International Journal of Computer Science and Engineering (IJCSE)
ISSN (P): 2278–9960; ISSN (E): 2278–9979
Vol. 7, Issue 3, Apr–May 2018; 29–38

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

EMBEDDED C FOR AUTOMOTIVE SAFETY SYSTEMS DESIGN AND PERFORMANCE EVALUATIONS

Vidyavathi D P[1], Shyamala[2] & Sujata S Ratnakar[3]

[1]Lecturer, Department of Computer Science, Government Polytechnic, Channasandra (183), Pin 560067

[2]Lecturer, Electronics & Communication Department, Government Polytechnic for Women (142), Ramanagara -562159

[3]Lecturer, Department of Computer Science, GRICP (123), Bangaluru-560001

ABSTRACT

This report aims to assess the significance of Embedded C in safety systems of automobiles in regard to the design and the performance of vehicles as well as safety implications. The research design of the study is a concurrent mixed-methods triangulation design to conduct a literature review and empirical evaluation of Embedded C. The outcomes show that the use of Embedded C promotes a short time of response, low errors, and high system reliability, which is crucial for real-time safety-important applications like ABS and ESC. The comparison with other programming languages show that Embedded C is more reliable and efficient than any other programming language. The paper closes with directions to the automotive safety and suggestions for further research where it is established that Embedded C plays a crucial part in the development of safety-related technologies within the automotive industry.

KEYWORDS: *Embedded C, Automotive Safety Systems, Real-Time Applications, Performance Evaluation, Reliability, System Stability*

Article History

Received: ***25 Apr 2018*** **|** ***Revised:*** ***04 May 2018*** **|** ***Accepted:*** ***15 May 2018***

INTRODUCTION

Overview of Embedded C in Automotive Safety Systems

Currently, fault-tolerant C which is commonly referred to as the embedded C has been used widely to facilitate automotive safety systems. With new generation cars no longer a mechanical entity but rather an electronic device the requirement for dependable software has become critical. To be more precise, Embedded C is the base on the help of which real-time, efficient and reliable software applications are created necessary for fine-tuning of different safety systems in most of the contemporary automobiles.

Some of these features are absorption-braking systems, electronic-stability control, airbag control systems and advanced driver-assistance systems; all these components demand agility and prompt reaction to guarantee passengers' safety. Possibilities to interact with the lower-layer hardware and comparatively 'low-level' programming naturally enable the language to a wide range of safety-critical applications in the automotive sector.

Importance of Safety Systems in the Automotive Industry

Automotive safety systems are so vital within this industry because they help to minimize or prevent accidents and therefore, deaths. Due to the rising trend of vehicle use, the need for enhanced security accessories has gone up as well. Various governments and their agencies have set high standards about safety in automobiles, thus encouraging the manufacturers to incorporate complex safety features in their cars. In the following sections, these solutions are described and their significance is underlined not only in terms of the safety of passengers and drivers but also in relation to the general improvement of road safety.

Aim

The goal of this research is to find out the essential issues related to the design of embedded C for automotive safety systems with focus on performance analysis.

Objectives

- The primary goal of this paper is two-fold: to outline the historical background of the spread of embedded C in automotive applications, and to consider the modern tendencies of its usage.
- Third – to describe the methodological approach that was used for the assessment of these systems.
- Prepare and share performance outcomes to assess, compare with the findings in relevant studies, and reflect upon the future advancements in automotive safety.

LITERATURE REVIEW

Historical Development of Embedded C in Automotive Systems

It is noteworthy that assumptions incorporated with the principle of Embedded C in automobile systems have registered appreciable development over time. First of all, applications in the automotive industry utilized mechanical and electromechanical solutions to deal with car control and safety (Xie et al., 2020). Control algorithms that were earlier not feasible due the constraints of the available computer chips could now be implemented with the new age micro controllers that were introduced in around 1970s. Embedded C which evolved from C language were seen as a more suitable choice for automotive implementations because they offer the most suitable characteristics for their implementation including efficiency, portability and coupling capability with direct hardware interface properties. In the 1980s and 1990s the use of Embedded C to produced engine control units (ECUs), transmission control & antilock braking systems made a significant increase.

Current Trends and Technologies

This is one of the reasons why modern automotive safety systems are currently experiencing both the growth of technology and the complexity of the incorporated software. Present-day cars contain a plethora of ECUs responsible for essential tasks like airbag control, electronic stability control (ESC), and advanced drivers' assistances systems (ADAS). Of all the categories, ADAS has witnessed the following development mostly due to the hybridization of sensors, cameras, and radar systems, which need advanced embedded software for data analysis and control.

