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The Role of Artificial Intelligence in Automotive Design: A Comprehensive Review

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Abstract:
Artificial intelligence (AI) is becoming more important with transformative impacts in the automotive design process. The role of AI in automotive technology is being chiefly investigated from the perspectives of information technology, mechatronics, mechanical engineering, control science, and computer simulation. This paper discusses the application and potential challenges of AI from the viewpoints of interdisciplinary technologies within automotive engineering. We systematically present the trends and applications regarding the combination of AI and automotive engineering, and discuss the possible problems as a result of integrating these interdisciplinary fields. In addition to discussing these questions, a final key issue is the necessity of educating not only engineers and researchers but also all stakeholders in the automotive industry in these fields.

The investigation of such interdisciplinary research will have significant impacts on the future of transformative re-engineering of the world. An overall scenario about the future will occur to the reader at the end of this paper. Future of the vehicles are being transformed from mechanical products into informatics systems. Practical deployment of onboard AI technology in new complex automotive environments demands novel functionality adjustments, adding machine learning processes able to cope with interpretability constraints, uncertainty, and energy efficiency. AI in vehicles has gained remarkable scientific attention as it has several applications in automotive in areas including intelligent systems, speech and image recognition, predictive intelligence, and recommendation systems. AI in automotive can transfer information that is initially in a physical form, such as a spoken command or a written text input, to a medium that can understand it logically or rationally, and thus allow the AI program to develop a response.(1)

Keywords: AI (Artificial Intelligence), Design, CAD (Computer Aided Design), Vehicle, Automotive

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(1) Abro, G. E. M., Zulkifli, S. A. B., Kumar, K., El Ouanjli, N., Asirvadam, V. S., & Mossa, M. A. (2023).Comprehensive review of recent advancements in battery technology, propulsion, power interfaces, and vehicle network systems for intelligent autonomous and connected electric vehicles. Energies, 16(6), 2925,p4.

I. Introduction

The automotive industry is undergoing a technology-enabled transformation with the advent of new digitalization initiatives. Among these is the growing dominance of artificial intelligence (AI). As far as AI is concerned, its footprint in automotive design is a matter of pivotal interest. The shortcomings of relevant methodologies are being addressed to promote AI's full integration in the field. The design community is tasked with understanding the repercussions of AI-driven developments in the design of automobiles and other vehicle types. This includes conceptions of unwarranted vehicular form applications. (1)

New technological advancements in computational power, coupled with the advent of widespread industrial digital twins and applications of emerging fields including autonomous driving and electrification, are driving the so-called momentum shifts in the industry. AI is rapidly accelerating across diverse sectors and industries. The need for a comprehensive introduction and discussion of different facets of the subject has likewise been recognized, describing AI as "a broad array of technologies that mirror human actions—like understanding speech or objects and decision-making, but much faster and over more data." Considering this, AI and asymmetrical responses and implications for automotive topics are increasingly receiving a wide range of creative industry and scholarly attention. (2)

AI has, among others, the potential to enrich processes while supercharging automotive capabilities and opening new ranges to explore. From this vantage, AI in automotive design concerning generative adversarial networks and the relationships between new technologies, designing, and future-making. As is explored in depth, the model is additionally diverse in structure and application. Overall, the paper invites the reader to sit at the inventive intersection of automotive, solution, creative, and fundamental research. It urges reflection on the co-evolution of AI technologies, social, creative, and environmental factors, as reckoned by automotive design in both its present and future incarnations.

(1) Kolekar, S., Gite, S., Pradhan, B., & Kotecha, K. (2021). Behavior prediction of traffic actors for intelligent vehicle using artificial intelligence techniques: A review. IEEE Access, Volume 9, p 135035

(2)Sharma, P. & Rana, C. (2024). Artificial intelligence-based object detection and traffic prediction by autonomous vehicles–A review. Expert Systems with Applications. Volume 255, Part C, 1 December 2024, 124664

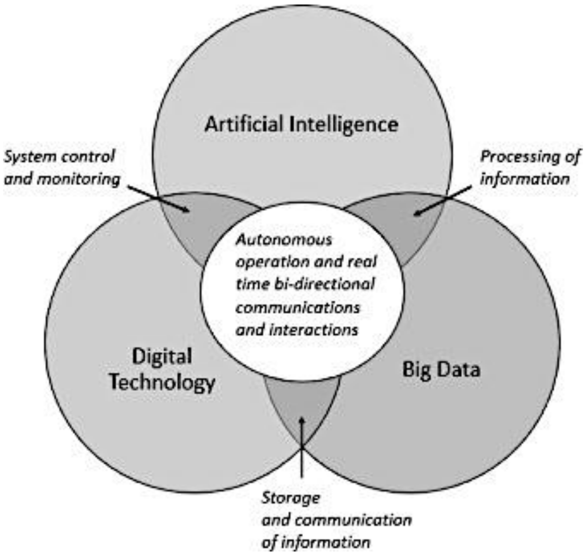


Fig.1. A Venn diagram showing the overlap between the artificial intelli- gence, big data and digital technology.

