Engineering the Future: Robotics in the Automotive Industry Explained

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Abstract:

The study provides an overview of the potential applications of industrial robots in the automobile sector, which is now the market's most significant client. An overview of the use of robots in global industry is provided in the first section of the article, which also discusses the state of industrial robot utilization. The most popular uses of robots, particularly in the automotive sector, are covered later, along with developments and outlooks for the field's future. The essay concluded with a specific project overview regarding robotized screw tightening on the car seat production line, which served as a model task from actual industrial practice.The many uses of robots in the automobile industry are examined in this review, including material handling, welding, painting, assembly line automation, and quality control. It emphasizes how collaborative robots (cobots) enhance human-robot interaction and how advances in machine learning and artificial intelligence maximize robotic performance.

Keywords: Industrial robot; robotics in automotive; production of passenger cars; transport and production; automated assembly line

1. Introduction:

Industrial robots and manipulators are being used for a variety of activities where human operators are no longer needed. Finding a proper and widely accepted description of "what exactly the industrial robot is" presents several unique challenges, mostly due to the disparities between the Euro-American and Asian (particularly Japanese) markets. Any mechanical or mechatronic device with kinematic pairs (joints) and a corresponding degree of freedom of movement is called a robot [1].

The automotive industry has long been recognized for its commitment to innovation, continuously embracing new technologies to improve production efficiency and product quality. One of the most significant advancements in recent years is the incorporation of robotics, which has transformed manufacturing processes and operational capabilities. Robots have become essential throughout various stages, from assembly lines to quality assurance, allowing automakers to optimize operations, lower costs, and enhance safety standards [2].

Robotics in the automotive sector encompasses a range of functions, such as welding, painting, and material handling, each playing a vital role in boosting production efficiency. Additionally, the rise of collaborative robots (cobots) has introduced a new model of human-robot interaction, promoting safer and more adaptable work environments [3,4].

This overview seeks to provide an in-depth analysis of the various functions that robots fulfill within the automotive industry. It will delve into the technological advancements that fuel these applications, the advantages gained by manufacturers, and the challenges associated with the widespread use of robotics. By examining the current landscape and future developments, we can gain a deeper understanding of the crucial role robotics will continue to play in the evolution of the automotive sector [5].

2. Current Developments and Patterns in the Automotive Sector's Use of Industrial Robots

These days, the manufacturing of passenger automobiles and transport vehicles—whether powered by a traditional internal combustion engine or the increasingly popular hybrid and electric drive systems, respectively—has grown increasingly complicated. Nowadays, a significant portion of all manufacturing processes need to be automated using two essential pieces of machinery: industrial robots and CNC machine tools [5]. Apart from addressing climate change, the 2030-year objectives would mandate cars with low or zero emissions, necessitating even more rapid and extensive automation of the next generation based on so-called "intelligent sensors" and collaborative and cognitive robots [6].

2.1 The automobile industry's present robots' situation:

Additionally, progress in artificial intelligence and machine learning is enhancing robotic performance, allowing for improved decision-making and adaptability in changing environments. As manufacturers increasingly adopt automation, they are also focusing on overcoming challenges such as workforce training and system integration to ensure smooth collaboration between humans and robots [7,8]. Overall, the current landscape reflects a strong dependence on robotics, which is fostering innovation and competitiveness in the industry.

General handling, arc and spot welding, automated assembly, paint spraying, joint sealing, visual inspection, and quality control are the most often used "robotized processes" in the automobile sector. Other duties like cleaning are also included [9]. These days, experts in the automotive sector are investigating new robotics activities since robots are more precise, effective, and able to carry out tasks that are more complicated and adaptable [10]. Consequently, the automotive sector continues to be one of the world's most automated supply chains and one of the biggest robot users [11]. Currently accounting for 30% of all industry investments, automotive robotics is the field that produces the greatest integration of industrial robots globally. We could highlight the following robotics applications in the automobile sector.

- Improve yearly production rates and process accuracy in the automotive sector;
- Automate and elaborate some activities with little human involvement;
- Ensure worker health and minimize potential occupational hazards;
- For the management of large and heavy goods, efficient operations and activities are created.

