Importance of knowledge management for CI/CD and Security in Autonomous Vehicles Systems

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Abstract: The development of autonomous vehicles (AV) entails complex design, production, testing, and deployment procedures that require excellent information and knowledge management in the event of security breaches. As researchers and managers, we must have a good understanding of the development of AV technology. Communication and information exchange, as well as knowledge management (KM) strategies and approaches, are undoubtedly important components. The most difficult challenge is to save the lives of drivers and passengers who use and travel in an AV that is partially or entirely managed by a machine learning model (ML) and artificial intelligence (AI). In this paper, we attempt to investigate the manufacturing process of AVs and intelligent vehicles (IVs), emphasizing the importance of information management (IM) within the factory and processes that are not explicitly articulated in the majority of scenarios. Furthermore, we discuss our method for using the knowledge management life cycle for information exchange in an organization, which could allow for faster and more efficient resolution of security issues within vehicle operating systems. This study seeks to provide an essential theoretical foundation to characterize the future scope of integrated manufacturing, which integrates software and the industry that employs it within the vehicle.

Keywords: autonomous vehicles, knowledge management, artificial intelligence, system integration, safety and security, System design with modeling and deployment

Introduction

Communication and knowledge management are crucial in ensuring the successful production of autonomous vehicles by facilitating seamless collaboration between stakeholders, investors, managers, and software developers involved in this process [1], [2]. The development of various technologies in the transport industry created significant changes with safer and more efficient ways of transport. Still, we also have other problems that did not exist until now. One of them is reflected in the increased complexity during production, which includes complex design, testing, and standardization of development procedures that require having sufficient information about the required final product. As result of their enhanced convenience, safety benefits, and possible commercial worth, autonomous cars, ships, and intelligent vehicles (IVs) [3] have received worldwide attention [4] increasing their demand and direct application in various environments that are dangerous for human life. In most cases, this creates certain security problems that have arisen due to the interconnection of several different software and hardware components of the system. Knowledge management (KM) is essential for this following security part with the possibility to capture, store, organize, and share knowledge within the production ecosystem of the automotive industry.

Risk management in cases of breaches and data leaks, requires checking the connection of several units such as Data management in the auto systems, information retrieval, decision-making algorithms processes, and communication systems are just some of the parts that security professionals must examine [2], [5], [6]. Regardless of industry or product, all companies rely on the knowledge of their employees to be successful which is why organizations must treat knowledge as an asset, it's not enough to just hire skilled employees. Instead, successful companies should build processes to store, grow and share knowledge to increase the knowledge base of the overall workforce using KM.

The continued advancement of technology has the potential to transform the way of transportation. Autonomous vehicle (AV) technology has an influence on logistics, supply chain management, and operational efficiency. These dramatic gains are accompanied by sophisticated security problems inside the underlying software systems. This discussion digs into the security issues surrounding autonomous car system software from the angle of industrial production, as well as the crucial role of preventing this by using Continuous Integration and Continuous Deployment (CI/CD) procedures in guaranteeing a secure, efficient, and sustainable manufacturing process [7].

In the dynamic environment of changes and demands of industrial production, certain security problems are in most cases inherited or difficult to solve since there is still no suitable relevant solution that would cover certain concerns. These security problems are not only of a technical or software nature, some concern moral and psychological attitudes, which create additional implications and difficulties in the production of system software that complies with all the required standards of one or more countries and regulatory bodies. This, therefore, affects the automotive and all other related industries of the production of hardware and software components on a chip or with directly integrated logic [8], [9].

In terms of depth, we covered insights into specific knowledge management techniques and methodologies for AV and IVs. Many studies have proposed novel approaches to capture, store, and utilize information in the autonomous driving ecosystem [10]. But the techniques involved frequently rely on a variety of fields, including artificial intelligence (AI), machine learning model (ML) [11], [12], big data analytics (BI) [13], and sensor technology. The research conducted within this work is part of the author's doctoral thesis and it's a continuation of previous research in this area. Where investigations in this paper should help industry and educational institutions to understand specific problems with practical answers to the information challenges that AV encounters during production and conducting certain relevant tests [14], [15]. The presented work should present an original scientific paper with a new approach of the organization in acquiring knowledge. The focus of the research itself is on outlining proposals and gaps, to ensure prevention of future security threats and information exchange in timely manner. Since there is a very high demand for experts in this field and AV gained recognition and became an active research subject with a growing interest in the use of CI/CD and information knowledge management [16–18]. Which is therefore another reason for the importance and relevance of this topic. The research's contributions and innovation stem from its complete examination and integration of new approach denoted as organizational process for knowledge management (OPKM).

