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Advancing Functional Safety in Automated Driving: A Methodological Approach to Legacy System Integration under ISO 26262

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Abstract: ***This article presents a novel method for enhancing the design of Functional Safety Concepts (FSC) in automated driving systems, addressing the challenges of integrating legacy components within the ISO 26262 framework. The proposed approach systematically leverages existing diagnostic specifications of legacy subsystems to assess their impact on safety-critical functions, producing abstracted reports suitable for vehicle architects. This method facilitates the creation of Preliminary Architectures (PA) and supports FSC verification argumentation. Tested on a safety-critical braking subsystem at Scania C.V. AB, the approach demonstrates several benefits: effective reuse of existing work products, comprehensive requirement gathering for automated driving, efficient parallelization of work across expertise domains, and broad applicability to various subsystems. Results indicate that this method not only enables cost-effective and robust design but also aligns with evolving industry standards for safety in automated driving systems. The article concludes by discussing the implications of this approach for the automotive industry and suggesting directions for future research in functional safety concept design.***
Keywords: ISO 26262, Functional Safety Concept (FSC), Legacy Diagnostics, Preliminary Architecture (PA), Safety Verification.

I. INTRODUCTION

The automotive industry is undergoing a rapid transformation driven by the advent of automated driving systems. This shift has brought functional safety to the forefront, with ISO 26262 emerging as the gold standard for ensuring the safety of electrical and electronic systems in road vehicles [1].

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However, the integration of legacy components into new automated driving architectures presents significant challenges, particularly in adhering to the top-down approach advocated by ISO 26262. While the standard provides a comprehensive safety lifecycle, it lacks specific guidance on leveraging existing systems—a common practice in the cost-sensitive automotive domain [2]. This gap in methodological support poses difficulties for vehicle architects and safety engineers, especially when balancing innovation with the need to maintain compatibility with proven, reliable systems. Our article addresses this challenge by proposing a novel method for designing Functional Safety Concepts (FSC) that systematically incorporates legacy diagnostic specifications within the ISO 26262 framework, thereby enhancing the safety and efficiency of automated driving systems.

II. LITERATURE REVIEW

A. ISO 26262 and Functional Safety In Automotive Industry

The ISO 26262 standard has become the cornerstone for functional safety in the automotive industry, providing a comprehensive framework for managing safety-related systems throughout the entire product lifecycle. Since its introduction, it has significantly influenced the development processes for electrical and electronic systems in vehicles [3]. The standard emphasizes a top-down approach to safety design, starting with hazard analysis and risk assessment, and progressing through the definition of safety goals, functional safety concepts, and technical safety concepts. However, the application of ISO 26262 to complex systems, such as those involved in automated driving, presents unique challenges. These challenges include the need for more sophisticated hazard analysis techniques, the integration of software-intensive systems, and the consideration of environmental factors that may affect system safety.

Characteristic	Legacy Systems	Modern Automated Driving Systems
Safety Standard	Pre-ISO 26262	ISO 26262 compliant
Complexity	Lower	Higher
Software Dependency	Limited	Extensive
Connectivity	Minimal	Highly connected
Adaptability	Fixed functionality	Adaptive and learning capabilities
Safety Mechanisms	Basic	Advanced, multi-layered

Table 1: Comparison of Legacy and Modern Automotive System Characteristics [5]

B. Legacy Systems Integration In Automated Driving

The integration of legacy systems into new automated driving architectures is a critical challenge faced by the automotive industry. While newer vehicles are designed with automated driving capabilities in mind, many existing vehicles and components were not originally conceived for such applications. This integration is crucial for cost-effectiveness and leveraging proven technologies, but it presents significant technical and safety challenges. Legacy systems often lack the comprehensive safety analysis required by ISO 26262, and their integration into modern architectures can introduce new failure modes and safety risks that need to be carefully assessed and mitigated.

C. Diagnostic Specifications And Their Role In Safety Assessment

Diagnostic specifications play a vital role in the safety assessment of automotive systems, particularly when integrating legacy components into newer architectures. These specifications typically include detailed information about system behavior, failure modes, and detection mechanisms. In the context of functional safety, diagnostic specifications can provide valuable insights into the fault detection and management capabilities of a system. However, the challenge lies in translating these often low-level, component-specific diagnostics into system-level safety concepts that align with the ISO 26262 framework.

