industry is undergoing a profound transformation driven by several key trends. This white paper explores the following major trends shaping the future of this industry and the challenges that accompany them.

2.1.1. SOFTWARE: ARISE OF A SOFTWARE-DEFINED VEHICLE

SDVs mark a significant trend in the automotive industry. Vehicles are no longer purely mechanical; they are becoming increasingly intelligent with sophisticated software governing various aspects. This trend includes the development of advanced driver assistance systems (ADAS) and autonomous driving (AD) capabilities, OTA capability, vehicle-cloud computing collaboration, etc., highlighting the industry's journey toward a future where vehicles are not only electric but also intelligent and capable of autonomous operation.

Software-defined vehicles not only bring intelligence such as ADAS/AD's AI and algorithms but also use the complex software on the complex hardware to implement most conventional vehicle functionalities, such as cockpit, smart chassis, power domain (BMS/VCU), body domain, etc. In addition, OTA capability and function/application updates in the vehicle life cycle need the new in-vehicle software layers, such as the vehicle operating system (VOS) and application.

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Software-defined systems empower vehicles to optimize performance dynamically, leveraging real-time data and user preferences. This optimization spans adaptive engine management, efficient energy utilization in electric vehicles, and dynamic adjustments to driving conditions, which culminate into a driving experience characterized by heightened efficiency, responsiveness, and sustainability.

2.1.2. HARDWARE: FROM DISTRIBUTED TO CENTRALIZED

The traditional automotive architecture, characterized by numerous electrical control units (ECUs) distributed throughout the vehicle, is undergoing a profound transformation. This shift involves transitioning towards a centralized computing platform or HPC, where the functions and capabilities of multiple ECUs are consolidated into a unified, centralized system; then, automakers can simplify the architecture, reducing the number of ECUs and associated wiring.

As vehicles become increasingly reliant on software for their operations, a centralized architecture provides a unified framework for implementing features such as connectivity, autonomous driving, and over-the-air updates. This consolidation not only simplifies the vehicle's electrical system but also enhances efficiency by facilitating seamless communication between different vehicle systems/components.

Centralized computing architectures offer scalability and adaptability, allowing for easier incorporation of future technologies and functionalities. As automotive technology continues to evolve, having a flexible and scalable platform is essential for seamlessly integrating new features, addressing security concerns, and ensuring compatibility with evolving industry standards.

2.1.3. ECOSYSTEM: IN-VEHICLE EXTENDS TO MULTI ECOSYSTEMS

With the ADAS/AD functionalities and new software and hardware, an electric smart car is not only a safe and efficient form of mobility but also an energy center and computing center. The fleet vehicles will work closely with smart cities and transportation, smart grid, smart data center with AI, etc. The vehicle ecosystem is extended into more ecosystems, and more innovations and new markets emerge.

2.1.4. AI: FROM SMALL MODELS TO A UNIFIED LARGE MODEL

As time goes on, the AI techniques in autonomous driving gradually evolve. It is seen that the multiple small models to handle various problems in perception, prediction, localization, and planning, etc., have evolved, such as bird's eye view (BEV) and transformer network, 3D occupancy network (OccNet), and world model, etc. In the

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meantime, since large-scale language models (LLMs) make breakthroughs in AI with the emergent technologies of commonsense knowledge and reasoning, an end-to-end solution with a unified large model is being considered. However, energy efficiency and sustainability are crucial factors in the design and operation of autonomous vehicles. Overreliance on computational-heavy models like LLMs could indeed pose challenges in terms of energy consumption, especially in resource-constrained environments such as electric vehicles.

2.2. CHALLENGES

While these trends promise a more sustainable, connected, and intelligent future for the automotive and transportation sector, they also present unique challenges that need to be addressed for successful implementation.

2.2.1. ESCALATING SOFTWARE COMPLEXITY

As vehicles become more reliant on software for operations, the complexity of software development increases exponentially. The integration of features such as infotainment, ADAS, and autonomous driving demands sophisticated software solutions. Managing this complexity poses a challenge for automakers, requiring robust development processes and frameworks to help ensure the reliability and performance of the software-defined systems. The failure of one module can potentially impact the performance of the entire system, emphasizing the need for robust interconnectivity.

Ensuring that software remains up-to-date, secure, and compatible with evolving technologies requires continuous testing and validation of software. Simulating real-world scenarios and edge cases and ensuring the resilience of software to unforeseen circumstances are challenges that automakers need to address comprehensively. Collaboration between different teams, including hardware and software engineers, becomes critical to achieve a cohesive and integrated software-defined system.

2.2.2. DATA-DRIVEN SOFTWARE DEVELOPMENT

The automotive industry is experiencing a paradigm shift towards data-driven software development. This entails collecting vast amounts of data to enhance intelligence, train artificial intelligence (AI) models for advanced driver assistance (AD/ADAS), improve telemetry and diagnostics, and enhance user experiences. Effectively harnessing and managing this data becomes crucial for the success of automotive software initiatives, necessitating the development of robust data infrastructure and analytics capabilities.

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