This paper is organized as follows: introduction, materials and methods, security concerns and research gaps for future research, autonomous vehicles, importance of knowledge management, results, and conclusion.

Methods and materials

The utilization of research questions formed the basis for the research approach adopted in this study. These study questions should focus on the educational features of industrial settings, with the goal of improving future accessibility and learning. To explore approaches and provide hands-on learning, we addressed the challenges that students and professionals face during their learning process. The research method was focused on the practical aspects of group administration and regulatory compliance to obtain industry-specific knowledge. The study approach is based on non-numerical data and organizational science methods, which include logistical concerns while designing the teaching process. The answers to the defined questions are offered in each of the following sections, with the results section being the most significant contribution of the new approach. The reviewed literature spanned a longer time range, from 2016 to 2024. The reasons for the specified study term are reflected in the requirements of this research paper. Whereas during the selection of relevant literature, was on the emphasis and the relationship between industry, software, and the generation of new knowledge.

Large language models were utilized to ensure the text's grammatical accuracy, implying the use of the Grammarly program.

Research Questions

The research in this paper will be structured and implemented according to the following research questions:

1. What are security concerns and research gaps in industrial production?
2. Why knowledge management is importance for CI/CD and Autonomous Vehicles?
3. How can a new approach be created in the organization of knowledge, production and creation of software for vehicles?

SECURITY CONCERNS AND RESEARCH GAPS FOR FUTURE RESEARCH

Our commitment to innovation, efficiency, and quality as researchers place us at the forefront of driving transformational improvements in industrial production. The current short- comings in the industry are mostly reflected in the partial application or complete neglect of the procedures regarding software, which is one of our research frameworks within this paper. Security-related research problems [19], [20] and current research gaps can be categorized and presented within the following units [21–23]:

1. Real-Time Intrusion Detection and Response: In an age when AVs are part of a dynamic, networked ecosystem- IoT [24], real-time intrusion detection and response is critical. This research gap necessitates the development of novel technologies capable of continuously monitoring the software landscape, detecting anomalies, and orchestrating rapid reactions to possible threats. By combining KM and CI/CD approaches, we maybe can build an agile system that not only automates software update deployment but also includes powerful intrusion detection capabilities Firefly algorithm (FA) [25]. This collaboration would allow us to protect production operations from potential dangers, assuring the continuous flow of AV manufacture in the factory.
2. Adversarial Machine Learning [26]: The integration of industrial manufacturing with machine learning (ML) is critical for achieving operational excellence and minimal interference with the operation of the vehicle itself. The vulnerability of ML models to adversarial attacks can be, on the other hand, a multidimensional difficulty when analyzing and seeing what led to a certain action. Supporting the rapid deployment of model additions, corrections, and adaptations requires including KM and CI/CD procedures into the equation. This collaboration would enable us to continuously strengthen machine learning models against adversarial attacks, ensuring that AV system software remains resilient, dependable, and aligned with growing production demands. Which in this way enables the application of appropriate relevant standards in different areas [27].
3. Secure Over-the-Air Updates [28]: AVs' ability to remotely update software has revolutionized maintenance and feature enhancement. But the main problem is the reliability of over-the-air updates, on the other hand, is a very difficult puzzle to solve when it comes to securing the integrity and encryption of updates/patches. The way of updating itself can be presented as a solution when one of the current research deficiencies dictates the creation of a system guarantee process to ensure the authenticity, reliability, trustworthiness, and non-disruptive nature of systems updates. We could in the future create smooth update CI/CD pipelines that adhere to strict security and standards constraints by combining the best practice techniques. This relationship would increase the adaptability of AV firmware and the entire manufacturing process by speeding up the data transfer.
4. Privacy-Preserving Data Sharing [29]: Collaborative production environments underscore the importance of secure data sharing by using methods such as KM. However, the intricacies of sharing data while preserving privacy demand innovative solutions and checkpoints in time, similar to backup solutions called snapshots used on Virtual Machines (VM). To establish controlled data-sharing frameworks that ensure sensitive information remains protected we would need to have and use data management systems software (DMS) [30] to solve this and ensure that sensitive information remains protected. This way of collaboration should empower the industry to balance between leveraging data insights for production