II. Historical Perspective of Automotive Design

The evolution of automotive design has unfolded over multiple technological eras, spanning from several decades to entire generations. These distinct epochs encapsulate significant trends in development and industrial capabilities witnessed globally. Early automotive designs were heavily shaped by mechanical innovations and design concepts derived from agricultural machinery, a trend that persisted into the 1920s. Notable advancements during this period included the implementation of cockpit controls and shock absorbers, which provided essential driver-assist features. As a technological transformation began to gain momentum in the United States, markedly different from the European landscape, vehicle interiors gradually progressed from basic mechanical systems to incorporate electric components. (3)

The landscape of automotive design underwent a dramatic shift during World War II, moving towards a more consumer-centric approach characterized by practical and functional aesthetics. This transformation laid the groundwork for the "Long, Low and Wide" design trend of the 1950s and 1960s, marking a pivotal change in style. This progression from mechanical to electric-centric design can be interpreted as an early iteration of design automation.

(3) Kolekar, S., Gite, S., Pradhan, B., & Kotecha, K. (2021). Behavior prediction of traffic actors for intelligent vehicle using artificial intelligence techniques: A review. IEEE Access, Volume 9, p 135035

The styling of car bodies underwent a gradual transformation, beginning with the automation of minor components of traditional vehicles, such as the fairings surrounding engines. By the mid-1980s, the integration of fuel-injected engines alongside early engine management computer systems facilitated the implementation of more affordable computer-aided design technologies in shaping car bodies like Autocad and SolidWorks software. This transition marked the conclusion of the mechanical design era, as the automotive industry embraced a digital design era propelled by advancements in micro-processing capabilities. The emergence of this digital epoch also fostered the development of sophisticated expert systems aimed at automating certain design processes for expert designers. These expert systems endeavored to encapsulate the knowledge of designers within the design process through an ontological framework, enabling them to function as data-driven sequential decision trees for novice practitioners or as decision-support mechanisms for design specialists. Despite their significant contributions to the digital age of automotive design, expert systems experienced a decline in industrial relevance due to the challenges posed by knowledge acquisition related to complex designs.

As automotive design philosophies evolved towards the incorporation of design rules, heuristics, and data-driven methodologies, the advent of artificial intelligence and expert systems began to capitalize on the abundant opportunities for design automation within the field. Specifically, advanced techniques such as case-based reasoning, neural networks, supervised learning, and, more recently, deep learning, have increasingly influenced the way car design aligns with consumer-oriented design trends. Reflecting on this evolution, electric vehicles emerged as manifestations of data-driven design principles during the digital design era of the 1980s. Up until recent times, commercial automotive design has relied significantly on pre-existing data-driven design information. Nevertheless, the challenge of integrating automotive aesthetic expertise in the modulation of car design remains an ongoing concern. [(1)]

2.1 Brief history of AI

As shown in Fig. 2, despite the overall upward trend, AI'sdevelopment had experienced notable alternations betweensurging and declining. After the notion was proposed in1956, the development of AI rapidly entered its first goldenage. However, in 1973, a report submitted by James Lighthillto the UK government suggested that most AI goals were tooambitious to be achieved by existing technologies. Since then,AI had been criticized and questioned. Subsequently, the researchof AI fell into the first winter in the 1970s. Startingfrom the late 1970s, the emergence of expert systems, whichsimulated how human experts solve domain-specific problemsusing knowledge, represented AI's reorientation fromtheoretical investigations to practical applications. As a result,the development of AI experienced a second surge. Startingfrom the late 1980s, the growth of expert systems met thebottleneck. For example, the general knowledge was lacking;the knowledge acquisition was difficult; the reasoningmethods were overly simple. As a result, the development ofAI experienced a second significant decline. In the 1990s, aspart of the Internet's sweeping trend, AI's importance washighlighted once again. Since 2011, with the boost of mobileInternet and cloud computing, the data volume has shownexplosive growth. With the rapid development of AI technologiesrepresented by the deep neural network, AI hassurpassed human performance in many fields, ushering in anew upsurge.[(2)]

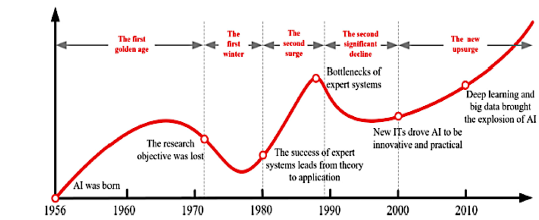


Fig. 2 Reflection of the development history of AI

III. Fundamentals of Artificial Intelligence

Artificial intelligence (AI) can be defined in multiple ways. For our purposes, we may find it useful to think of AI as the science of creating machines, particularly computer programs, that can perform tasks that would normally require human intelligence. Although AI expands into further realms, such as robotics, AI in automotive design is mainly linked to data science and predictive analysis. The major branches in AI dealing with data analysis and prediction include machine learning (ML), where neural networks are positioned, as well as the more basic algorithmic approaches such as regression, classification, and clustering. One of AI's main working mechanisms consists of the in-depth analysis of data. These technologies do not rely on predefined