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This translation process requires a systematic approach to ensure that all relevant diagnostic information is considered in the overall safety strategy for automated driving systems [4].

III. PROPOSED METHOD

A. *Overview of the approach*

Our proposed method aims to address the challenges of integrating legacy systems into modern automated driving architectures while adhering to the ISO 26262 functional safety standard [5]. The approach centers on leveraging legacy subsystems' existing diagnostic specifications to comprehensively assess their influence on safety-critical functions. This method bridges the gap between legacy system knowledge and the requirements of ISO 26262, enabling a more efficient and robust design process for Functional Safety Concepts (FSC).

The core steps of our approach include:

1) Identification and collection of legacy diagnostic specifications
2) Analysis and categorization of diagnostic information
3) Mapping of diagnostic data to ISO 26262 safety concepts
4) Generation of abstracted safety reports for vehicle architects
5) Integration of findings into Preliminary Architectures (PA) and FSC verification

B. *Leveraging Legacy Diagnostic Specifications*

Legacy diagnostic specifications often contain valuable information about system behavior, fault detection mechanisms, and failure modes [6]. Our method systematically extracts and analyzes this information to inform the safety assessment process. We propose a structured approach to categorize diagnostic data based on its relevance to different Automotive Safety Integrity Levels (ASIL) and its potential impact on safety goals.

The categorization process involves:

1) Identifying safety-relevant diagnostic information
2) Assessing the completeness and adequacy of existing diagnostics
3) Determining gaps in diagnostic coverage for modern safety requirements
4) Prioritizing diagnostic data based on its criticality to safety functions

This systematic analysis allows for a more comprehensive understanding of the legacy system's capabilities and limitations in the context of functional safety.

C. *Integration with ISO 26262 Framework*

The final step of our method involves integrating the insights gained from legacy diagnostic specifications into the ISO 26262 framework. This integration is crucial for ensuring that the reuse of legacy components aligns with modern safety standards and practices.

Key aspects of this integration include:

1) Mapping legacy diagnostic capabilities to ISO 26262 safety mechanisms
2) Identifying additional safety measures required to meet ASIL requirements
3) Developing strategies to address gaps between legacy diagnostics and ISO 26262 expectations
4) Creating traceability between legacy system behaviors and safety goals

By systematically integrating legacy diagnostic information into the ISO 26262 process, our method enables more informed decision-making in the design of Functional Safety Concepts. This approach not only facilitates the reuse of valuable legacy components but also ensures that safety considerations are comprehensive and aligned with current standards.

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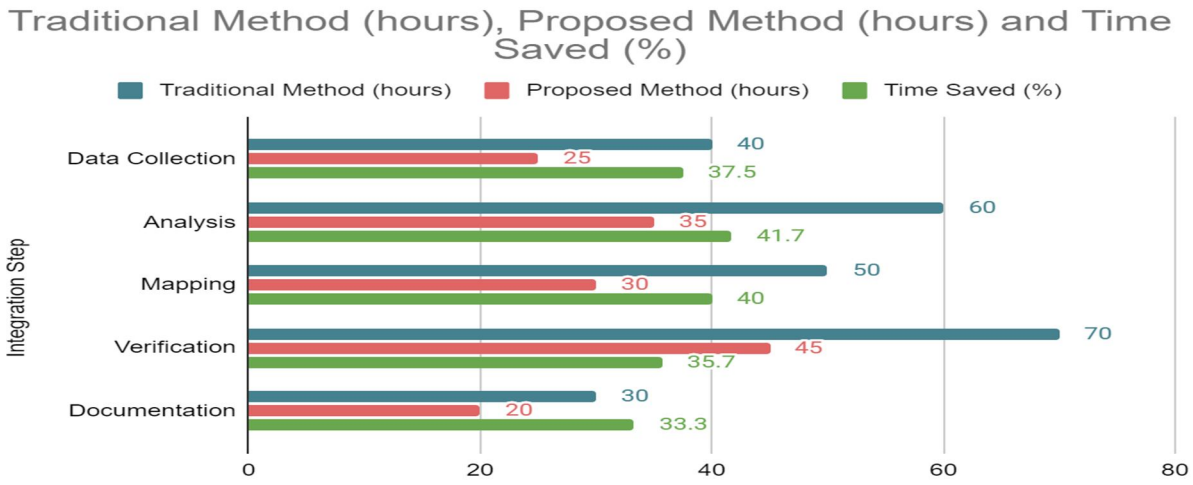