optimization while respecting privacy rights and adhering to regulatory obligations created by government bodies.

5. Testing and Validation [31], [32]: Robust testing and validation procedures are the bedrock of quality assurance in industrial production. In the context of AV systems software, this research gap requires exploring automated testing methodologies that encompass the intricacies of software interactions. Using CI/CD integration we could offer a conduit for implementing comprehensive testing protocols that rigorously assess the software's security, functionality, and performance. The result for the industry in this case would mean a software production process organized and controlled by CI/CD tests that have undergone meticulous validation to minimize the potential defects and vulnerabilities.

Based on the conducted research and the collected knowledge, we saw that the best solution for solving the majority of research deficiencies could be implemented and partially solved by applying CI/CD pipelines. Incorporating CI/CD approaches into the fabric of AV system software development would create a transformative opportunity and a significant advantage for every car company. By addressing these research gaps, we could build a comprehensive approach that not only leverages our production-related knowledge but also infuses it with the agility, inventiveness, and scalability of requests created by end customers. This integration could improve the resilience of manufacturing sectors, fortify the industry against upcoming obstacles, and pave the way for the secure, economical, and continuous incorporation of new technologies into industrial manufacturing procedures.

AUTONOMOUS VEHICLES

Autonomous vehicles (AV) can be defined as self-driving cars, buses, trucks, and lorries that employ modern technology to negotiate highways, rivers, and seas without human involvement. They use a combination of cameras, radars, lidar systems in general, and GPS to carry out these tasks, accurately evaluate their surroundings, and make real-time decisions. Autonomous vehicles play an important role in enhancing road safety, reducing traffic congestion, and providing accessible transportation options, making them the ideal option for persons who are unable to drive or do not believe they are capable of driving a car independently. We tried to look at different production perspectives that would have the opportunity of direct application in the industry. Since information knowledge management for AV production is characterized by its breadth and depth, there is limited research specific to direct practices of use in this context. Interesting research for us was covering knowledge management theories in the medical industry and their business conditions for the production of different products.

Specifically, the most complex historical example is certainly the production of vaccines [33] during the pandemic period (COVID-19). Based on the findings of this research, we may also apply effective management practices to the automotive industry. Based on this, we try to create a good foundation for future researchers within this field and industry that has one of the most complex software [34], [35]. The research covers a wide range of subtopics and provides a thorough overview of the field's challenges and prospects to further advance knowledge and contribute to the development of AV.

Importance of Knowledge Management

Knowledge Management (KM) is the backbone that keeps the development process constant and secure in the world of AVs. We can present this with an example of a well-organized library where engineers and industry specialists share their knowledge and expertise. This sharing aids in the development of dependable AV systems by learning from previous occurrences and near-misses in factory production. KM promotes collaboration across many domains, ensuring that everyone's expertise contributes to the larger picture of safety and innovation. Picturing the evolution of AV software is a well-orchestrated orchestra with CI/CD in the role of conductor that guides the orchestras [36].

The rhythm of automated testing steps that seamlessly weave new code, test it thoroughly, and deploy (staging, testing, production) improvements without missing a beat. Like a diligent dirigent, CI/CD ensures for us that the AV software orchestra never misses a note, while a user is playing and using our final product - AV. Importance is in accelerating and pushing the introduction of new features, maintaining a high standard of quality (QA), and efficiently adapting the AV technology to the ever-changing road ahead, governed by standards.