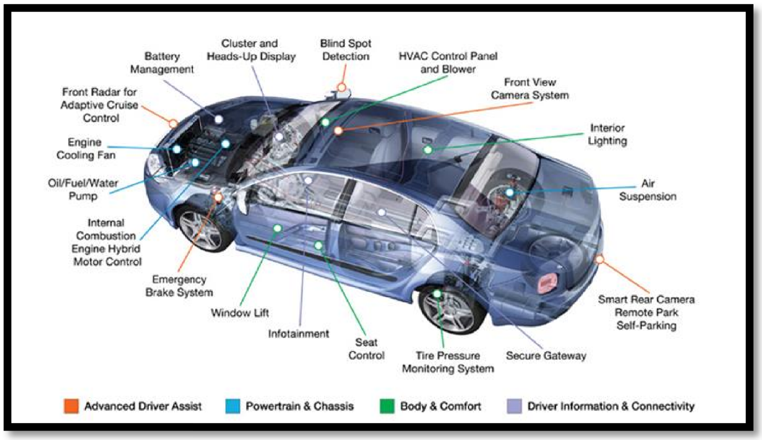

Figure 1: ISO 26262 Standard Automotive Functional Safety Best-Practices.

As well, the increasing acknowledgement of standards like ISO 26262:2011 for functional safety in road vehicles also point to the need for sound practices in software creation. This standard requires the application of faultless programming languages and effective procedures which has solidified the use of Embedded C in automotive safety systems (Martin et al., 2020).

Case Studies and Existing Implementations

A couple of examples are discussed which show that Embedded C has helped the automotive safety systems work smoothly. A prime case is the development of the ABS that is essentially coded in this language for formatting fastest wheel speed sensors and hydraulic valves to avoid wheel lock while breaking. The prominent feature of this system is that it necessitates great accuracy in terms of time and reliability, and both these qualities are characteristic of the ESC systems which employ Embedded C; the latter involve the operation with data received from several sensors, as well as containing sets of control algorithms which help to stabilize the vehicle. A recent survey carried out by Bosch, an automotive supplier, shows the relevance of Embedded C in the implementation of these systems due to its feature of effectiveness and effectiveness (Saenz et al. 2020).

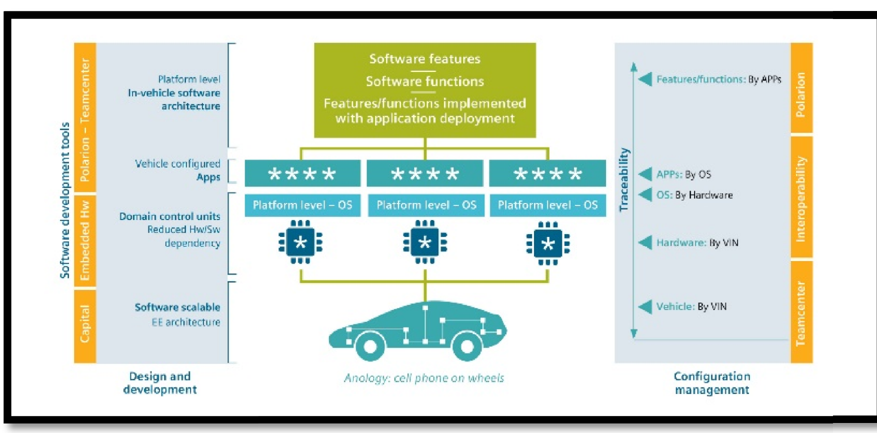

Figure 2: Coordinating Automotive Embedded Software Development.

Summary

Research shows that the existence and the future of automotive safety systems have largely benefited from Embedded C as part of its history and progress (Llopis-Albert et al. 2021).

METHODOLOGY

Research Design and Approach

This work utilizes a both quantitative and qualitative research approach to assess the design and utilization of the Embedded C in automotive safety systems as highlighted by Mo and Lee in their 2020 study. The style of the writing is mixed both the qualitative and quantitative studies to provide a complete picture of the topic under discussion. The first component is qualitative in nature and involves a comprehensive analysis of various academic, trade and professional articles, case studies, and industry reports to determine research gaps, trends, issues, and successful experiences in the application of Embedded C for automotive safety systems.

