Literature Review of Industrial Application of Robotic Arms

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1 History of Robotic Arms

A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks. Computer science, mechanical engineering, electrical engineering and other technologies are used to develop robots that can substitute for humans. Robots are widely used in manufacturing, assembly, packaging, mining, transport, earth and space exploration, surgery, weaponry, laboratory research, safety, and the mass production of consumer and industrial goods [1].

Robots can take on any form but some are made to resemble humans in appearance. This is said to help with the acceptance of a robot in certain replicative behaviors usually performed by people. Such robots attempt to replicate walking, lifting, speech, cognition, and basically anything a human can do. Many of today's robots are inspired by nature, contributing to the field of bio-inspired robotics. However, some people may alternatively perceive robots as dangerous technological ventures that will someday lead to the demise of the human race, either by outsmarting humans or out muscling us and taking over the world, or by turning us into completely technology-dependent beings who passively sit by and program robots to do all of our work [2].

The history of robotic arms dates back to the invention of the first industrial robotic arm, the Unimate, created by George Devol and marketed by Joseph Engelberger in 1961. This pioneering robotic arm featured hydraulic actuators and three axes, primarily used in industrial tasks such as material handling and welding, marking the beginning of automation in manufacturing [3, 4]. The evolution of robotic arms progressed through multiple generations incorporating servo-control, computer interfaces, and greater degrees of freedom, exemplified by innovations such as the Stanford arm developed in 1969, which featured six axes and sensor-based control [3, 4].

Beyond industrial applications, the technological advancement of robotic arms has extended into surgical and prosthetic fields. The da Vinci Surgical System, a notable example in medical robotics, integrates robotic arms to perform minimally invasive surgeries with high precision, expanding the arm's role from manufacturing to healthcare [3, 5]. More recent developments emphasize the integration of artificial intelligence and embodied intelligence in robotic arms, enabling adaptive, autonomous operation in complex environments [6].

Thus, robotic arms have evolved from simple hydraulically driven devices to sophisticated multifunctional robots with applications spanning industry, medicine, and beyond, continually advancing through innovations in control, sensing, and AI technologies [3, 4, 6].

2 Industrial Applications of Robotic Arms

Industrial robotic arms are programmable manipulators designed to replace humans in performing repetitive, dangerous, or precision-required tasks across various industries including automotive, electronics, and hazardous material handling. A robotic arm consists of links connected by joints that allow rotational or translational motion, with an end effector analogous to a human hand that can be designed for specific tasks like welding, gripping, or spinning. Modern control approaches utilize haptic technology and accelerometer sensors to capture natural human arm movements, allowing the processing unit to generate corresponding control signals that replicate these movements in the robotic arm, providing greater flexibility compared to traditional manual controllers where each joint is controlled separately [7].

Software simulation and control development employ platforms like LabVIEW for creating graphical user interfaces and Arduino for inverse kinematics calculations that convert desired end-effector positions into specific joint angles. The simulation process enables users to input object coordinates, visualize robot movements, and test pick-and-place operations in a virtual environment before physical implementation. Key design parameters for simulation include degrees of freedom (typically 3-6 DOF), workspace analysis, position accuracy, and bilateral communication between master control devices and slave robot systems with force feedback capabilities, ensuring effective performance validation prior to hardware deployment [7].

3 Laser Cutting

The use of these simulations and development helps robotic arms excel in environments where accuracy is critical. One of these interesting areas is laser cutting. Robotic laser cutting has strong potential to change the way metal manufacturing operates in the Industry 4.0 era. A study done by Nikose et al. (2024) compares traditional flat-bed CNC laser cutting machines with robotic laser cutting systems, focusing on flexibility, cost, accuracy, and digital integration. They note that while flat-bed machines remain the most common, robotic systems provide more adaptability, easier digital control, and better compatibility with automation and artificial intelligence. The authors conclude that robotic laser cutting can be a more efficient and affordable option for small and medium-sized manufacturers, especially those producing various products in small batches, and they recommend further research to improve and expand its industrial use [8].

Inspired by the research paper, the project presents a laser-cut robotic arm that can cut acrylic sheets using a small laser fixed at the end of the arm as the end-effector. The goal is to let the arm make clean and accurate cuts on given paths instead of doing it by hand to automate the whole process. Such systems are usually found in factories to make custom parts or signs. The design and testing will be done using ROS2, Python, and MuJoCo.

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