The intersection of security concerns, industrial production, and the integration of CI/CD practices represents a pivotal junction that defines the future trajectory of both AV production and the broader automotive industry. This convergence underscores the significance of addressing security challenges and research gaps, forging a path toward innovation, efficiency, and sustainable growth.

The industry has to fulfill some of the core basic items, to be profitable and maintain it in the long term. Therefore, from the point of view of business, it is necessary to fill in the following items:

1. Efficiency and quality: The quest for operational excellence is at the heart of industrial production. Integrating CI/CD principles into antivirus software development simplifies update distribution, lowers manual intervention, and shortens the production cycle. This integration speeds up the detection and resolution of security flaws, resulting in increased manufacturing efficiency and the upholding of rigorous quality standards that concern the very health and life of passengers, as well as the driver. The capacity to quickly resolve these issues through regular updates guarantees that manufacturing processes stay nimble and responsive to changing industry needs in the future.
2. Compliance and Regulation: The automotive sector is subject to an expanding regulatory framework aimed at assuring vehicle system security and privacy. The inclusion of compliance processes demonstrates a proactive commitment to regulatory compliance by developing secure update pipelines, keeping correct records, and quickly installing security fixes. This proactive approach not only reduces legal risks for the industry but also promotes responsible and dependable members of the transportation ecosystem.
3. Safety and reliability: In the automotive business, the importance of safety and dependability cannot be emphasized. Where increasing the safety of pedestrians, vehicle occupants, and the environment by ensuring the security of AV system software which controls the normal functioning of all systems is of essential importance. Since implementation of safer AVs requires quickly fixing security flaws and hardening software against potential threats and preventing remote control by third parties. This, in turn, builds customer trust, promotes widespread adoption, and solidifies the industry's position as a safety steward. This as a final result ensures a stable and continuous financial income for the company and the vehicle model they sell on the market. Collaboration and Innovation: The collaborative attitude that pervades industrial production finds an echo in embracing KM and CI/CD principles to develop an innovative culture that allows quick experimentation, iteration, and adaptability. Innovation and the possibility of cooperation is the key to the success of applying and adding new technologies to the existing system of a single vehicle. The use of these approaches promotes cross-functional collaboration among production engineers, cybersecurity specialists, software developers, and stakeholders/investors that are interested in listening. By applying this process of exchanging ideas and knowledge, the industry is able to speed up innovation, culminating in the development of cutting-edge technologies that push the frontiers of AV manufacturing.
4. Sustainability: At the heart of modern industrial production philosophy are sustainable methods and integration to address security concerns with research gaps that coincide with sustainability goals. Sustainability is mostly reflected in the ability to react effectively on time and solve problems without impairing the ability to use functionality with swift software upgrades, rapid bug repairs, and vulnerability patching in the whole AV system lifespan. This extended lifecycle decreases the need for frequent physical hardware upgrades while also supporting resource efficiency and environmental responsibility concepts.
5. Market Competitiveness: Involves automobile sales, with global competitors competing for market share being intensely competitive

and requires industry participants to gain a competitive advantage by adopting specific processes that can improve the security and reliability of their AV systems software. This means that companies that can quickly deploy new features, upgrades, and security updates can position themselves as leaders in innovation, responsiveness, and customer happiness.

6. Economic Resilience: Robust AV production has far-reaching economic repercussions in case of lacking a safe and efficient manufacturing process. This in the worst case can result in a negative effect, which all companies try to avoid and achieve a positive side to long-term growth, job creation, and economic sustainability. Minimization of negative effects is mostly realized through continuous research and testing to protect itself against potential disruptions, unforeseen liabilities, and reputational damage by addressing security risks and research gaps. This resilience strengthens the industry's ability to overcome problems, adapt to changing consumer tastes, and remain a driving force in the global economy.

Based on the mentioned units, we can see that certain expertise is needed in the application of technologies and best software practices during factory AV production. The integration of all these factors is a very complex and difficult task for industrial production as a transformative element of society and the creation of a trajectory in the modern movement. This is why recognizing these entities and solving them through research projects can lay the foundation for a future characterized by efficiency, safety, innovation, sustainability, and market competitiveness. Where the position and financial benefit can be achieved by companies that are pioneers and the first to apply in their production, making them the leaders that shape the future of transportation and the appearance of vehicles.

