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Project 565

AV4EV: Open-Source Modular Autonomous Electric Vehicle Platform for Making Mobility Research Accessible

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16. Abstract

When academic researchers develop and validate autonomous driving algorithms, there is a challenge in balancing high-performance capabilities with the cost and complexity of the vehicle platform. Much of today's research on autonomous vehicles (AV) is limited to experimentation on expensive commercial vehicles that require large skilled teams to retrofit the vehicles and test them in dedicated facilities. On the other hand, 1/10th-1/16th scaled-down vehicle platforms are more affordable but have limited similitude in performance and drivability. To address this issue, we present the design of a one-third-scale autonomous electric go-kart platform with open-source mechatronics design along with fully functional autonomous driving software. The platform's multi-modal driving system is capable of manual, autonomous, and teleoperation driving modes. It also features a flexible sensing suite for the algorithm deployment across perception, localization, planning, and control. This development serves as a bridge between full-scale vehicles and reduced-scale cars while accelerating cost-effective algorithmic advancements. Our experimental results demonstrate the AV4EV platform's capabilities and ease of use for developing new AV algorithms. All materials are available at AV4EV.org to stimulate collaborative efforts within the AV and electric vehicle (EV) communities.

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1. Project Abstract

This report outlines the development and capabilities of AV4EV, an open-source, modular autonomous electric vehicle platform designed to enhance the accessibility of mobility research. Current autonomous vehicle (AV) research often relies on expensive commercial platforms, limiting experimentation to well-funded institutions with large expert teams. AV4EV addresses this challenge by providing a cost-effective, easily reconfigurable, and widely deployable platform that balances high-performance capabilities with practical accessibility. The report details the platform's modular hardware, flexible software stack (including Autoware integration), and its successful application in various research areas, from urban driving to precise mapping and high-speed autonomy. By fostering a broader research community, AV4EV aims to accelerate innovation in autonomous driving by lowering the barriers to entry for academic researchers and students.

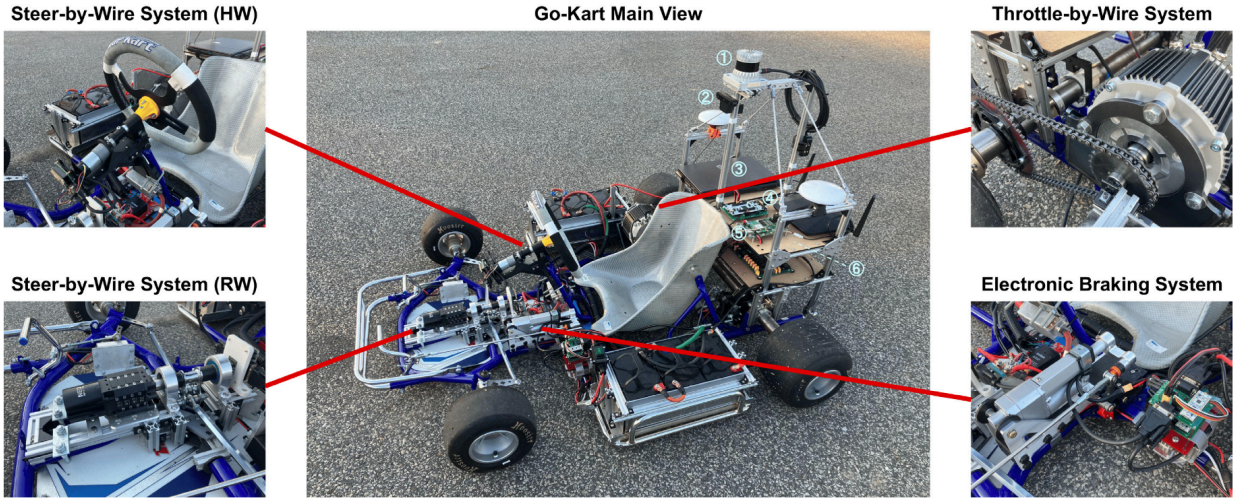


Fig. 1: Go-kart platform overview with Steer-by-Wire System (SBWS) including its hand wheel (HW) and road wheel (RW) components, Throttle-by-Wire System (TBWS), and Electronic Braking System (EBS). The sensors and computing units mounted on the double-deck rear shelf are enumerated from top to bottom as follows: (1) Ouster LiDAR, (2) OAK-D camera, (3) Onboard laptop, (4) Main Control System (MCS), (5) Sepentrio GNSS, and (6) IMU, concealed from the main view perspective, is positioned on the lower deck.