Fig. 1: Integration Effort Comparison [7]

IV. FUNCTIONAL SAFETY CONCEPT DESIGN PROCESS

A. *Assessment Of Legacy Subsystems' Influence On Safety-Critical Functions*

This step involves a comprehensive analysis of how legacy subsystems interact with and influence safety-critical functions in the context of automated driving. We propose a systematic approach that includes:

1) Identifying safety-critical functions in the automated driving system
2) Mapping legacy subsystems to these functions
3) Analyzing the potential impact of legacy subsystem failures on safety-critical functions
4) Evaluating the adequacy of existing diagnostic and safety mechanisms in legacy subsystems

This assessment provides a foundation for understanding the safety implications of integrating legacy components into modern automated driving architectures.

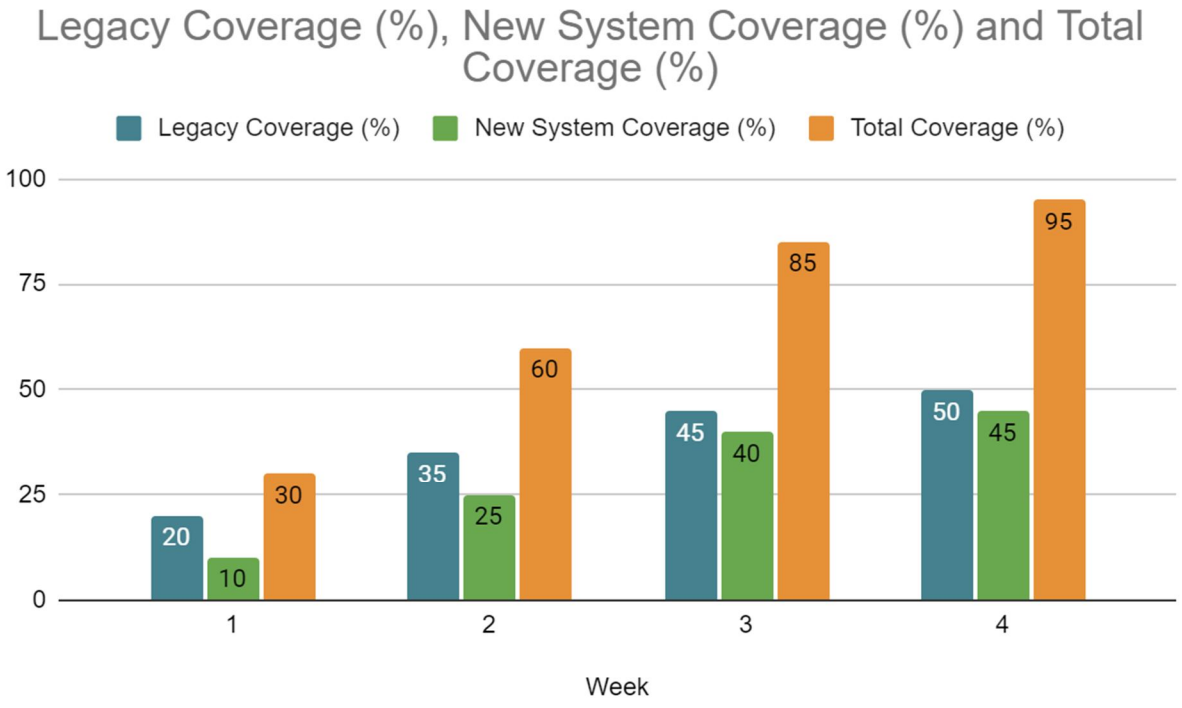


Fig. 2: Safety-Critical Function Coverage Over Project Timeline [8]

B. Generation Of Abstracted Reports For Vehicle Architects

Based on the assessment in 4.1, we generate abstracted reports tailored for vehicle architects. These reports:

1) Summarize the safety-critical interactions between legacy subsystems and automated driving functions
2) Highlight potential safety gaps or vulnerabilities
3) Provide recommendations for additional safety measures or modifications
4) Present the information in a format that facilitates high-level architectural decision-making

The goal is to provide vehicle architects with clear, actionable insights that inform the overall system design while abstracting away unnecessary technical details.