Results

We decided to use this paper as an educational instrument to help new aspiring DevOps engineers or software developers in the automotive industry gain a better understanding of how the aforementioned technologies work and how to implement them in their projects, assuming that we weren't the only ones who struggled to understand microservices and management.

INTEGRATION OF KNOWLEDGE MANAGEMENT IN AUTONOMOUS VEHICLES

The main reason for the importance of application is that KM can be utilized to manage and monitor all of a company's knowledge and AV production processes. But first, it is necessary to understand the processes of knowledge application and how the handling process works. The main reason is reflected in the knowledge of the individual, which is based on an understanding, which consists of discrete or intangible skills.

The field of knowledge management distinguishes two forms of knowledge. We have an explicit understanding of knowledge or abilities that can be pure to articulated and understood. Although other types of knowledge form are related directly to how quickly we can transfer knowledge to others, this is known as formal or codified knowledge. Additionally, we may divide these knowledge types into four categories [16]:

1. Factual knowledge is data that are measurable, observable, and verifiable
2. Conceptual knowledge is concerned with viewpoints and systems
3. Expectational knowledge refers to knowledge that is based on expectations, hypotheses, or judgments Methodological knowledge is concerned with problem solving and decision making.

Within the production process, information can be structured into several crucial aspects that cover and apply the knowledge of all workers in the factory [16], [27], [35]. With our new approach known as the organizational process for knowledge management (OPKM) we can present and organize this process as shown in Figure 1. This is a proposal for a process that should be implemented in 7 steps to minimize the impact of security breaches. That is why efficient information and knowledge management is very important for the production of AV (Figure 1) for several reasons as follows:

1. Knowledge creation processes - Design: In the design phase, extensive data must be collected from various sources including customer re-

quirements, regulatory standards, environmental conditions, etc., which must be organized systematically to design reliable AV systems. The following knowledge is included and used in this part: explicit and tacit knowledge. The steps outline specific actions such as data collection methods, stakeholder involvement, and documentation requirements.

2. Application of acquired knowledge - Manufacturing: During the manufacturing process itself, it involves different stages, such as assembly line operations with multiple robots working together autonomously; therefore, it requires accurate instructions or programs delivered at precisely defined intervals resulting from efficient data flow management throughout these phases.
3. Knowledge structuring - Testing: Rigorous testing is necessary during different scenarios such as harsh weather conditions or unexpected events such as system failures or accidents. To conduct thorough testing protocols and effectively analyze test results using statistical methods, analysis tools should be available within a comprehensive knowledge base accessible to all relevant stakeholders.
4. Knowledge Auditing - Deployment: After the successful completion of development stages, deploying an AV on roads requires compliance with regulatory standards and legal considerations must be taken into account while ensuring the safety of passengers and other road users. The efficient management of information plays a vital role in meeting these requirements.
5. Creation of new knowledge - final product: Information is collected during the use of the vehicle and new knowledge is gained that can later be used during the production of a new series of vehicles. Also, in this way, new knowledge is recreated and the existing knowledge is supplemented.
6. Recreating knowledge: measuring the acquired knowledge and carrying out the evaluation.
7. Restarting the learning process: re-realization and initiation of all steps 1-6 in this process.

Integration between information and knowledge management systems facilitates seamless collaboration between stake- holders involved in AV production processes. Researchers have suggested various technologies or platforms, such as cloud- based storage systems or collaborative project management tools that enable real-time sharing of access control security measures to ensure that stakeholders can contribute their expertise throughout the development lifecycle of different phases, offering input suggestions based on lessons learned from previous projects that improve the overall quality of the final product [36]. Implementing effective information and knowledge management systems is not without challenges in this domain. The processes themselves can be represented through the following cycle, which is shown in Figure 1.

