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Affordable Automation: Strategies for Cost Reduction and Efficiency Improvement in Daily Robotics

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Abstract

The study examined how robotics technologies can increase productivity in industries. As we all know, artificial intelligence (AI) is on the rise in the market, and industries are becoming increasingly reliant on AI to handle multifaceted tasks. Robotics is one of the most prominent fields in manufacturing and science, where engineers are focusing on developing robots that can perform specific tasks and deliver accurate results. As technology progressed, by 2005, 90% of all robots were used in car assembly in automotive factories. Today, robots serve a wide range of purposes, including healthcare, space exploration, and military applications. In the future, robotics and sensor technologies are expected to advance significantly, along with machine learning and AI capabilities, becoming even more impressive and sophisticated. This study aims to provide an overview of the field of robotics. The researcher concluded that robotics is revolutionizing the future of work across various industries. In many ways, robots have become an integral part of daily life.

Keywords: Autonomous, robotics, sustainable, artificial intelligence, cost-cutting, efficiency, manufacturing

INTRODUCTION

Robotics is a multidisciplinary study of the practice of creating, constructing, using, and operating robots. The phrase "robotics" is an extension of the word "robot." Czech playwright Karel Ōapek first used this phrase in his 1920 drama Rossum's all-purpose robots.—German National Library, 2020.

The robotics community aims to develop intelligent machines that can assist and benefit people in various ways. Robotics in mechanical engineering is responsible for designing and constructing the physical structures of robots, whereas robotics in computer.

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Techniques for robotic automation have been a focus of scientific research. Robotics is influenced by a wide range of disciplines, including software, electrical, and biomedical engineering. In labor-intensive, repetitive, or disagreeable jobs, such as assembly, cleaning, monitoring, and transportation, it can replace people [1–4].

The domains of artificial intelligence (AI), machine learning, and robotics have begun to intersect in the past few years. Nowadays, the word "bot" is not used to describe a physical robot to help prevent confusion. Instead, it refers to a computer-controlled robot without a physical body. Robotics is expanding rapidly as a result of the advancement of technology, which makes the study, creation, and testing of new robots useful for a variety of applications. Robotics is a vast field of technology with many applications that have the potential to drastically alter many industries and our way of life. This is a field that does not move away [3]. It is conceivable that robotics and AI will combine even more seamlessly in the future, which will result in the future, which will lead to the development of progressively more sophisticated and practical robots (Figure 1).

The Control System

In summary, the controllers act as the brains of the robot arms. They function as the main processors of an industrial robot arm and can be programmed to run automatically or allow humans to operate them manually. These control consoles come in a range of configurations, depending on the type of processing power required. Large complex computer systems can be found in factories and enterprises, whereas some controllers are small, simple joysticks.

The Sensor System

The newer variants feature sensors, whereas older models do not. These sensors are responsible for enabling robot hands to perceive their surroundings and respond and adjust accordingly. These sensors are necessary if two or more robots operate together to avoid collisions. Alternatively, they allow the robot to precisely grasp a delicate object to prevent damage.

Robot Arm

The arm itself, which consists of the elbow, shoulder, and wrist joints, is the primary component of a robotic arm. In most cases, the shoulder is located near the base of the arm and is connected to the controller. It can spin and move in both directions. The central placement of the elbow allows for independent movement of the upper and lower parts. Finally, at the ultimate end of the factory robot arm is the wrist that is attached to the end effector.

End-of-Arm Tool

The work on a robotic arm is performed at the end-of-arm tooling, or EoAT. This is the point at which the robot contacts the workpiece. Robots utilize a vast variety of tools, much like humans, to perform tasks. Another name for robotic end-of-arm tooling is “end effector.” The robot’s hand, wrist, and tool were all parts of the EoAT. Vacuum cleaners and welding tools are examples of end effectors.