C. Creation of Preliminary Architectures (PA)

Using the insights from the abstracted reports, we develop Preliminary Architectures that:

1) Integrate legacy subsystems with new automated driving components
2) Incorporate necessary safety mechanisms to address identified gaps
3) Define clear interfaces between legacy and new components
4) Ensure compliance with ISO 26262 requirements

These PAs serve as a blueprint for the final system architecture, balancing the reuse of legacy components with the safety requirements of automated driving.

D. Argumentation for FSC verification

The final step involves developing a robust argumentation for the verification of the Functional Safety Concept. This includes:

1) Demonstrating how the integrated system meets safety goals
2) Providing evidence of the effectiveness of safety mechanisms
3) Addressing any residual risks associated with legacy subsystems
4) Showing traceability between safety requirements and implemented measures

This argumentation is crucial for demonstrating compliance with ISO 26262 and ensuring the overall safety of the automated driving system[7].

V. CASE STUDY: SAFETY-CRITICAL BRAKING SUBSYSTEM AT SCANIA C.V. AB

A. Implementation of the proposed method

In this subsection, we detail the application of our proposed method to a safety-critical braking subsystem at Scania C.V. AB. The implementation process includes:

1) Identifying and collecting legacy diagnostic specifications for the braking subsystem
2) Analyzing and categorizing the diagnostic information based on its relevance to different ASILs
3) Mapping the diagnostic data to ISO 26262 safety concepts
4) Generating abstracted safety reports for Scania's vehicle architects
5) Integrating the findings into Preliminary Architectures (PA) and the Functional Safety Concept (FSC) verification process

We describe the challenges encountered during implementation and how they were addressed, providing insights into the practical aspects of applying our method in a real-world scenario [8].

B. Results And Performance Evaluation

This subsection presents the outcomes of applying our method to Scania's braking subsystem. We evaluate the performance of our approach based on several criteria:

1) Effectiveness in identifying safety-critical interactions between the legacy braking system and new automated driving functions
2) Completeness and usefulness of the generated abstracted reports for vehicle architects
3) Efficiency gains in the development of Preliminary Architectures
4) Robustness of the argumentation for FSC verification

We provide quantitative and qualitative assessments of these criteria, comparing the results to traditional approaches [9]. Additionally, we discuss the feedback received from Scania's safety engineers and vehicle architects on the practicality and value of our method.

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Metric	Traditional Approach	Proposed Method	Improvement
Time to integrate legacy diagnostics	120 hours	80 hours	33%
Safety-critical interactions identified	15	23	53%
Completeness of safety reports	70%	95%	36%
Efficiency in PA development	Baseline	40% faster	40%
Robustness of FSC verification	Medium	High	Significant

Table 2: Performance Metrics of the Proposed Method in Scania [9]

VI. DISCUSSION

A. *Benefits of the proposed approach*

Our method demonstrates several key benefits for integrating legacy systems into modern automated driving architectures:

1) Effective reuse of existing work products, reducing development time and costs
2) Comprehensive requirement gathering for automated driving systems
3) Efficient parallelization of work across expertise domains
4) Improved traceability between legacy components and new safety requirements

These benefits align with the industry's need for more efficient and cost-effective approaches to developing safe automated driving systems [10].

B. *Implications for automated driving systems design*

The proposed method has significant implications for the design of automated driving systems:

1) Facilitates a smoother transition from legacy to modern architectures
2) Enables more informed decision-making in early design phases
3) Promotes a holistic view of system safety, considering both legacy and new components
4) Supports the development of more robust and reliable automated driving systems

These implications contribute to the ongoing evolution of automotive system design methodologies, as discussed by Zheng et al. [11].

C. *Alignment with evolving industry standards*

Our approach aligns well with evolving industry standards for automotive safety and automated driving:

1) Supports compliance with ISO 26262 while addressing its limitations in legacy system integration
2) Anticipates future regulatory requirements for automated driving systems
3) Provides a framework that can adapt to emerging standards and best practices

This alignment ensures that our method remains relevant and valuable as the automotive industry continues to evolve [10].