2.2 future scope of automation in robotics:

The future of automotive robotics is set to be revolutionary, influenced by several significant trends and developments:

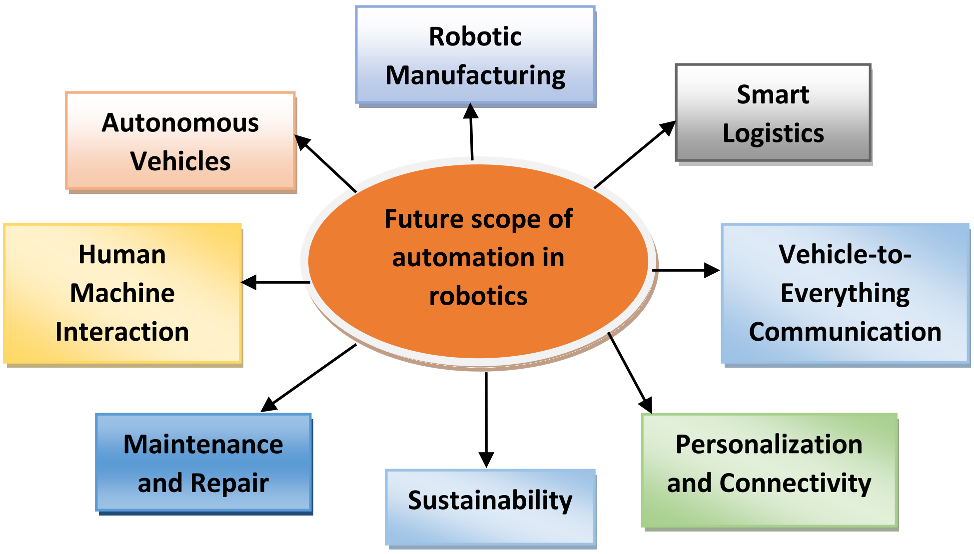

Figure 1: Automation in Robotics: A Vision for the Future

- Autonomous Vehicles: Ongoing advancements in AI and machine learning will lead to more advanced self-driving cars. Improved sensors, data processing, and algorithms will allow vehicles to navigate complex environments safely [12].

- Robotic Manufacturing: Automation in vehicle production is expected to rise, with robotics playing a vital role in assembly lines. Collaborative robots (cobots) will work alongside human workers, boosting efficiency and safety [13].

- Smart Logistics: Robotics will transform the supply chain, making autonomous delivery vehicles and drones more common. These innovations will enhance last-mile delivery and inventory management.

- Vehicle-to-Everything (V2X) Communication: Future vehicles will communicate with each other and with infrastructure, such as traffic lights and road signs. This will improve traffic flow, decrease accidents, and enhance the overall driving experience.

- Personalization and Connectivity: Robotics will create more tailored driving experiences. Vehicles will adapt to individual preferences through AI, and advanced connectivity features will enrich user interaction and entertainment.

- Sustainability: Robotics will optimize energy use and minimize waste in manufacturing and driving. Electric and hybrid vehicles, along with efficient robotic systems, will significantly reduce the automotive industry's carbon footprint.

- Maintenance and Repair: Advanced robotics and AI will enable predictive maintenance, allowing vehicles to self-diagnose problems before they become serious, thereby enhancing safety and reliability.

- Human-Machine Interaction: As vehicles become increasingly autonomous, the interaction between humans and machines will evolve. Improved user interfaces and AI-driven assistance will facilitate easier engagement for drivers.

- These trends suggest a future in which automotive robotics not only improves efficiency and safety but also redefines mobility and the overall driving experience.

3. Application of Robotics with vision system in automobiles:

A notable example of a robotized application featuring an integrated vision system is the automated guided vehicle (AGV) utilized in warehouses [14]. These AGVs come equipped with cameras and advanced vision technology that enables them to navigate complex environments, avoid obstacles, and carry out tasks such as picking up and transporting items.

Key Features:

- Navigation and Mapping: The vision system allows AGVs to map their surroundings, identifying shelves, pathways, and obstacles, which helps them plan efficient routes in real time.