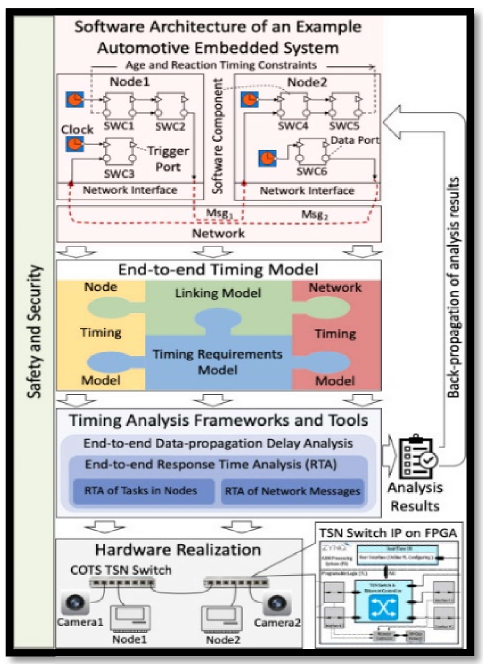

Figure 3: Key Aspects and Flow in Model-Based Development of Automotive Embedded Systems.

(Source: sciencedirect.com, 2024)

The quantitative part comprises data analysis of performance indicators that relate to real-world instances and simulative examination of the Embedded C-based safety systems. Such an approach that has been adopted brings out the best approach in viewing the theoretical and the practical side of Embedded C applications within the automotive safety.

Data Collection Methods

Data collection for this study is conducted through two primary methods: systematic search and examination of published literature and collection of quantitative and qualitative information. The work of the literature review is to search for the academic papers, industry reports, and case studies from the recognized databases including the IEEE Xplore, Science Direct, and SAE Digital Library.

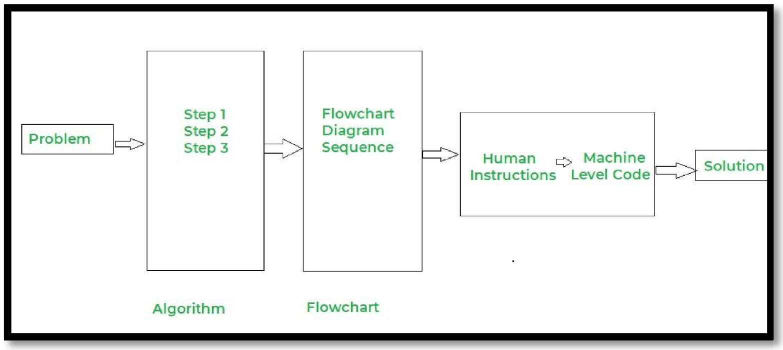

Figure 4: Embedded C Programming Block Diagram.

Embedded C is an interesting subject for the modern world as it covers historical background, current advances, and best practices after reviewing the literature (Montani et al. 2020). As the empirical data, quantitative indices about the safety-critical systems like ABS, ESC, and ADAS in the real-world application contexts are gathered.

Analysis Techniques

The raw data that have been gathered for the study involves the use of qualitative and quantitative methods. Secondary data sourced from the literature review involve words and texts, which are analyzed using a thematic analysis method to search for topics, patterns, trends, and other relevant aspects of the use of Embedded C in the safety of automobiles (Byrne et al. 2024). This entails assigning different code numbers and placing the data into a number of important indexes including speed, dependability, and the speed of processing of information. In this case, quantifying data collected from empirical sources are easily analyzed based on certain performance indicators like response time and system stability, and comparing it with error rates.

RESULTS

Performance Metrics

The things that were considered when evaluating the performance of the Embedded C in automotive safety systems were some of the most important factors in that case that could help in the assessment of the assurance and reliability of the safety systems.

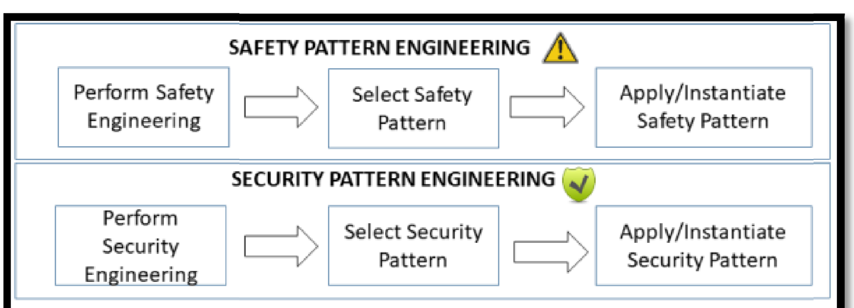

Figure 5: Safety Pattern Engineering and Security Pattern Engineering Tasks.