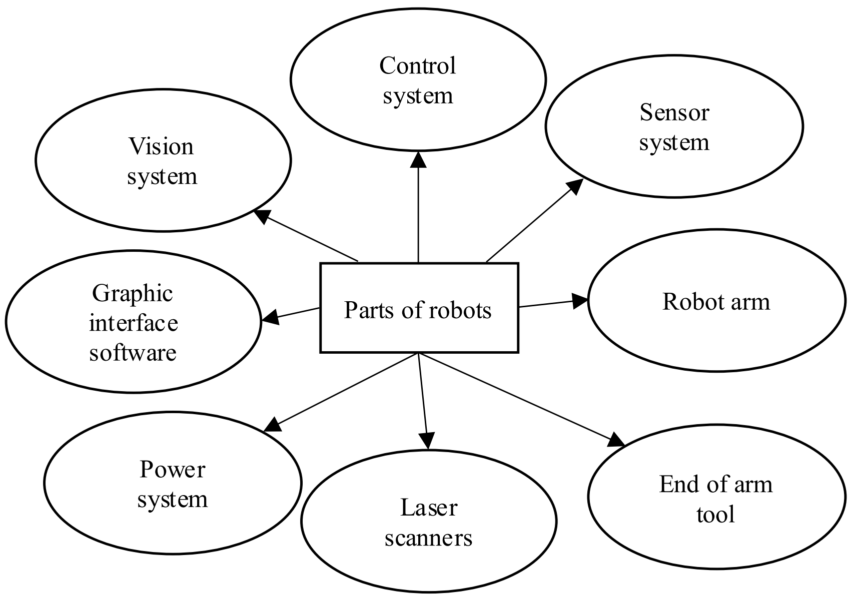

Figure 1. Parts of robots.

Laser Scanners

Numerous processes have changed as a result of the industrial application of laser technology. The handheld barcode scanners are equipped with lasers. They can measure machined items precisely. Large distances can also be measured by using lasers. Lasers are typically used in complex vision systems. Owing to computer vision, autonomous navigation and obstacle avoidance are now possible in mobile robots. The application of laser scanners in industrial robotic vision is among the most popular applications. LiDAR, an acronym for Light Detection and Ranging, is used in these scanners. Akin to Radio Detection And Ranging (RADAR) is LiDAR. After emitting an electromagnetic energy pulse, the LiDAR sensor tracked the reflection that returned from the closest object. The time taken for reflections to return was measured.

Power Systems

For robots to function, their motors, actuators, sensors, and control systems require a steady power supply. Examples of common power systems include fuel cells, tethers, hybrid power systems, electric power, hydraulic power, and pneumatic power. Electric power is the most extensively used power source because of its effectiveness, low noise level, and ease of control. Pneumatic power is utilized for applications that are lightweight, small, and clean, whereas hydraulic power is used for robots with high torque, power, or load capacity. Hybrid power systems balance the performance, efficiency, and dependability by combining several power sources.

The Graphical Interface Software

With the rapid advancement of technology, new models now feature graphical user interface software that allows for the command and control of the robotic arm. Robots using graphical interface software (GUI) are better at picking and putting materials, because it is a quicker and more effective way to control them.

Vision System

The technology that lets a robot "see" is called a robotic vision system. These systems provide them with the ability to recognize, navigate, examine, and manage various parts or jobs. A computer and one or more cameras comprise the robotic vision system. A computer processing software program enabled the robot to make sense of its surroundings. The robot then performs the designated duty by following the program instructions, which are provided by the employees of the manufacturing plant.

Robots differ greatly in size, shape, and capability, and each has its unique qualities. Nonetheless, many robots have certain common characteristics that allow us to classify them. There are a few classification categories for robots (Figure 2).

