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AI Reshaping the Automotive Industry

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Abstract

This introductory article opens the section by giving an overview of the state-of-the-art Artificial Intelligence (AI) technologies in automotive manufacturing and the current AI development in areas such as quality optimisation and analytics and predictive maintenance. It presents future potential and opportunities for AI in the automotive manufacturing sector, covering trends of using AI, industrial internet of things (IIoT) and robotics technologies in production and logistics optimisation, quality, and maintenance. Finally, the article introduces the five contributions to this section, highlighting the use of AI and IIoT in various scenarios in automotive manufacturing processes and challenges and technological advancements.

Keywords: artificial intelligence (AI), industrial internet of things (IIoT), automotive production, automotive logistic, optimisation, predictive maintenance.

1.0.1 Introduction and Background

The automotive industry and its production and logistics processes are a complex network that must implement high planning, operation, quality, and security processes. To handle this complexity and ensure high productivity, processes have been optimised for several decades of

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technological developments. The development of highly networked systems and intelligently supported processes offer a new era in automation and process optimisation. With the more recent developments in AI, new opportunities are being established to implement productions more efficiently, humanely, and with higher quality. Finally, AI also helps to make the processes and production systems more flexible and modular because the intelligence of the control system is implemented deeper into the individual production processes [1].

1.0.2 AI Developments and Future Trends for AI Technologies in Automotive Industry

The weak and light AI process already supports planning and production. Bots can trigger demand mediation; camera systems ensure the quality of the products, or intelligent algorithms optimise the demand control for the line supply. With the consistent implementation of sensors at the plant level, their intelligent and fast networking via service bus systems and the analysis of relevant data and AI algorithms, a new quality of data transparency and value is created. The development of core functions in the automotive industry processes through AI capabilities is presented in Figure 1.0.1.

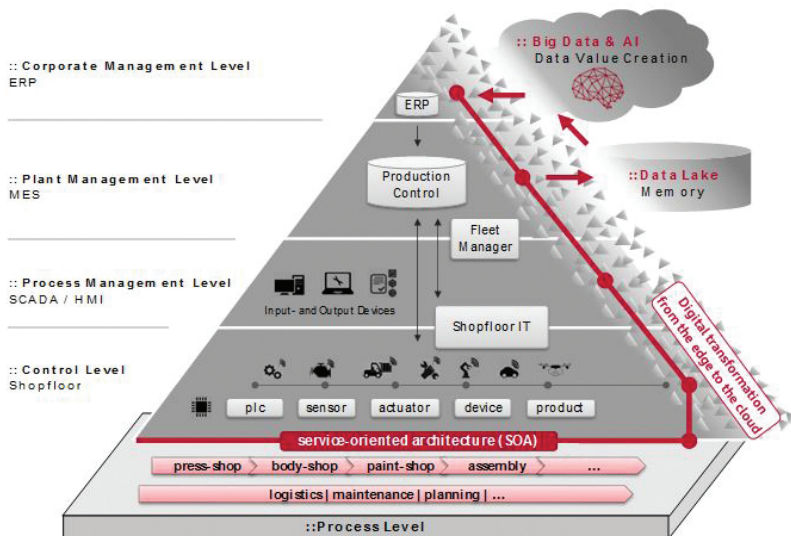


Figure 1.0.1 Further development of core functions in the processes of the automotive industry through AI capabilities [1].

This makes it possible to react to process and quality problems earlier or to automate the right decisions for the next process steps proactively. The use of new systems that automate routine tasks allows people to concentrate on the actual competencies of their function in the production system and being assisted by the intelligent system. In the past few years and during the AI4DI project, three essential AI topics have frequently emerged in the automotive industry: operational, prediction and detection intelligence. These topics are currently primarily developed and used in the productions and logistics of the automotive industry. A short description of these topics is given below.