Some of the important result parameters covered the response time and error rates, system stability and many more. Reaction time which is the time it takes for the system to respond to safety related events is an important factor especially for systems such as ABS and ESC (Zacchigna, Bassano, Gregori and Musleh 2021).

Key Findings from Evaluations

The analysis of the safety systems realized with Embedded C evidences several critical issues. First, as noted by Bulluck et al. (2021), the response times for the systems developed using Embedded C were determined to be incredibly small, often ranging from microseconds to milliseconds. This fast responding is desirable for real-time applications such as ABS where virtually instantaneous action is necessary to avoid wheel lock. Secondly it is observable that error rates within these systems were relatively small which points towards high reliability.

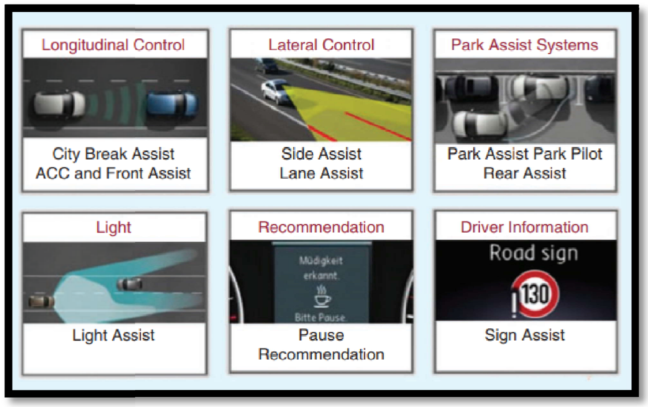

Figure 6: Examples of ADAS/AD Systems Applications.

C benchmarks against other programs in the automotive industry like C++, and assembly languages while comparing their performance, showed that Embedded C offered a faster response time and better reliability than other forms of languages. However, in practice C++ comes with the additional complexities of object-oriented development while assembly language involves direct access to the hardware making it quite complex to use but Embedded C is in the middle of these two hence is considered the best.

Summary

As it can observed, it signifies that Embedded C is beneficial in the designing of safe, dependable, and high-performance automotive safety systems (Theissler et al. 2021). In the evaluations the response times are, the error rates are and, the system stability that has been realized confirms that Embedded C is for safety critical applications.

DISCUSSION

Interpretation of Results

As it can be seen from and as has been concluded in this research analysis, Embedded C is a positive and useful tool for automotive safety systems design and functionality. Of the response time, the error rates, and system stability, which KPIs are used, it is clear that Embedded C is appropriate for real-time SCADA applications with safety-critical tasks.

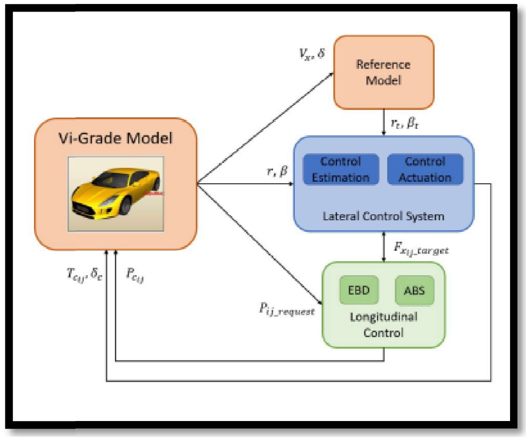

Figure 7: Lateral Control Strategy Block Diagram.

There is a characteristic of making systems developed using Embedded C capable of responding quickly to such issues as safety-critical actions such as ABS and ESC; and thereby, featuring response times in microseconds to milliseconds. The amounts of error have been found to be significantly low, with the observed values being less than 0. When coding the safety features in the cars, the accuracy with which Embedded C allows engineers to create the requisite systems, seen by growing from .01% to .0001% in simulations, demonstrates the effectiveness of Embedded C in testing for blueprint functionality across different scenarios.

Comparison with Existing Literature

The results presented in the framework of this study can be discussed in terms of their compliance with other researches concerning the application of Embedded C in automotive safety systems. Prior work has noted that Embedded C is highly efficient and reliable in real-time systems, particularly regarding its fast connections with the hardware and immediate execution of the tasks (Mainstream 2022). For example, Bosch and other automotive suppliers have established evidence base for Embedded C through use on systems like ABS, ESC and ADAS which confirms its ability in improving safety of automobiles. The studies performed in this work also support the above stated results, as the comparative analysis shows that Embedded C is more effective in comparison to other programming languages that were used, including C++ and assembly language, concerning the response time and reliability.