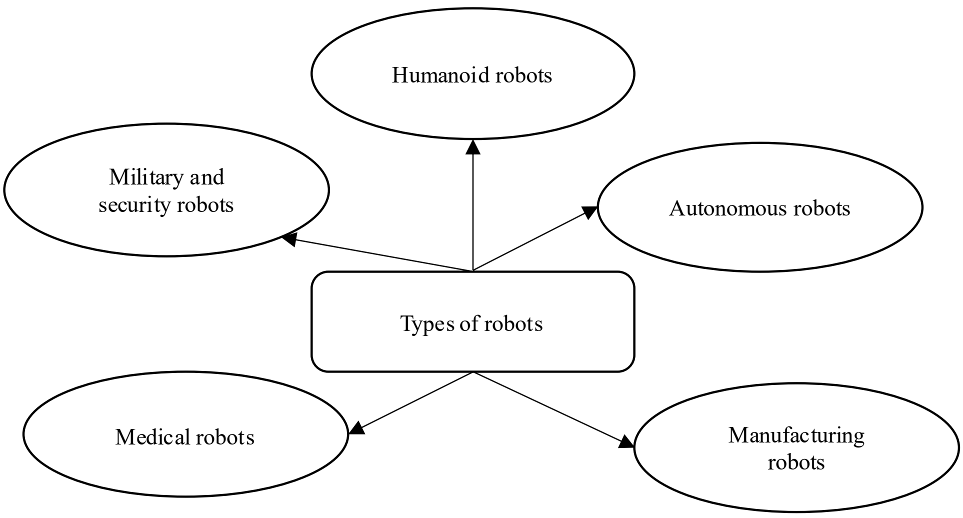

Figure 2. Types of robots.

TYPES OF ROBOTS

Humanoid Robots

Humanoid robots are mechanical machines with human-like arms, legs, and heads that can walk and control items in a manner similar to humans. Similar to humanoids, a robot's body usually has a machine-like appearance. Humanoids have sparked people's curiosity more than any other class of robot [1].

Autonomous Robots

A robot that has been designed and programmed to operate on its own in its environment and for extended periods without human intervention is said to be autonomous. Strong characteristics allow self-governing robots to understand their physical environment, and these machines frequently carry out activities that were formerly completed by humans, such as maintenance and direction [5].

The Manufacturing Robots

An industrial robot, sometimes known as a manufacturing robot, is designed to automate labor-intensive production tasks such as those required by a continually moving assembly line. They are placed in certain locations inside an industrial facility, and because they are large, heavy robots, they are the center of attention for all other worker tasks and activities [5].

The Medical Robots

Medical robots enable minimally invasive procedures, social engagement for elderly patients, regular and customized monitoring of patients with chronic illnesses, and intelligent medicine. Technological developments have enabled robots to perform a greater variety of complex activities in the healthcare sector. Restoring dexterity following a stroke or assisting with percutaneous coronary intervention (PCI) are two examples of precise activities [5].

The Military and Security Robots

Robots for military and security applications include a broad range of durable and resilient robot systems that can perform duties such as surveillance and other jobs that would be dangerous for people. Security robots are mobile systems that focus on private properties and enterprises [5].

LITERATURE REVIEW

Robert B. Kozma—Sustainable autonomy of intelligent systems (2021). The goal of this study is to increase the lifetime and self-sufficiency of autonomous systems. To allow intelligent systems to adapt, learn, and evolve in dynamic contexts while preserving resources and reducing external dependencies, his work focused on developing algorithms and approaches. The field of autonomous systems is moving closer to long-term sustainability, durability, and robustness in practical applications due to Kozma's efforts [5].

Yingxu Wang—The emerging field of autonomous systems and its theoretical foundations (2021). This study report provides insightful information about the methods and tenets that support the creation and functioning of self-governing systems. To clarify the difficulties and complexities of reaching real autonomy, his study examines a variety of viewpoints, from systems engineering to cognitive research. Wang provided comprehensive knowledge of autonomous systems by combining theoretical frameworks from other fields, opening the door for developments in robotics, AI, and other fields [6].

Ahmed Khanlari (2015) explored the benefits and difficulties of incorporating robotics instruction into the classroom. They identified barriers to widespread implementation, including curricular alignment, teacher preparation, and resource limitations. This study also highlights how students' critical thinking, problem-solving, and teamwork skills can be enhanced by training robots. To fully utilize robotics in education and equip students with upcoming technological challenges, a thorough assessment highlights the necessity of supportive legislation, professional development programs, and creative teaching approaches [7].