(1) Khalil, R. A., Safelnasr, Z., Yemane, N., Kedir, M., Shafiqurrahman, A., & Saeed, N. (2024). Advanced learning technologies for intelligent transportation systems: Prospects and challenges. IEEE Open Journal of Vehicular Technology. vol. 5, pp. 397-427

(2) Lei Wang1 &Zhengchao Liu1 & Ang Liu2 & Fei Tao3, (2021), Artificial intelligence in product lifecycle management, The International Journal of Advanced Manufacturing Technology 114:771–796.

logics and rules but can explore existing patterns and characteristics in data. A small pre-known proportion of a massive amount of learning inputs and outputs, as well as smart and heuristic algorithms, are required for machine learning models' success. (1)

In the realm of automotive activities, as well as in various other domains, the primary advantage of employing artificial intelligence (AI) as a technical support tool stems from the significantly reduced computational time associated with these models when compared to traditional engineering models. For example, a structural analysis may require several hours to complete, particularly when faced with intricate conditions in the finite element model. It is crucial to recognize that AI systems must possess both syntactic and semantic coherence for effective modeling; in other words, their foundational theories should be informed by data and experiential evidence. The most formidable challenge in the development of AI algorithms lies in the necessity to generate substantial quantities of appropriately curated data to ensure that the system can be adequately trained and tested under comparable operational circumstances. The substantial volume of big data, as opposed to mere algorithmic sophistication, constitutes a significant advantage of AI. This advantage relates to the capability of capturing greater complexity, which is derived from an extensive dataset rather than from superior algorithms. AI endeavors to augment and replicate human sensory perception and matching processes, extending beyond mere consciousness. In industrial settings, the integration of AI technologies with human intelligence enables organizations to derive new insights that may have previously been difficult to obtain. Lastly, it is important to underscore that AI continues to evolve, with new frameworks being actively developed. (2)

IV. Applications of Artificial Intelligence in Automotive Design

Automotive design today goes beyond building and planning the perfect vehicle; it is a kind of fashion or art form that inspires and influences people. In the automotive design process, from conceptualization to the final product, numerous opportunities for the application of artificial intelligence (AI) have emerged. Intelligent design systems are claimed to make product development and design processes more efficient and support the creativity of modern, federated design teams. (3) (Rong et al.2021)

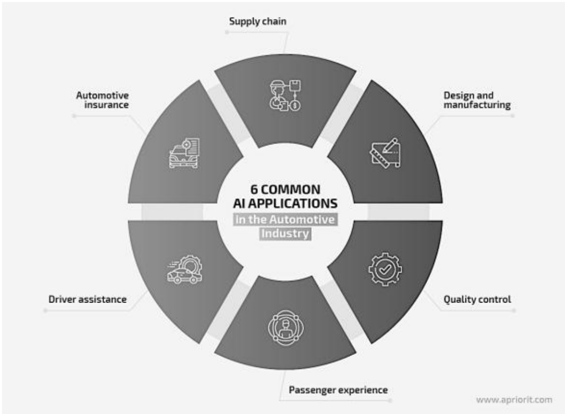


Fig.3

AI has facilitated the application of generative design using the function and nature of the vehicle. Earlier design had to go through numerous prototypes before vehicles were better utilized. AI cuts the work on these extra prototypes. Predictive modeling during design and production is another enormous application area for AI. The latter improves in predicting increased degradation of lithium-ion batteries, which was previously tricky for engineers to detect. These aspects help lower the cost of vehicle production and lead to more efficient designs, which can be created for lower prices in a shorter time span. AI is also beneficial in attaching individual personalized designs, where vehicle design, comfort, and function could be matched to the individual's specific preferences. Automobile manufacturers are now using this individual approach in a more advanced way. In an AI-aided mall parking area kiosk, a system advises customers of available spaces, sets their spa, and is convened by proprietary software that can be filled with connective sensors. (4)

It is crucial to enumerate some of the most effective design platforms that enhance AI-assisted designs and concept development, as well as to explore the trajectory of this field. The application of AI facilitates real-time simulation of dialogue between engineers and the software, producing innovative ideas while generating sketches. Design and simulation platforms driven by performance leverage neural networks to expedite the simulation process. This technology boasts distinct and