- Operational intelligence relates to real-time dynamic process analytics that delivers visibility and insight into machines, process-generated data, streaming events, and business operations. These solutions run queries against streaming data feeds and event data to deliver analytic results as operational instructions. This provides the ability to make decisions and immediately act on these analytical insights through manual or automated actions.
- Prediction intelligence refers to solutions that use the knowledge gained from operational intelligence to determine the effects of real-time data using autonomous methods in forward-looking time series. Predictions are made regarding the behaviour of the process, or the product based on the learned historical comparisons.
- Detection intelligence addresses solutions that autonomously show deviations and abnormalities to defined as well as learned target states. These use various sensor technology options such as camera systems, sound sensors or other proximity sensors to detect objects, compare them with the system, and make statements about their condition. Sensing for object and status detection can be done by different senses – e.g., visually, acoustically, and sensitive.

Relevant AI technologies and methods for the implementation are suitable data clustering processes, neural networks, and intelligent sensing. Accordingly, ML and deep learning are essential areas of development, whereby physical objects play a significant role and process data that predict system behaviour. Therefore, pre-processing of the data with clustering algorithms (Gaussian mixture / K-Means) and time series prediction and anomaly detection with neural networks are primary fields of action to be further developed and implemented. However, the greatest challenge in the implementation is the secure integration in the clocked and complex processes, which must not be interrupted under any circumstances.

Implementing this in a wide-ranging legacy systems environment requires extensive protection and standardisation of the interfaces needed to source systems and sensor levels. Predictive maintenance and quality management represent an essential field of currently practical and efficient AI solutions.

1.0.3 AI-Based Applications

AI4DI project partners are developing AI and IIoT technologies with applications in different areas of the automotive industry sector, as illustrated in Figure 1.0.2.

The articles included in this section cover several demonstrators and actionable insights into how AI and IIoT are used in the automotive process and product applications. A brief overview of the articles in this section are presented in the following paragraphs.

The article “*AI for Inbound Logistics Optimisation in Automotive Industry*” addresses the challenges of the inbound supply process on production sites in the automotive industry (such as volatile supply chains) and argues for the use of AI- technology to manage its complexity and ensure the making of the right decisions in critical areas. A demonstrator use case of design and implementation of a Material Planning Decision Support System is presented, operating in the production site and attempting to optimise the complete inbound logistics process. The challenge is to fuse information dynamically from all sources into a single dataset and integrate it with user

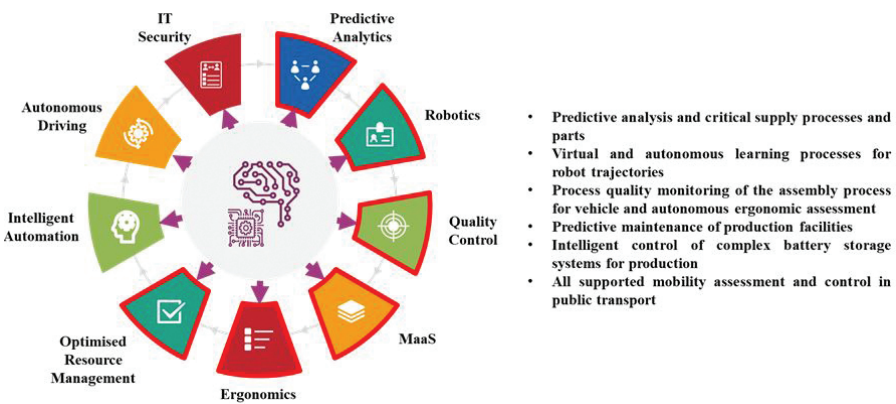


Figure 1.0.2 AI4DI – Development of AI solutions addressing different approaches [2].

requirements specified as short user journeys and label and integrate human experience-based knowledge for alternative courses of action.