The research paper "*Introduction to Mobile Robotics" by Antonio Marin-Hernandez* (2020) provides a thorough understanding of the principles and developments in mobile robots. Marin-Hernandez investigated several subjects, including mobile robot applications, sensor technologies, navigation algorithms, and locomotion processes. By combining recent research, this study is an invaluable resource for specialists, academics, and students interested in mobile robotics because it provides a comprehensive review of the area.

Laura Connolly—An Open-Source Platform for Cooperative, Semi-Autonomous Robotic Surgery (2021). A new method for robotic surgery technology is presented in this study report. This platform encourages cooperation and creativity in the creation of semi-autonomous surgical systems by utilizing open-source concepts. Connolly's innovation can transform healthcare delivery by addressing the demand for accessible and reasonably priced robotic surgery technologies [8]. The results of this study highlight the importance of open platforms in developing robotic surgery and enhancing patient outcomes.

Yousif E. Abdelgabar—Motion control of a three-active-wheeled mobile robot and collision-free human following navigation in outdoor environments (2016) examined cutting-edge methods to guarantee secure and effective human-robot interaction. To facilitate accurate navigation while maintaining a safe distance from people, his research incorporated cutting-edge motion control algorithms [9]. Abdelgabar's research helps to create autonomous mobile robots that can function in harmony with people in outside environments by tackling problems such as obstacle avoidance and dynamic path planning.

Gyula Mester (2019)—New trends in robotics education discusses the emerging pedagogical approaches and technological advancements that shape the field. His paper examines new advances, such as transdisciplinary integration, virtual robotics labs, and project-based learning. Mester emphasized the value of practical experience and teamwork in developing students' robotics abilities. His work fosters passion for STEM (Science, Technology, Engineering, and Mathematics) subjects and prepares students for the changing demands of the robotics industry by investigating cutting-edge teaching strategies and curriculum designs [10].

Amy Eguchi—Robotics as a Learning Tool for Educational Transformation (2014). The significant effects of incorporating robotics into education are examined in this research report. Eguchi illustrated how robots promote life-changing learning experiences by looking at a variety of educational environments. Her work focuses on assisting children in developing their capacity for creativity, critical thinking, and problem-solving. Eguchi illustrated how students participate in interdisciplinary inquiry through practical robotics exercises, equipping them for the problems that lie ahead in technologically advanced societies [11]. This essay promotes the broad use of robotics as a driving force for innovation and reform in education.

Linda Daniel and Miltiadis D. Lytras (2018) used a case study approach to investigate how robotics might be used as a tool to advance inclusive education. This study examines how children with different learning difficulties might benefit from robotics in terms of engagement and learning. Singh investigated the usefulness of robotics in promoting inclusion and accommodating a range of abilities in educational environments by examining specific situations. The results offer important new information on how robotics can help diverse students and advance inclusive teaching methods [12].

Ales Jelinek—Vector Maps in Mobile Robotics (2015) examined the use of vector maps in mobile robots. Vector maps are powerful tools for the localization and navigation of robotic systems. Literature on vector maps was examined in Jelinek's study with a focus on the advantages and disadvantages of these methods for various robotic applications. The study examines various methods for creating and applying vector maps, providing information on their efficacy as well as areas for future development and application in mobile robotics [13].

Patil Swati Shamrao, and Dr. R.N. Awale—Simulation of nonlinear filter-based localization for indoor mobile robot (2016). The work explores the use of nonlinear filters to improve localization accuracy in indoor environments, with a particular focus on mimicking indoor mobile robot localization. The authors assessed the performance of these filters under different conditions by using a simulation approach. This study aims to clarify the effectiveness of nonlinear filter-based localization methods for indoor mobility robots to advance robotic navigation and localization technologies [14].

Sabrina Jocelyn, Damien Burlet-Vienney, Laurent Giraud, and Adel Sghaier—Collaborative Robotics: Assessment of Safety Functions and Feedback from Workers, Users and Integrators in Quebec (2019) examined the market for collaborative robots in Quebec, focusing on safety features and feedback from customers, employees, and integrators. This study collected information from different stakeholders involved in the deployment and operation of these robots and evaluated the efficacy of safety precautions in collaborative robotics. It offers insightful information regarding the difficulties and practical ramifications of implementing collaborative robots in actual environments [15].