(1) Arévalo, P., Ochoa-Correa, D., & Villa-Ávila, E. (2024). A Systematic Review on the Integration of Artificial Intelligence into Energy Management Systems for Electric Vehicles: Recent Advances and Future, World Electric Vehicle Journal.15, no. 8: 364.
(2) Abro, G. E. M., Zulkifli, S. A. B., Kumar, K., El Ouanjli, N., Asirvadam, V. S., & Mossa, M. A. (2023). Comprehensive review of recent advancements in battery technology, propulsion, power interfaces, and vehicle network systems for intelligent autonomous and connected electric vehicles. Energies, 16(6), 2925,p7
(3) Rong, Y., Han, C., Hellert, C., Loyal, A., &Kasneci, E. (2021). Artificial intelligence methods in in-cabin use cases: A survey. IEEE Intelligent Transportation Systems Magazine, 14(3), p132.
(4) Xu, X., Li, H., Xu, W., Liu, Z., Yao, L., & Dai, F. (2022). Artificial intelligence for edge service optimization in internet of vehicles: A survey. Tsinghua Science and Technology, vol. 27, no. 2, p. 271

pragmatic applications, encompassing the optimization of automotive crash simulations and guiding appropriate methodologies in construction design. Furthermore, in the domain of automotive design, the past few decades have witnessed a rise in the utilization of industrial robots capable of performing specific tasks and assembling designated objects.[1]

4.1 CAD Design and Parameters
There are various tools used to analyze the behavior of themechanical parts of a vehicle during the mechanical andthermal loading of the parts. In this analysis, the initial 2Dsketching of the parts under investigational concern wasdone in AutoCAD and the 2D sketch was then convertedinto the 3D model using SOLIDWORKS 3D modelling softwareto give an illustrative finish and natural appearance ofthe parts.[2]

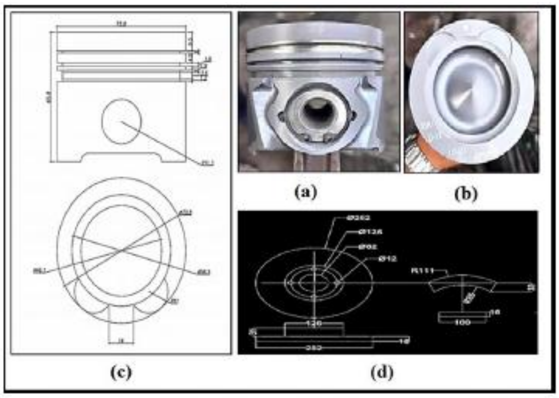


Fig. 4. (a) actual photograph of piston head, (b) actual photographof disc brake rotor, (c) 2D drafting image of the piston head, (d) 2D drafting image disc brake rotor

For the motion analysis of the parts CATIA V5and lastly to comprehend the physical behavior of the partsand how they rely on the material selected.At times minor but continuous deformationsmay also lead to major failure of the parts.[3]

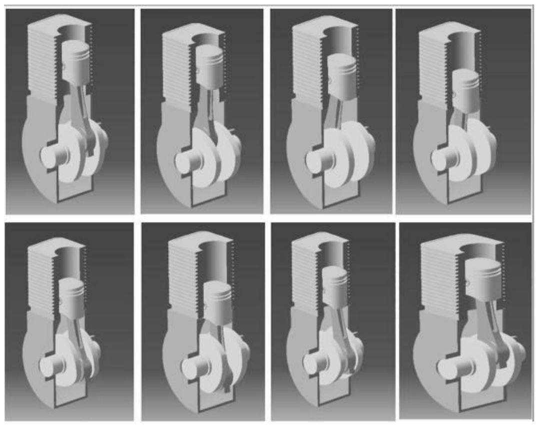


Fig. 5 Motion analysis of Piston Cylinder

V. AI in Vehicle Styling and Aesthetics

AI is increasingly used in automotive design, particularly to support vehicle styling and aesthetics. By incorporating big data sets and consumer insights and feedback, AI tools can now help designers create visually attractive vehicles according to current trends. The role of AI in this process involves data collection and prediction of future trends, as well as the generation of new forms or recombination of successful visual features of products, all based on data-driven insights. The primary goal is to provide designers with a vast amount of information to make their choices, keeping in mind the company's style, heritage, and target. The so-called iterative design – additive or combinatory – is also performed, thanks to AI-supported generative design algorithms that allow the creation of new iterations with a high number of options.[4]

Generative design is a tool that allows people to interact closely with algorithms, creating a myriad of design options without manually first-generation sketches of the form. The user interface is designed to democratize this process and ensure that final designs are a fusion of human creativity and artificial intelligence-induced exploration. Resizable phases and not the initial inspiration, this interaction between computational algorithms and human designers demonstrates how artistic design creates tools and brings technologies that are already changing the design world. Studies from various industries and case studies have shown that generative design already plays a crucial role in the production of car bodies, as well as in interior design. This work mainly involves the development of engineering solutions rather than aesthetics. Characterizing aesthetics and linking them to consumer tastes, preferences, or cultural factors is one of the new

(1) Olugbade, S., Ojo, S., Imoize, A. L., Isabona, J., & Alaba, M. O. (2022). A review of artificial intelligence and machine learning for incident detectors in road transport systems. Mathematical and Computational Applications, 27(5), 77.
(2) Paul, Subhodeep, Roy Pallab, (2024), Design and Analysis of Automotive Vehicle Components with Composite Materials Using ANSYS 18.1, journal of Institution of Engineers (India), p 3.
(3) Paul, Subhodeep, Roy Pallab, (2024), Ibid, p 5.