The article “*State of Health Estimation using a Temporal Convolutional Network for an Efficient Use of Retired Electric Vehicle Batteries within Second-Life Applications*” addresses the need for state-of-health estimation algorithms to ensure safe and efficient usage of retired electric vehicle batteries (lithium-ion batteries) within second-life applications and proposes a data-driven approach, capable of overcoming the drawbacks of traditional less-robust estimation algorithms. The novel machine learning algorithm is based on a temporal convolution network and can deal with the highly nonlinear dependence on the changes of environment and working conditions during the operation. The network has been trained and tested with data gathered from commercial industry applications in energy storage, and the results show that it can predict the state of health with high accuracy.

The article “*Optimising Trajectories in Simulations with Deep Reinforcement Learning for Industrial Robots in Automotive Manufacturing*” presents a proof of concept for the applicability of reinforcement learning for industrial robotics by demonstrating a use case on automatic generation and optimisation of trajectories for applying the sealant material on car bodies (to prevent water intrusion and hence corrosion) using industrial manipulators. The Markov Decision Process (MDP) formalisation of an agent to reduce the amount of manual work involved in offline programming shows promising results. The methodology is yet to be verified and validated by comparing the agent solution with the hand-crafted trajectories and various degrees of involvement of human experts.

The article “*Foundations of Real Time Predictive Maintenance with Root Cause Analysis*” addresses the importance of autonomous systems to be equipped with a detection system to observe faulty behaviour in real time and predict failing operations. To avoid critical scenarios, finding the corresponding root cause is essential; hence, the focus of the article is on discussing the foundations behind diagnosis, i.e., the detection of failures and the identification of their root causes in the context of predictive maintenance. The article also explores the applicability of various diagnostic algorithms in real-time simulation environments, particularly artificial intelligence methods, including model-based diagnosis, machine learning and neural networks.

The article “*Real-Time Predictive Maintenance – Model-Based, Simulation-Based and Machine Learning Based Diagnosis*” addresses the importance of autonomous systems to be equipped with a detection system

to observe faulty behaviour in real time and outline its root cause. The underlying background is presented in a previous article “*Foundations of Real Time Predictive Maintenance with Root Cause Analysis*”. This article explores the applicability of various diagnostic algorithms in real-time simulation environments. A simplified DC motor model with fault injection capability was developed, and three diagnostic methods (model-based, simulation-based and machine learning) were employed. The measurements have been compared, limitations identified and conclusions drawn. Preliminary results are promising, but more work is needed to address the challenges of efficiency and reliability of the diagnostic solutions.

The article “*Real-Time Predictive Maintenance – Artificial Neural Network Based Diagnosis*” addresses the importance of autonomous systems to be equipped with a detection system to observe faulty behaviour in real time and outline its root cause. The underlying background is presented in a previous article “*Foundations of Real Time Predictive Maintenance with Root Cause Analysis*”. A second article “*Real-Time Predictive Maintenance – Model-Based, Simulation-Based and Machine Learning Based Diagnosis*” explores the applicability of three diagnostic methods in particular (model-based, simulation-based and machine learning) on a simplified DC motor model with fault injection capability. This article explores yet another method – artificial neural network (ANN) diagnostics – and its applicability with two use cases, one using an acausal six-phase e-motor model to simulate faults and the other for fault detection based on vibration measurements. Both simulation and measurement data are used for the ANN training. Two ANNs were designed, one for behaviour diagnosis and the other for the vibration sensor’s microcontroller. Preliminary results are promising; the method can be applied to edge devices and can be implemented in real-time predictive maintenance applications.

Acknowledgements

This work is conducted under the framework of the ECSEL AI4DI “Artificial Intelligence for Digitising Industry” project. The project has received funding from the ECSEL Joint Undertaking (JU) under grant agreement No 826060. The JU receives support from the European Union’s Horizon 2020 research and innovation programme and Germany, Austria, Czech Republic, Italy, Latvia, Belgium, Lithuania, France, Greece, Finland, Norway.

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