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Advances in Automation Systems for the Automotive Industry

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The evolution of industrial processes through automation has led to increased efficiency, precision, and adaptability. Incorporating automation and robotics into manufacturing and production has been a key driver of progress in various industries [1]. The capacity to enhance quality and repeatability, mitigate human error, and accelerate production rates has rendered these concepts indispensable across diverse sectors. Furthermore, the significance of automation is further emphasized in the era of Industry 4.0, where smart manufacturing and mechatronics play fundamental roles [2]. Automation encompasses the utilization of diverse control and sensor systems alongside actuators to control machinery, thereby diminishing the necessity for human intervention. Automation is widespread across various industries, with the automotive sector emerging as a main driver for the advancement of automation systems, by pursuing high productivity and enhanced product flexibility [3, 4]. A notable advancement in automation is the integration of Industry 4.0 principles, by the combination of digital technologies with industrial processes [5]. As a result, different principles have been adopted, such as Internet of Things (IoT), artificial intelligence (AI), and big data. The communication and decision-making abilities of machines leads to the concept of "smart factory" [6], which excels in production line efficiency, productivity, and fewer stoppages. Using real-time system monitoring and optimization, businesses can reduce material waste and power requirements, while enhancing product quality.

In recent years, the automotive industry has witnessed major advancements in automation systems, which revolutionized the manufacturing processes and improved vehicle production:

- One significant improvement are collaborative robots, or cobots, which work seamlessly alongside human operators. These robots, equipped with advanced sensors and vision systems, increase the efficiency of tasks such as component assembly and welding [7].
- Another major development is the integration of Artificial Intelligence (AI) in automotive production systems. AI algorithms, powered by machine learning, contribute to intelligent decision-making in manufacturing operations. From predictive maintenance to quality control,

AI-driven systems optimize production by identifying patterns, predicting failures, and ensuring consistent product quality [8].

- The automotive industry has been implementing the concept of "digital twins", which consist of virtual replicas of physical manufacturing processes. Digital twins facilitate real-time monitoring and analysis, enabling manufacturers to identify and address potential issues before they impact the production line. This concept increases the production efficiency, and reduces stoppages and maintenance costs [9].

- The adoption of 5G technology has also played a crucial role in advancing automated processes in the automotive sector. Actually, it provides high-speed and low-latency communication, leading to continuous connectivity among robotic systems and allows for real-time data exchange and decision making. As a result, the coordination between various manufacturing systems is significantly improved [10].

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