(4) Ahmad, T., Zhu, H., Zhang, D., Tariq, R., Bassam, A., Ullah, F.,&Alshamrani, S. (2022). Energetics Systems and artificial intelligence: Applications of industry 4.0. Energy Reports, volume 8, p334

research challenges that automotive companies are trying to address by integrating artificial intelligence. [(1)]

VI. AI in Vehicle Performance Optimization

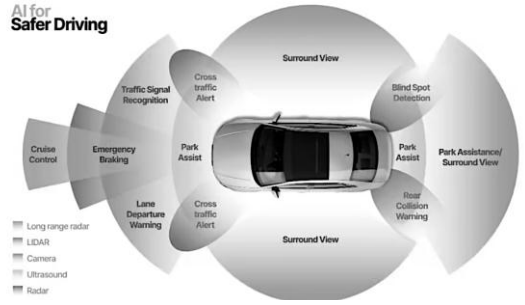
To effectively respond to the dynamic nature of customer expectations and enhance the overall driving experience, it is imperative that vehicle performance is optimized to meet user requirements across diverse conditions. The wide array of feasible designs and the multitude of variables influencing vehicle performance are increasingly being refined through the application of artificial intelligence. Central to these advancements is the extensive repository of data encompassing various aspects including vehicle dynamics, fuel systems, control architectures, combustion processes, emissions, and engine performance, alongside a growing range of supplementary data. Machine learning algorithms play a critical role in this landscape by facilitating the analysis, prediction, and improvement of vehicle performance metrics. Furthermore, these AI technologies are integral to the creation of adaptive systems capable of continuously monitoring vehicle performance in real time, thereby enabling the implementation of optimal control strategies.[(2)]

In analyzing the development of a saloon 4x4 vehicle, it is essential to recognize the importance of optimizing various parameters to fulfill consumer expectations comprehensively. The primary parameters of concern include gear shifting, steering angle, throttle control, and braking mechanisms, among others. Optimal performance is contingent not only upon achieving the precise numerical specifications of these elements but also on leveraging artificial intelligence to accurately gather and interpret data necessary for effective state recognition. An illustrative case of successful optimization is found in a competitively designed vehicle, where participants recorded favorable outcomes. This optimization process not only elevates customer satisfaction regarding vehicle performance but also facilitates the integration of AI in the design and development phases. This integration allows for the investigation of alternative driving solutions, such as electric mobility, which aligns with evolving consumer preferences. Within this analytical framework, the optimization of the vehicle system distinctly emphasizes the enhancement of fuel efficiency. [(3)]

VII. AI in Safety and Crash Testing

In the automotive industry, safety is one of the key areas where AI could have great value. This chapter will address AI and crash testing, including applications that are used directly by crash carriers, a development of collaborations with them, and efforts within the automotive industry using crash data. These applications are mainly used to improve the quality and efficiency of crash tests and the crash test vehicles.[(4)]

AI has been broadly utilized in the development of safety features, such as the automatic emergency braking system, lane departure warning, and more, to create a vehicle that is expected to achieve a five-star rating. The technologies included in the advanced driver-assistance systems will enable the professional driver to enjoy their task and maintain a better safety margin from potential hazards, and may help reduce truck rollovers, run-offs, and rear-end collisions. AI can be used to make driving a commercial vehicle in urban environments easier, such as moving through low speeds in traffic, parking assistance, going through curves, overtaking, and being vigilant. Overcoming the limitations that AI may present in appreciating the full context of a scenario or in providing more reliable predictions of what naturalistic studies consider as 'critical incidents' or even preventing incidents that did not occur represents some of the challenges that AI systems would need to resolve to participate in future safety designs. The applications of AI in pre-crash and crash scenarios can affect engineering strategies, using the AI system to design a smaller frontal crush zone to minimize pedestrian impact potential and then detect and initiate any necessary countermeasures.[(5)]



(1) Olugbade, S., Ojo, S., Imoize, A. L., Isabona, J., & Alaba, M. O. (2022). A review of artificial intelligence and machine learning for incident detectors in road transport systems. Mathematical and Computational Applications, 27(5), 77.

(2) Ahmad, T., Zhu, H., Zhang, D., Tariq, R., Bassam, A., Ullah, F.,&Alshamrani, S. (2022). Energetics Systems and artificial intelligence: Applications of industry 4.0. Energy Reports, volume 8, p335

(3) Cugurullo, F. (2020). Urban Artificial Intelligence: From Automation to Autonomy in the Smart City. Journal of Frontiers in Sustainable Cities,vol 2,p4.

(4) Sarker, I. H. (2022). AI-based modeling: techniques, applications and research issues towards automation, intelligent and smart systems. SN Computer Science. 3:158

(5) Cugurullo, F. (2020). Urban Artificial Intelligence: From Automation to Autonomy in the Smart City. Journal of Frontiers in Sustainable Cities,vol 2,p4.