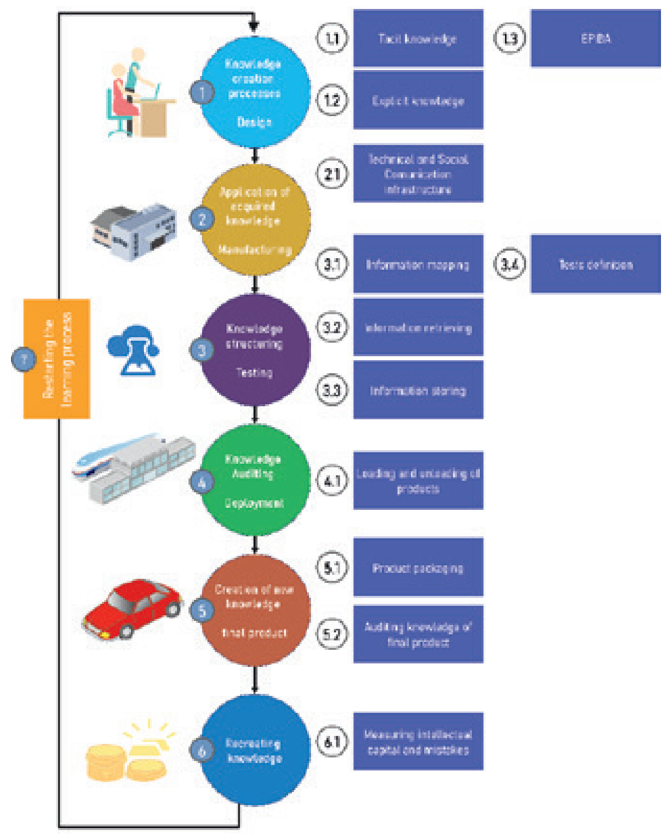

Fig. 1. *The Knowledge Management Life Cycle for AV hardware and software production - organizational process for knowledge management (OPKM). Source: author's contribution.*

Real-world examples highlight successful KM implementations in various industries. By exploring these case studies, we managed to get valuable insights into best practices. That is why we noticed that certain companies focus more on collaboration platforms for seamless communication sharing design specifications or test results with advanced analytic techniques. For predictive maintenance, the best method is to use the captured data from vehicle sensors to enhance overall performance [36]. In addition, cultural barriers, organizational resistance, and law changes can also pose difficulties during the implementation process that need to be addressed [37-39]. Some mitigation strategies include conducting thorough risk assessments, implementing robust security measures, fostering a culture of knowledge sharing, providing training programs, and promoting understanding as the first rule of importance for stakeholders that are involved.

Discussion

In the dynamic arena of software development, the intended order of flow phases orchestrates a debate and a compelling dance of innovation and correctness. This is occasionally referred to as performance since it starts with defining the goal and then moves on to planning, software development, and testing, constructing intricate patterns of participation. Integration, like a symphony combining instruments, harmonizes disparate elements.

Safety improvements are significant with KM, and sharing information across a fleet allows AVs to better anticipate and reduce dangers. For example, if one car encounters a hazard, the knowledge is rapidly shared to avoid similar events in other vehicles.

KM also encourages cross-disciplinary collaboration, bringing together skills in AI, machine learning, and data analytics. This promotes discussion and innovation, resulting in more advanced and reliable AV systems.

In summary, combining knowledge management with AVs improves decision-making, assures continuous learning, and increases safety, hence promoting business innovation and operational efficiency in the autonomous vehicle industry.

Conclusion

Effective information and knowledge management plays a crucial role in the production of AV and any other final product. The complex nature of designing, manufacturing, testing, and later deploying AVs demands seamless collaboration among all involved in the production process. By integrating various management systems and KM, organizations can overcome challenges related to data privacy, security concerns, and ethical issues while promoting a culture of knowledge sharing. Future case studies should demonstrate the positive results that can be achieved through the implementation of effective communications in the context of producing any type of intelligent vehicle. When ensuring successful production processes, will be imperative that organizations recognize the importance of efficiency and the best management practices throughout all phases of the development lifecycle of software and hardware. This could give the opportunities to capitalize on their emerging technology on the market, together with sharing knowledge, value, and trust that is created within a company that takes care of its employees.

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The author(s) declare(s) that they have no conflict(s) of interest.

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