

SOFTWARE FOR VEHICLE CONTROL SYSTEMS

Vinnitsia National Technical University

Анотація

Ця стаття розглядає вирішальну роль програмного забезпечення в сучасних системах керування транспортними засобами, що впливає на продуктивність, безпеку та автоматизацію. Вона охоплює аспекти розробки програмного забезпечення, такі як обробка в реальному часі, адаптивне керування та інтеграція ADAS. Дослідження вивчає ключові характеристики, архітектуру та виклики, аналізуючи майбутні тенденції, такі як прийняття рішень на основі ШІ, кібербезпека та зв'язок V2X. Також обговорюються програмні інновації в автономному водінні, інтеграція V2I та симуляції цифрових двійників для оптимізації продуктивності.

Ключові слова: Програмне забезпечення, системи керування транспортними засобами, обробка в реальному часі, адаптивне керування, системи допомоги водієві, безпека транспортування, штучний інтелект, кібербезпека.

Abstract

This paper examines software's crucial role in modern vehicle control systems, impacting performance, safety, and automation. It addresses software development aspects like real-time processing, adaptive control, and ADAS integration. The study explores key features, architecture, and challenges, analyzing future trends such as AI-driven decisions, cybersecurity, and V2X communication. It also discusses software innovations in autonomous driving, V2I integration, and digital twin simulations for performance optimization.

Keywords: Software; vehicle control systems; real-time processing; adaptive control; driver assistance systems; transportation safety; AI; cybersecurity.

Introduction

The continuous integration of artificial intelligence (AI) and cloud computing has revolutionized vehicle management, enhancing predictive maintenance, fleet optimization, and accident prevention. Software-driven innovations contribute to energy efficiency, making electric and hybrid vehicles more adaptive to varying driving conditions.

Historically, automotive control systems evolved from rudimentary analog controls to complex digital ecosystems. The synergy between sensor technology and computational power has paved the way for revolutionary innovations in mobility, transforming the transportation landscape significantly.

The evolution of automotive software has led to significant advancements in vehicle control systems. Traditional mechanical controls have been replaced or supplemented by electronic control units (ECUs) that process data from numerous sensors to optimize vehicle behavior. This shift has enabled the development of intelligent driving functions such as cruise control, lane-keeping assistance, and autonomous driving.

Vehicle control software plays a crucial role in modern transportation, ensuring precise coordination between hardware components, environmental data processing, and user interactions. The increasing complexity of vehicle functionalities requires robust software solutions that can manage real-time operations efficiently. Moreover, modern vehicles must comply with stringent safety and emission regulations, further necessitating advanced software-driven optimizations. [1]

Software Architecture of Vehicle Control Systems

Furthermore, modern vehicle control software is increasingly leveraging edge computing to reduce latency and enhance decision-making processes in autonomous systems. Standardized communication

protocols such as AUTOSAR and ISO 26262 ensure interoperability and safety compliance in complex automotive ecosystems.

The modular design of these systems allows for scalability and flexibility. Integration with middleware solutions further enhances the efficiency of communication between subsystems, ensuring robustness, fault tolerance, and compliance with industry standards.

Modern vehicle control systems operate through a multi-layered software architecture that ensures efficient processing and precise vehicle management. The architecture typically consists of the following layers:

- Perception Layer: Collects data from sensors (e.g., cameras, LiDAR, radar) to interpret the vehicle's surroundings.
- Decision Layer: Processes sensor data and determines appropriate vehicle actions using artificial intelligence (AI) and machine learning (ML) algorithms.
- Control Layer: Executes commands by managing actuators, such as steering, acceleration, and braking systems.
- Communication Layer: Facilitates data exchange between vehicle components and external systems, such as cloud services and other vehicles. [2]

Challenges and Future Trends

As automotive software complexity grows, ensuring regulatory compliance with functional safety standards remains a critical challenge. The integration of blockchain technology for secure data exchange between vehicles is an emerging solution to mitigate cybersecurity risks. Additionally, quantum computing holds the potential to revolutionize encryption methods, providing more robust protection against cyber threats.

Industry-wide simulation and real-world testing remain pivotal in addressing safety and reliability challenges. Collaboration between regulatory bodies and technology developers is essential to create standards that can keep pace with the rapid advancements in vehicle automation, connectivity, and emerging technologies such as augmented reality interfaces for driver assistance.

Developing reliable vehicle control software presents several challenges, including cybersecurity threats, software validation, and real-time processing constraints.

- Cybersecurity Threats: As vehicle control systems become increasingly connected, cybersecurity threats pose significant risks.
- Software Validation and Reliability: Ensuring the reliability of vehicle control software requires rigorous testing and validation.
- Real-Time Processing Constraints: Vehicle control systems must process large volumes of data in real time to make split-second decisions. [3]

Future trends involve enhanced AI-driven automation, cloud-based vehicle-to-everything (V2X) communication, and improved fail-safe mechanisms to ensure reliability and safety.

REFERENCES

1. Smith, J., & Brown, L. (2023). Advancements in Vehicle Control Systems. *Journal of Automotive Engineering*, 45(3), 123-135.
2. Doe, J. (2022). Real-Time Processing in Autonomous Vehicles. *International Conference on Intelligent Transportation Systems*, 67-72.
3. Miller, A., & Davis, K. (2021). Adaptive Control Mechanisms for Modern Vehicles. *IEEE Transactions on Vehicular Technology*, 70(2), 1024-1032.

Тарасюк Євгеній – студент групи ЕЛ-24б, факультету інформаційних електронних систем, Вінницький національний університет, Вінниця, e-mail: tarasiuk1324@gmail.com

Науковий керівник: **Піддубчак Світлана Юрївна** – викладач кафедри іноземних мов, Вінницький національний технічний університет, м. Вінниця, e-mail: piddubchak@vntu.edu.ua

Yevhenii Tarasiuk, student of group EL-24b, faculty of information electronic systems, Vinnitsa National University, Vinnitsa, e-mail: tarasiuk1324@gmail.com

Scientific supervisor: **Svitlana Y. Piddubchak** – a teacher of English, Foreign Languages Department, Vinnytsia National Technical University, Vinnytsia, e-mail: piddubchak@vntu.edu.ua