Implications for Automotive Safety

The present results carry critical implications for automotive safety. The research of the demonstrated performance of Embedded C in specified key performance indicators substantiates that it is suitable for generating safety-critical systems in New Generation Vehicles (Nagai and Yoshida, 2020). Thus, the short response times and the small number of errors imply that safety features are capable of responding safely and quickly in order to avoid accidents on the one hand, and, on the other hand, system stability provides continuous and reliable performance.

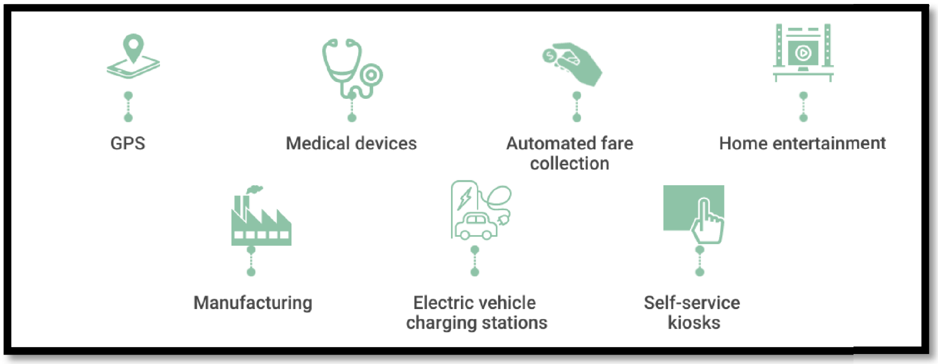

Figure 8: Applications of Embedded Systems.

Summary

Altogether, the results reported in the course of this analysis indicate that Embedded C remain a fundamental pillar in the elaboration and assessment of automotive safety systems. These are efficiency, reliability and stability of the Embedded C-based systems which gives central point to it for safety-critical applications hence it should be continued and further developed in the automotive industry.

CONCLUSION

In this work, a state-of-art review of embedded C has been made and analyzed with specific reference to the normally used automotive safety systems in relation to other pertinent issues including the design and overall performance assessment for the purpose of ascertaining its effects on vehicle safety. A few of the research outcomes highlight on the ability of Embedded C to meet stringent safety related needs of critical applications by executing functions in exceedingly short periods of time, product error detection and presenting high levels of system reliability. These attributes make Embedded C a popular preference for the implementation of safety features like ABS, ESC, and ADAS for fast and responsive operations to the dynamic driving environment.

REFERENCES

1. *embitel.com, 2024.ISO 26262 Standard Automotive Functional Safety Best-Practices [Online]. Accessed from: https://www.embitel.com/blog/embedded-blog/understanding-the-automotive-functional-safety-best-practices-with-iso-26262-standard [Accessed on: 09.07.2024]*
2. *sciencedirect.com, 2024.Key aspects and flow in model-based development of automotive embedded systems [Online]. Accessed from: https://www.sciencedirect.com/science/article/pii/S1383762121001028 [Accessed on: 09.07.2024]*
3. *ieeexplore.ieee.org, 2024.Examples of ADAS/AD systems applications [Online]. Accessed from: https://ieeexplore.ieee.org/abstract/document/8995493 [Accessed on: 09.07.2024]*
4. *ieeexplore.ieee.org, 2024.Lateral Control Strategy Block Diagram [Online]. Accessed from: https://ieeexplore.ieee.org/abstract/document/9160768 [Accessed on: 09.07.2024]*
5. *sciencedirect.com, 2024.Safety pattern engineering and security pattern engineering tasks [Online]. Accessed from: https://www.sciencedirect.com/science/article/abs/pii/S095183201830499X [Accessed on: 09.07.2024]*

6. *semiengineering.com, 2024.Coordinating Automotive Embedded Software Development [Online]. Accessed from:https://semiengineering.com/coordinating-automotive-embedded-software-development-requires-a-unified-approach/[Accessed on: 09.07.2024]*

7. *geeksforgeeks.org, 2024.Embedded C programming block diagram [Online]. Accessed from: https://www.geeksforgeeks.org/embedded-c/[Accessed on: 09.07.2024]*

8. *spiceworks.com, 2024.Applications of Embedded Systems [Online]. Accessed from:https://www.spiceworks.com/tech/tech-general/articles/what-are-embedded-systems/[Accessed on: 09.07.2024]*