VIII. AI in Manufacturing Processes

AI is increasingly finding its application in production systems across industries, automating and digitalizing entire processes with the promise of enhancing productivity. The automotive sector is investing heavily in this area, and an interesting view on the subject has been provided. In this paper, we, however, aim to present a summary of the other side of the megatrend reservoir – the application of AI in automotive manufacturing processes. Historically, industries have been able to apply AI to devise models that can perform specific functions with high precision and efficiency. Gradually, however, AI has also been making inroads into the physical systems and designs of the industry. By training neural networks with physics-based simulations, it was able to design shapes for robots and wind turbines that are considerably more innovative than those designed by engineers.(1)

The integration of neural networks for maintenance prediction within assembly lines, assembly stations, and vehicles offers considerable advantages related to vehicle manufacturing, operational expenses, and overall customer satisfaction. Notably, this approach can yield reductions of up to 21% in unscheduled maintenance occurrences and a 32% decrease in extended maintenance delays, contributing to enhanced vehicle uptime, particularly for heavy-duty applications. Global automotive manufacturers are increasingly leveraging artificial intelligence technologies to conduct rigorous quality assessments of their products. For instance, a recent deployment at a manufacturing facility features an AI-driven system that scrutinizes the visualization of critical surface points on vehicles, detecting minute deviations of as little as 100 micrometers—achieving this with greater speed and accuracy compared to prior camera-based systems. Moreover, AI-powered adaptive technology can advise suppliers on optimal part supply schedules and the most efficient routes for raw material transportation, thereby mitigating the likelihood of disruptions within the supply chain. On a broader scale, AI applications within factory operations can effectively minimize waste by enhancing energy utilization and reducing material scrappage. (2)

(1) Boukerche, A., Tao, Y., & Sun, P. (2020). Artificial intelligence-based vehicular traffic flow prediction methods for supporting intelligent transportation systems. Computer networks.p121

(2) Ali, A. M., & Moulik, B. (2021). On the role of intelligent power management strategies for electrified vehicles: A review of predictive and cognitive methods. IEEE Transactions on Transportation Electrification, 8(1), p369.

IX. AI in Supply Chain Management

The provision of components from diverse suppliers worldwide to automotive manufacturers for the assembly of the final product presents significant challenges, particularly in the domains of effective tracking and cost management within freight logistics operations. Given the dynamic nature of component requirements, which frequently fluctuate in terms of volume and type due to periodic orders throughout the supply chain, maintaining optimal inventory levels remains a complex task. This discourse examines the implementation of artificial intelligence, notably through deep learning and big data analytics, aimed at enhancing supply chain operations, encompassing inventory management, renewable components for automotive producers, logistics, and various additional constraints pertinent to the process. The application of AI technologies within the automotive supply chain proficiently generates valuable insights via real-time data analysis and forecasting, thereby facilitating informed decision-making related to inventory, logistics, and other critical elements. (3)

Various models have been employed to facilitate decision-making processes, including machine learning, artificial neural networks, deep learning, and big data analytics. These robust algorithms proficiently identify numerous actions aimed at minimizing operational costs within supply chain networks. The resulting data yield valuable insights, which have undergone thorough evaluation. Moreover, artificial intelligence technologies enhance detection and updating capabilities, providing real-time notifications in response to disruptions in the supply chain, thereby mitigating potential damages. Numerous case studies highlight that the automotive industry, by employing application-based AI techniques, has successfully decreased operational costs and enhanced customer service. Nevertheless, it is important to recognize that while AI demonstrates effectiveness, it also raises concerns related to cybersecurity and industrial espionage. These issues particularly pertain to the quality of information being exchanged and the imperative for trusted and accountable decision-making at the board level, necessitating informed human judgment. A collaborative approach should be considered alongside established practices that leverage collective intelligence, integrating human decision-making processes that utilize intuition and wisdom.(4)

(3) Rinchi, O., Alsharoa, A., Shatnawi, I., & Arora, A. (2024). The Role of Intelligent Transportation Systems and Artificial Intelligence in Energy Efficiency and Emission ReductionKing Abdullah Petroleum, Studies and Research Center,p5.

(4) Ahmad, T., Zhu, H., Zhang, D., Tariq, R., Bassam, A., Ullah, F.,&Alshamrani, S. (2022). Energetics Systems and artificial

X. AI in User Experience and Human-Machine Interaction

Artificial intelligence (AI) plays a significant role in enhancing the user experience through human-machine interaction in contemporary vehicles. Various technologies and tools are employed to analyze the behavior of drivers and passengers, facilitating the customization of the vehicle's user interface. This customization may include adjustments to noise and temperature settings, as well as the provision of relevant content such as music, news, and even social media updates that the user is likely to engage with at that moment. In the case of autonomous vehicles, which are evolving into mobile offices or living spaces, there exists the potential for the integration of greater intelligence. Beyond a mere personalized user interface, advanced systems can identify the driver through voice recognition, gestures, fingerprints, and facial features, thereby regulating access to the vehicle and specific content and functionalities. (1)

