# Industrial Robotic Applications Report

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## I. Introduction

Industrial robotics is one of the fastest-growing fields in modern technology, enabling significant advances in automation, efficiency, and safety. Once limited to repetitive manufacturing tasks, robots are now entering industries that previously had limited automation, such as healthcare, food processing, and agriculture. This review explores recent advancements in industrial robotics, focusing on human-robot collaboration, object recognition, path planning, and optimization, as well as applications in the medical, agricultural, and food industries.

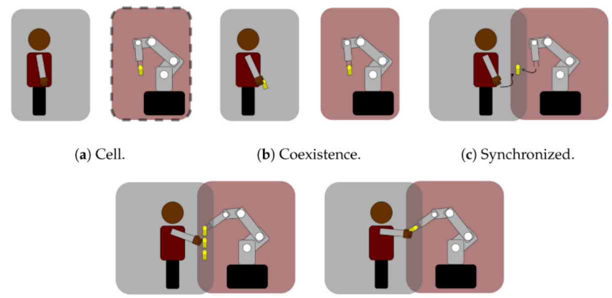
In robotic applications, time data processing allows these machines to achieve higher precision in tasks such as surgical procedures, food sorting, and crop harvesting. These innovations are driving a new era of automation, where robots are not only tools but integral partners in diverse industrial operations.

The scope of this review includes: Recent developments in human-machine interaction (HMI) and its increasing role in industries whether medical , food industry , assembly and material handling applications.

## II. Literature Review

### A. Human-machine Interaction (HMI)

Recent advancements in Human-Robot Collaboration (HRC) emphasize human-centered automation by integrating human activities with Cyber-Physical Production Systems (CPPS). This approach focuses on adapting industrial manipulators to the physiological characteristics of human operators, using biometric signals like stress, fatigue, and motion tracking. In a collaborative environment, a CPPS enables a robotic arm to assist a human operator in a joint manipulation task, where the robot adapts its task execution speed and operation based on real-time monitoring of the worker's condition. This ensures improved interaction and efficiency in the manufacturing process [1].



(a) Cell. (b) Coexistence. (c) Synchronized.

(d) Cooperation. (e) Collaboration.

Figure 1: Human–robot cooperation levels [5]: (a) no collaboration, the robot remains inside a closed work cell; (b) coexistence, removed cells, but separate workspaces; (c) synchronisation, sharing of the workspace, but never at the same time; (d) cooperation, shared task and workspace, no physical interaction; (e) collaboration, operators and robots exchange forces. [2]

### B. Medical Applications

Serial robotic manipulators have revolutionized medical applications, particularly in surgery, by enhancing precision, dexterity, and reducing human error in complex procedures. One of the most prominent examples is the da Vinci Surgical System, which has been widely adopted for minimally invasive surgeries such as urology, gynecology, and cardiac operations. Yang et al. in 2024 adressed these systems, which utilize serial linkages to control end-effectors, enabling surgeons to perform tasks with enhanced precision and stability. In recent years, research has focused on improving the haptic feedback, control algorithms, and integration of machine learning (ML) for adaptive robotic behavior during surgery [3]. These manipulators are often structured with a series of revolute joints connected in a chain-like formation, enabling rotation around a fixed axis at each joint. This 7-DOF structure allows for intricate maneuvers such as rotation, pivoting, and precise angular adjustments, which are crucial in surgeries that require high precision in confined spaces, such as laparoscopic procedures [4].

### C. Applications in Agriculture

The development of agricultural robots is gaining momentum to address labor shortages and rising food production demands. Deploying multiple cooperating robots can reduce task duration, accomplish tasks impossible for a single robot, or enhance efficiency. This study [5] presents a cooperation strategy where two heterogeneous robots work together for grape harvesting: one robot (the expert) performs the harvesting, while the other (the helper) carries the harvested grapes. The cooperative methodology ensures safe and effective robot interactions. Field experiments validated the coordinated navigation algorithm and demonstrated the cooperative harvesting method, with recommendations for future improvements. The study also explores using logical, explainable decision-making based on mathematical lattice theory to enhance cooperation between autonomous robots in agricultural applications [5], [6].