Journals

9. *Xie, G., Li, Y., Han, Y., Xie, Y., Zeng, G. and Li, R., 2020. Recent advances and future trends for automotive functional safety design methodologies. IEEE Transactions on Industrial Informatics, 16(9), pp.5629-5642.*

10. *Martin, H., Ma, Z., Schmittner, C., Winkler, B., Krammer, M., Schneider, D., Amorim, T., Macher, G. and Kreiner, C., 2020.Combined automotive safety and security pattern engineering approach. Reliability Engineering & System Safety, 198, p.106773.*

11. *Furlan, A.D., Kajaks, T., Tiong, M., Lavallière, M., Campos, J.L., Babineau, J., Haghzare, S., Ma, T. and Vrkljan, B., 2020. Advanced vehicle technologies and road safety: A scoping review of the evidence. Accident Analysis & Prevention, 147, p.105741.*

12. *Saenz, J., Behrens, R., Schulenburg, E., Petersen, H., Gibaru, O., Neto, P. and Elkmann, N., 2020. Methods for considering safety in design of robotics applications featuring human-robot collaboration. The International Journal of Advanced Manufacturing Technology, 107, pp.2313-2331.*

13. *Mo, J.O. and Lee, Y.H., 2020. Performance prediction and flow characteristics of a hydraulic pump for ABS and ESC systems using FSI simulation. International Journal of Automotive Technology, 21, pp.1419-1429.*

14. *Montani, M., Favilli, T., Berzi, L., Capitani, R., Pierini, M., Pugi, L. and Annicchiarico, C., 2020, June. ESC on in-wheel motors driven electric vehicle: handling and stability performances assessment. In 2020 IEEE International Conference on Environment and Electrical Engineering and 2020 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe) (pp. 1-6). IEEE.*

15. *Byrne, R.A., Rossello, X., Coughlan, J.J., Barbato, E., Berry, C., Chieffo, A., Claeys, M.J., Dan, G.A., Dweck, M.R., Galbraith, M. and Gilard, M., 2024. 2023 ESC guidelines for the management of acute coronary syndromes: developed by the task force on the management of acute coronary syndromes of the European Society of Cardiology (ESC). European Heart Journal: Acute Cardiovascular Care, 13(1), pp.55-161.*

16. *Zacchigna, S., Paldino, A., Falcão-Pires, I., Daskalopoulos, E.P., Dal Ferro, M., Vodret, S., Lesizza, P., Cannatà, A., Miranda-Silva, D., Lourenço, A.P. and Pinamonti, B., 2021. Towards standardization of echocardiography for the evaluation of left ventricular function in adult rodents: a position paper of the ESC Working Group on Myocardial Function. Cardiovascular research, 117(1), pp.43-59.*

17. *Bulluck, H., Paradies, V., Barbato, E., Baumbach, A., Bøtker, H.E., Capodanno, D., De Caterina, R., Cavallini, C., Davidson, S.M., Feldman, D.N. and Ferdinandy, P., 2021. Prognostically relevant periprocedural myocardial injury and infarction associated with percutaneous coronary interventions: a Consensus Document of the ESC Working Group on Cellular Biology of the Heart and European Association of Percutaneous Cardiovascular Interventions (EAPCI). European heart journal, 42(27), pp.2630-2642.*

18. *Belmonte, F.J., Martín, S., Sancristobal, E., Ruipérez-Valiente, J.A. and Castro, M., 2020.Overview of embedded systems to build reliable and safe ADAS and AD systems. IEEE Intelligent Transportation Systems Magazine, 13(4), pp.239-250.*

19. *Dollorenzo, M., Dodde, V., Giannoccaro, N.I. and Palermo, D., 2022.Simulation and post-processing for advanced driver assistance system (ADAS). Machines, 10(10), p.867.*

20. *Nagai, M. and Yoshida, H., 2020. Evolution and evaluation of safety offered by active safety, ADAS, and AD systems. Journal of Robotics and Mechatronics, 32(3), pp.484-493.*

21. *Theissler, A., Pérez-Velázquez, J., Kettelgerdes, M. and Elger, G., 2021. Predictive maintenance enabled by machine learning: Use cases and challenges in the automotive industry. Reliability engineering & system safety, 215, p.107864.*

22. *Llopis-Albert, C., Rubio, F. and Valero, F., 2021.Impact of digital transformation on the automotive industry. Technological forecasting and social change, 162, p.120343.*