Artificial Intelligence (AI) plays a pivotal role in enhancing the functionality of so-called smart in-vehicle systems, which include features such as voice recognition, natural language processing, and the generation of artificial data. These capabilities facilitate a human-machine dialogue characterized by natural language and AI-driven emotion recognition. Additionally, the system can learn from gesture control, recognizing specific gestures employed by the driver to improve the quality of interaction. Consequently, AI empowers intuitive controls within the human-machine interface and delivers comprehensive audio information regarding navigation, surrounding environments, and vehicle control operations. A potential innovative application of AI could involve providing auditory warnings to visually impaired individuals or guiding them through various locations via verbal communication. The existing voice control systems can be augmented to manage several functionalities within the vehicle, such as recommending alternative routes or fuel stops. Furthermore, an advanced voice assistance system could offer real-time support to drivers, operating proactively without the need for explicit inquiries. The system would analyze the driver's gaze direction toward external objects and furnish relevant explanations based on their visual focus. For instance, should the driver glance at a billboard, the system would provide a succinct overview of the advertisement that may be unreadable to them. In addition, numerous case studies have demonstrated that the vehicle's interior can be tailored to invigorate the driver for dynamic driving scenarios or to promote relaxation during autonomous driving periods. Ultimately, AI is instrumental in advancing toward highly automated, and potentially fully autonomous, driving by enhancing safety through a reduction in human technological interactions. Presently, the primary challenges involve ensuring a seamless and user-friendly integration of the diverse systems and their corresponding solutions, resulting in automotive-quality outcomes. Accomplishing this objective necessitates extensive advanced user research encompassing areas such as anthropometry, ergonomics, haptic and visual perception theories, as well as medical and psychological factors related to human comfort, behavior, and acceptance. (2)

XI. Challenges and Limitations of AI in Automotive Design

The implementation of Operational Design Domains (ODDs) will lead to the extraction of substantial volumes of data, which introduces new challenges in the realms of data engineering and quality assurance. Numerous tools and processes have been developed to facilitate the automation and cleansing of data; however, it is imperative to craft these tools within a framework of methodologies that properly considers this specific context. Issues such as algorithmic bias, fairness, and the ability to generalize pertain to analogous concepts and may be influenced by the challenges associated with the lack of access to or the modeling of numerous edge cases within the training and validation datasets. This phenomenon is intricately connected to experience-based safety reasoning, which frequently constitutes a principal focus within functional safety management standards. While autonomous systems derive benefits from environmental perceptions accumulated over extensive periods, the training data is typically gathered under a constrained set of conditions. (3)

The importance and difficulty of automating a robust understanding of privacy requirements related to conception, design, and the execution of autonomous systems are significant. Several direct ethical implications are relevant. Firstly, transparency versus trade secrecy are long-standing issues in aerospace and automotive design, but the level of opacity that is expected in the intellectual suggestion

intelligence: Applications of industry 4.0. Energy Reports, volume 8, p334

(1) Cugurullo, F. (2020). Urban Artificial Intelligence: From Automation to Autonomy in the Smart City. Journal of Frontiers in Sustainable Cities,vol 2,p6.

(2) Li, J., Herdem, M. S., Nathwani, J., & Wen, J. Z. (2023). Methods and applications for Artificial Intelligence, Big Data, Internet of Things, and Blockchain in smart energy management. Energy and AI, p212

(3) Sarker, I. H. (2022). AI-based modeling: techniques, applications and research issues towards automation, intelligent and smart systems. SN Computer Science. 3:158

and creation phase is likely misaligned with existing transparency expectations for AI/ML driving design. Secondly, it is expected that the public will want to know who is legally responsible if an AI-backed automotive system malfunctions, and attributing accountability may be a necessity to achieve political will for the integration of AI and robotics. It also remains an open question whether manufacturer liability or fault attribution may act against the adoption of autonomy in some cases. In principle, open challenges discussed explain that risks may accumulate and eventually cause accidents if not properly managed. Guidance for best practices in the design and operation of autonomous systems has been proposed. While AI systems offer significant potential, there appears to be little national-level guidance on the limitations of AI to inform these considerations. AI training is primarily handled through oversight by academic and research bodies, and the attendant output courses do not tend to focus on limitations or best practices in AI function. (1)

XII. Ethical Considerations in AI-driven Automotive Design

Several significant ethical questions are raised by the integration of artificial intelligence (AI) into the automotive design chain. Is consumer consent required if their car collects and sends data about them? Should this data be shared with the relevant authorities? Can we trust autonomous vehicle algorithms? What if there is any bias in the algorithms driving decision-making concerning life and death? Should decision-making about vehicle design be transparent? Answers to these questions are currently the subject of discussion across a variety of disciplines. (2)

The implementation of artificial intelligence (AI) applications in the realm of vehicle design carries significant implications for consumer safety and may catalyze substantial societal changes, including issues such as structural unemployment and environmental impacts. Therefore, the establishment of an ethical framework is imperative. Nonetheless, manufacturers continue to exhibit uncertainty regarding the application of AI in automotive contexts and the regulations that should govern such practices. There exists a pressing need for a contemporaneous overview of pertinent discussion topics and emerging requirements to enhance the comprehension of pertinent experts in leadership roles. From a practical perspective, AI is currently employed to formulate ethical algorithms capable of identifying hazardous designs and represents a novel approach to risk management. The consideration of ethical concerns is integral to corporate social responsibility, as it addresses the interests of various stakeholders. A wide array of techniques has been developed by experts, employed, and modified over time.