- Object Recognition: The built-in cameras can identify various types of pallets, packages, or bins, enabling the AGV to determine the best methods for loading and unloading items.

- Quality Control: Some AGVs are capable of inspecting products as they traverse the warehouse, utilizing vision systems to detect damaged items or ensure accurate labeling [15].

- Collaboration: With their advanced vision capabilities, these robots can safely work alongside human staff, sensing their presence and adjusting their movements to prevent collisions.

Benefits:

- Increased Efficiency: Automating transport tasks allows warehouses to minimize manual labor and boost throughput.
- Enhanced Accuracy: Vision systems aid in accurately locating and handling items, reducing inventory management errors.
- Safety: The ability to detect and react to changing environments enhances the safety of both the AGVs and human workers.
- This application demonstrates how the integration of vision systems into robotic technologies improves functionality and efficiency in industrial environments [16].

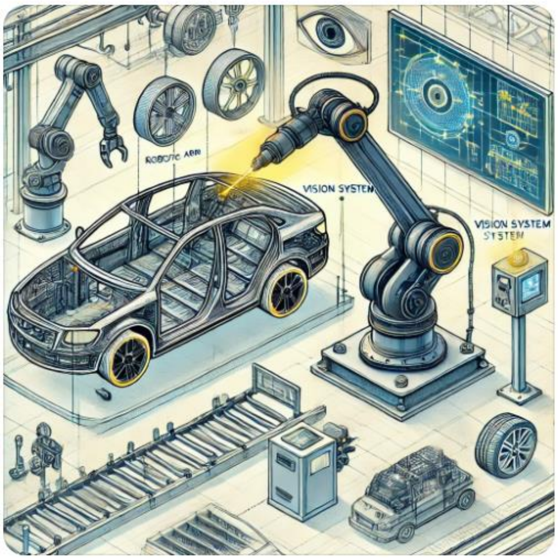

Figure 2: Application of robotics in assembly line scheduling of vehicles

The diagram demonstrates the use of robotics integrated with a vision system in automobile manufacturing. Below is an overview of the main components and their functions:

- Robotic Arm: Located on the assembly line, the robotic arm is tasked with jobs such as part assembly, welding, or quality control. It has actuators for precise movements [17].

- Vision System (Camera or Sensor): Positioned on or near the robotic arm, this system uses cameras or sensors to "see" and recognize parts of the vehicle, like the doors, windows, or chassis. It gathers real-time images and relays them to the control system for processing.

- Automobile: As the vehicle or its parts move along the assembly line, the vision system identifies key features or assembly points, directing the robotic arm for tasks such as aligning parts or conducting inspections.
- Control System: Acting as the central controller, it receives image data from the vision system and instructs the robotic arm. The control system interprets the image information to guide the robot's precise actions.

- Assembly Line: This conveyor belt transports cars through different stages of production. The robotic arm and vision system operate in harmony as the car progresses along the line.

Process Overview:

- The vision system captures images as the car approaches.
- The control system analyzes these images to determine the exact position of parts or areas needing attention.
- The robotic arm follows these commands to perform tasks like placing components, tightening screws, or conducting inspections.
- If a mistake or misalignment is detected, the vision system notifies the control system, which adjusts the robotic arm's actions or stops the process for manual intervention.
- This combination of robotics and vision technology enhances precision, accelerates production, and minimizes errors in automobile manufacturing.

Conclusion:

In today's era of automation and the adoption of Industry 4.0, it is crucial for robots to be integrated into car production processes [18]. This is because the demand for faster, more accurate production and higher-quality parts is continuously increasing. Additionally, it is important to comply with regulations aimed at addressing the negative effects of climate change, by implementing technologies that reduce overall production time and minimize environmental impact [19]. By cutting production time and using robots to replace workers in repetitive tasks, total production costs per vehicle are reduced, leading to higher company profits. After a general introduction to industrial robotics in the first section of this paper, we examine the global use of industrial robots, particularly the automation of common processes in the automotive industry [20]. Moreover, the paper highlights key trends in automotive robotics, including the use of "cobots," parallel robots with intelligent sensors, and other advanced technologies.

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