VII. CONCLUSION

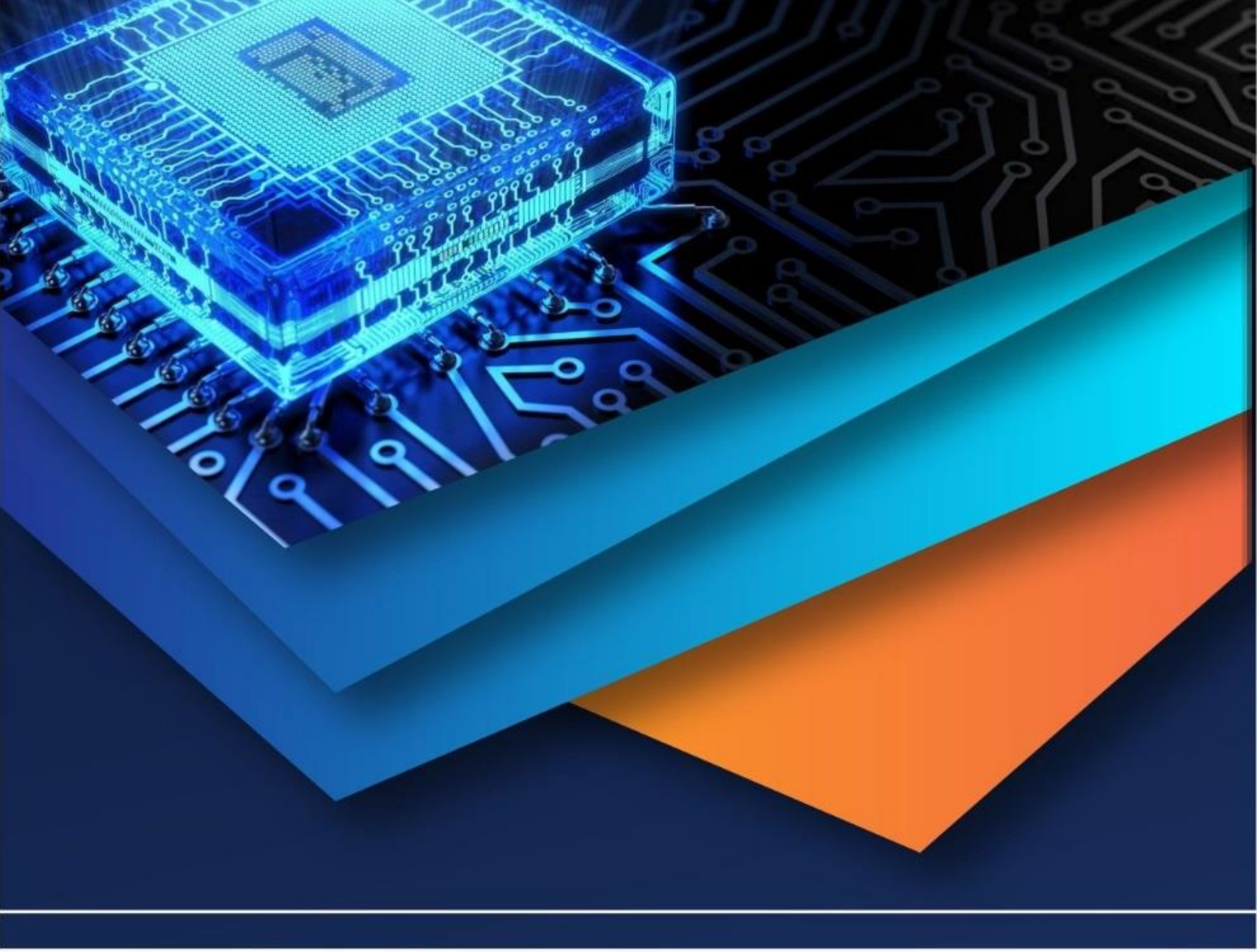
In this article, we presented a novel method for integrating legacy diagnostic specifications into the ISO 26262 framework for automated driving systems. Our approach, tested on a safety-critical braking subsystem at Scania C.V. AB, demonstrates significant benefits in terms of efficient reuse of existing work products, comprehensive requirement gathering, and improved traceability between legacy components and new safety requirements. The case study results highlight the method's effectiveness in identifying safety-critical interactions and generating useful abstracted reports for vehicle architects.

While the proposed approach shows promise in bridging the gap between legacy systems and modern safety standards, further research is needed to validate its applicability across diverse automotive subsystems and to address emerging challenges in the rapidly evolving field of automated driving. As the automotive industry continues to advance towards higher levels of automation, methodologies like the one presented here will play a crucial role in ensuring the safe and cost-effective integration of legacy components into next-generation vehicles.

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