Consequently, ethical sensitivity may be recognized as a novel capability encompassing a set of competencies that effectively connect and leverage specific behaviors. In order to cultivate innovative ethical motivations, it is essential that these be harmonized with business motivations, strategies, and objectives. Manufacturers are concurrently investigating the evolving relationship between innovation and the ethical obligations inherent in responsible automotive design. Collaborative efforts are necessary to devise standardized guidelines for product safety and quality, engaging managers, designers, engineers, and labor representatives in the process. Such guidelines should be subject to regular review, maintain enforceability, remain current, and be auditable by regulatory authorities. Concerns have been articulated regarding the objectivity and shared understanding of these guidelines, which may lead to disputes during performance evaluations or credit requests. Nevertheless, industry consolidation, heightened consumer awareness, and increasing environmental concerns are fostering a trend that encourages surpassing ethical benchmarks, thereby motivating both manufacturers and consumers to prioritize safety, efficacy, and quality concurrently. Trust and confidence, particularly in the context of AI, can be fostered through a heightened commitment to ethical principles.(3)

XIII. Future Trends and Innovations in AI and Automotive Design

Augmented Reality As investment in AI continues to rise, emerging technologies such as data analytics, artificial intelligence, and augmented reality promise to transform not only the way vehicles are sold, but products are created and manufactured. VW is developing its digital ecosystem, BMW has already deployed AI-powered digital assistants in the form of in-car personal assistants, and Ford has made a significant investment in the use of virtual reality for vehicle design. The future scan also identified key tasks and technologies that will be of key focus in the

(1) Khayyam, H., Javadi, B., Jalili, M., & Jazar, R. N. (2020). Artificial intelligence and internet of things for autonomous vehicles. Nonlinear approaches in engineering applications: Automotive applications of engineering problems, p39.

(2) Nikitas, A., Michalakopoulou, K., Njoya, E. T., & Karampatzakis, D. (2020). Artificial intelligence, transport and the smart city: Definitions and dimensions of a new mobility era. Sustainability, 12(7), p2789.

(3) Khayyam, H., Javadi, B., Jalili, M., & Jazar, R. N. (2020). Artificial intelligence and internet of things for autonomous vehicles. Nonlinear approaches in engineering applications: Automotive applications of engineering problems, p45.

coming years, including advanced data analysis, miniaturization, and augmented reality. (1)

AI and Industry As an output of the annual World Model for automotive design, the team calculates future outputs and capacity for the sector on an annual and cumulative basis. The tool can analyze millions of possible futures for the sector, driven by AI and incorporating factors including capacity, storage levels, energy availability, regulation, plus many others. The series outlines key AI trends in the design of connected and autonomous vehicles, electric vehicles, and user-centric design, as well as discussing the innovations that can be expected in this space and the significant potential barriers to innovation. (2)

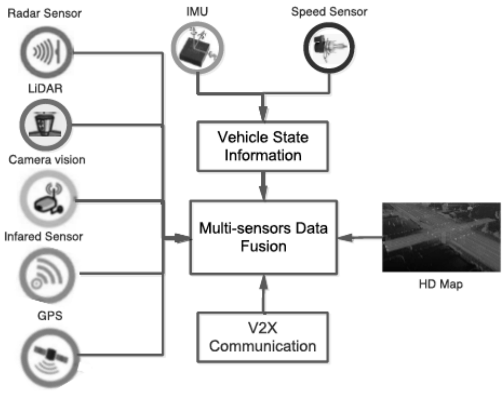


Fig. 6. Multi-sensor data fusion.

Artificial Intelligence and Industry Trends AI is increasingly being integrated into a variety of design areas including: 1) excellence and luxury, which in the future will link into the Smart City AI work stream; 2) innovation and aesthetics, where neural networks are being used to create new designs and atmospheres; 3) designing for the future, where the team collaborated with an AI, collaborative robot, and an artist to produce future-facing artwork; 4) as well as a whole host of other international projects.(3)

XIV. Conclusion

The research pointed out that AI technological advances have an increasingly significant impact on various sectors of the automotive industry, including automotive design, production, and user experience. Moreover, the integration of ethical aspects of AI application was emphasized. There was also a need to address the challenges of designing automotive systems with AI applications to responsibly integrate AI technologies into the automotive industry. However, the paper did not discuss the high-level design for the future of AI in the field of automotive. Current levels of study and discussion on the subject should be maintained. For wider dissemination, the insights from these studies can be guided by basic research questions relating to the various domain-related opportunities that AI offers in order to bring innovations, improvements, or added value in relation to automotive design both now and in the near future, within the design focus of the journal where a link between automotive, user, and design directions is naturally drawn.

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