2. Project Overview

The field of autonomous driving is rapidly evolving, demanding innovative research and development. However, a significant barrier to entry for many academic institutions and researchers is the prohibitive cost and complexity associated with developing and testing algorithms on full-scale, commercial autonomous vehicles. These vehicles typically require substantial financial investment, specialized facilities, and large, skilled teams for retrofitting and testing. This limits advanced AV research to a select few, hindering the overall pace of innovation.

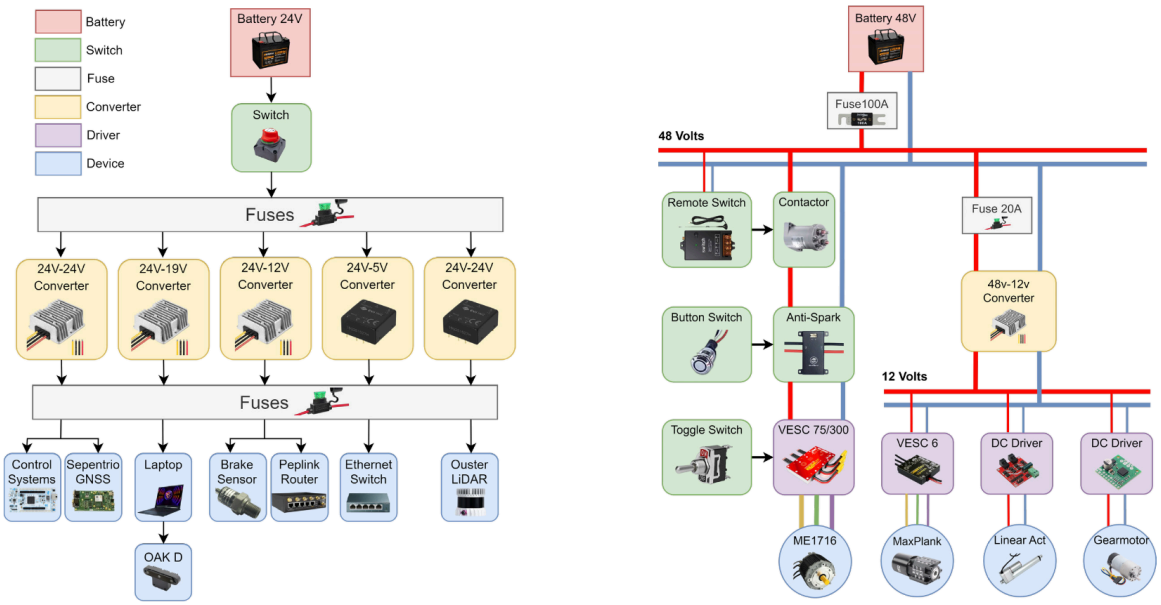
The AV4EV project was conceived to democratize autonomous mobility research. It aims to provide an affordable, accessible, and highly flexible open-source platform that enables

researchers and students to experiment with and validate autonomous driving algorithms in real-world scenarios without the need for extensive resources. The platform's design emphasizes modularity, allowing for easy customization and integration of new technologies, and its open-source nature promotes collaboration and rapid iteration within the research community. By bridging the gap between theoretical algorithm development and practical deployment, AV4EV seeks to accelerate progress in diverse areas of autonomous mobility.

3. Main Contributions

The AV4EV platform makes several significant contributions to autonomous mobility research:

- 3.1. Accessible and Cost-Effective Platform Design:
  AV4EV introduces a novel approach to autonomous vehicle research by providing an open-source, low-cost platform. This directly addresses the current challenge where high-performance AV research is often limited to expensive commercial vehicles. By reducing the financial and logistical barriers, AV4EV enables a much broader range of academic institutions, researchers, and students to engage in cutting-edge mobility research.
- 3.2. Modular Hardware Architecture:
  A key contribution of AV4EV is its highly modular hardware architecture. This design allows for flexible integration of various sensors (e.g., LiDAR, cameras, radar, IMU), computing units (e.g., NVIDIA Jetson, industrial PCs), and other components. This modularity ensures that the platform can be easily adapted and reconfigured for different research objectives and experiments, promoting versatility and future-proofing the system against technological advancements.
- 3.3. Flexible Software Stack with Autoware Integration:
  AV4EV features a flexible software stack built around the Robot Operating System (ROS) and seamlessly integrates with Autoware, a leading open-source software for autonomous driving. This integration provides researchers with a robust and familiar environment to develop, test, and deploy their algorithms, leveraging the extensive functionalities and community support available within the Autoware ecosystem.
- 3.4. Comprehensive Testbed Capabilities:
  The platform is engineered to serve as a comprehensive testbed for a wide array of autonomous driving functionalities. This includes, but is not limited to, sensing and perception, localization and mapping, motion planning, and control algorithms. Its design facilitates rigorous testing and validation of algorithms in real-world driving conditions, which is crucial for advancing the reliability and safety of autonomous systems.
- 3.5. Real-World Driving Capabilities:
  Unlike purely simulated environments or limited testbeds, AV4EV is capable of real-world autonomous driving. It supports various driving scenarios, including urban driving, parking, and precise mapping. This real-world capability is essential for validating algorithms under diverse and unpredictable conditions, providing invaluable insights that cannot be replicated in simulations alone.



(a) Sensing (b) Motor

Fig. 2: Sensing (left) and motor (right) power system with connections and devices.

4. Results

The deployment and evaluation of the AV4EV platform have demonstrated its effectiveness and versatility in advancing autonomous mobility research:

- 4.1. Versatility in Research Applications:
  AV4EV has proven to be a highly versatile platform, successfully deployed in various research applications. This includes, but is not limited to, the development and testing of advanced perception algorithms, precise localization and mapping techniques, and sophisticated motion planning and control strategies. Its adaptability has facilitated research across different autonomous driving challenges.

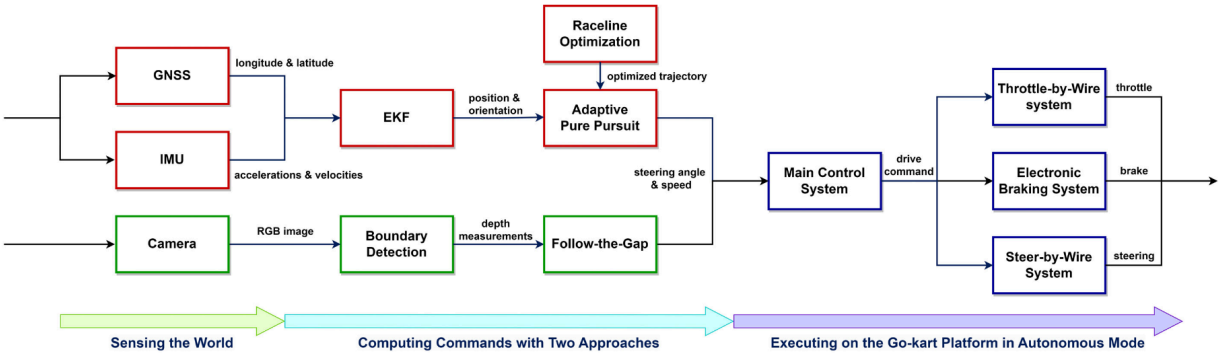


Fig. 3: Software pipeline for go-kart autonomous driving capabilities: GNSS-based adaptive pure pursuit (red), camera-based follow-the-gap (green), go-kart mechatronics execution (blue).

- 4.2. Performance and Reliability:
  Despite its cost-effectiveness, AV4EV demonstrates competitive performance in

real-world autonomous driving scenarios. The platform's integrated hardware and software components exhibit robust reliability, enabling consistent execution of complex autonomous tasks. This performance ensures that research conducted on AV4EV yields meaningful and reproducible results comparable to those obtained on more expensive platforms.

- 4.3. Impact on Research Accessibility and Collaboration:
  The open-source nature and accessibility of AV4EV have significantly lowered the barriers to entry for autonomous driving research. This has enabled more academic institutions and research groups to participate in cutting-edge mobility studies. The platform actively fosters collaboration among researchers, promoting knowledge sharing and accelerating the development of innovative autonomous solutions within a broader and more diverse community.

5. Authors

The development and research presented in this report were conducted by the following individuals:

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