In the field of agricultural robotics, end effectors designed for fruit harvesting are considered mechatronic subsystems. Their primary function is to individually detach fruit from stems and deposit them into temporary storage containers [7]. Robotic harvesting is a multifaceted process that integrates video cameras and recognition algorithms to identify ripe fruit, followed by gripping the fruit with a specialized gripper, moving it using a manipulator arm, and placing it in a designated storage area.

Yeshmukhametov et al. showcased in 2019 that harvesting grippers in agricultural applications can generally be categorized into two types. The first type includes precision grip end effectors, which are commonly employed for crops such as strawberries, apples, tomatoes, and sweet peppers (as discussed in [8]. The second type involves compression-based grippers, which feature larger contact areas between the fingers and offer limited or no capacity to transfer movement through the fingers. An example of these grippers is those that function by gripping and vibrating the trunks, as noted in [36].

### D. Food Industry

As the global population grows, so does the demand for food, putting pressure on suppliers to improve efficiency and sustainability. Robotics and automation are seen as critical solutions in this sector, although the food industry has been slower to adopt these technologies compared to others. Robotics is being used in food production, packaging, and even cooking. With the development of robotic devices, such as soft grippers, handling delicate food items has become more efficient, reducing the risk of damage and contamination. In recent years, especially due to COVID-19, there has been a notable increase in automation and AI-enabled robotic applications in the restaurant industry, enhancing both food processing and service operations. [9] A study by Sanket et al. in 2022 [10] offers an in-depth evaluation of the use of robotics in the food processing industry, highlighting a relatively novel application area. The review emphasizes the transformative potential of robots in food handling, serving, palletizing, and packaging operations. Key considerations such as robot dynamics, economic efficiency, kinematics, human-robot interaction, hygiene, safety, and maintenance are discussed.

### E. Assembly and Material Handling

Segura et al. [11] introduces and analyzes Context-Aware Cloud Robotics (CACR) for advanced material handling. Unlike the One-Time On-Demand Delivery (OTODD) method, CACR features context-aware services and effective load balancing. The paper outlines the system architecture, advantages, challenges, and applications of CACR. It also details key functions for material handling, such as decision-making mechanisms and cloud-enabled simultaneous localization and mapping. A case study demonstrates CACR's energy-efficient and cost-saving capabilities, with simulations confirming its superiority in improving energy efficiency and reducing costs in cognitive industrial IoT applications.

Another Four key structural components, in the following paper [12], were identified: interaction levels, work roles, communication interfaces, and safety control modes. The study found that physical contact-based collaboration, such as screwing assembly of small parts and handling heavy-weight objects, is well-suited for the automotive industry. Additionally, certified augmented and virtual reality devices emerged as effective assistive technologies for safety and training needs. The categorization provided helps practitioners select compatible structural components that align with modern manufacturing requirements for highly personalized products.

A specific functionality is proposed by Blatnicky et al. of the designed robotic manipulator which is the possibility of gripping of circular objects. [13]

## III. Conclusion

In our selected industrial application, we propose designing a desktop 4-DOF serial manipulator system specifically for **cooperative pick-and-place tasks**. This setup will involve two manipulators working in tandem to demonstrate multi-robot cooperation by playing an **interactive X-O game**. The game not only makes the demonstration more engaging but also effectively showcases the concept of Multi-Robot Systems (MRS) Cooperation in a clear, tangible manner. By using the serial robotic manipulators to strategically place game pieces, this research illustrates how cooperative robots can work together to achieve common objectives, highlighting both their coordination and adaptability in industrial applications. By exploring the dynamics of robot cooperation in a controlled setting, we aim to lay the groundwork for practical implementations of multi-robot systems in real-world scenarios, driving innovation and improving operational workflows.

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