Richard Hurry—Reinforcement Learning for Robotics: Challenges and Opportunities (2023). The application of reinforcement learning (RL) methods to robots is the subject of this research study. They overcome certain difficulties in implementing RL in robotic systems, such as sample inefficiency, safety issues, and practical implementation. This study examined how RL can be used to improve autonomy and adaptability in a variety of settings for robotic control, manipulation, and navigation tasks [16].

Barry Andrew Trimmer, Bram Vanderborght, Yiğit Mengüç, and Michael Tolley—Soft Robotics as an Emerging Academic Field (2015) provides a comprehensive review of the literature on soft robotics, an academic field that is expanding rapidly. It examines several topics related to soft robotics, such as its foundations, uses, difficulties, and potential. The authors discussed the possible effects of soft robotics on a variety of industries, including manufacturing, healthcare, and exploration, and they highlighted significant contributions made by researchers around the globe [17]. Overall, the report provides insightful information about the rapidly changing field of soft robotics research.

With an emphasis on a single probabilistic framework, Clement Moulin-Frier and Pierre-Yves Oudeyer (2013), provided an overview of the literature on exploratory approaches in developmental robotics. They illustrated the value of curiosity-driven exploration in learning complex tasks by synthesizing a body of research on the exploration strategies used by autonomous agents. This study examines a number of probabilistic models, such as information gain techniques and Bayesian optimization, which are used for direct exploration. This review sheds light on how probabilistic frameworks can improve developmental robotics exploration [18].

Danny Zhu's (2016) automatic generation of augmented reality (AR) representations for self-governing robot systems was investigated in this study. This study explored the creation of methods and algorithms to produce AR overlays that improve comprehension and interaction with the surroundings and behavior of robots. Zhu hoped to expedite the production of AR visuals by automating this procedure, thereby increasing their use and suitability for a range of robotic applications. The technique, findings, and ramifications of the automated AR visualization creation approach are discussed in this paper [19].

Philippe Morignot's (2014) study examined the complex relationship between robotics and AI, which also probably investigates how developments in AI technology affect robotics and vice versa. While robotics applications provide real-world data and difficulties in influencing AI development, they might also cover how AI algorithms allow robots to perceive and interact with their surroundings. Understanding the mutually beneficial interaction between these two domains and its implications for upcoming technological developments is probably facilitated by Morignot's work [20].

Kevin I-Kai Wang and Andrew Tzer-Yeu Chen (2016) investigated how computer vision can be used to make the humanoid robot Baxter capable of playing chess. The project aims to create a system that enables the Baxter robot to play chess on its own by identifying the chessboard and pieces using computer vision techniques. The performance and efficacy of the proposed system in playing chess were assessed by the authors, who also detailed the methodology and findings of their trials [21].

The research paper by Eli Kolberg and Raphi Amsalem (2014) explored the activation of robotic manipulators using eye movements. This study examined the viability and efficiency of controlling robotic manipulators using eye movements. The authors analyzed current studies on eye-controlled robotics and considered both possible uses and difficulties through a review of the literature. By presenting innovative eye-movement-based control techniques, this study seeks to improve human-robot interactions [22].

Dinesh Manocha, Zherong Pan, and Chonhyon Park—Robot Motion Planning for Pouring Liquids (2016). The difficulties and potential solutions for employing robots to automate the pouring process are examined in this study report. The authors reviewed several approaches to motion planning in dynamic situations, taking container shape and liquid dynamics into account. To provide insight into the latest techniques for accurately and efficiently transferring liquids using robotic systems, they reviewed the literature on motion planning and robot manipulation [23].

Omur Arslan and Daniel E. Koditschek (2016) described a novel approach for accurate robot navigation using power diagrams. They proposed a system that uses the computational efficiency of power diagrams to produce workable routes for robots with intricate geometries in situations with obstacles. Their approach overcomes the shortcomings of the current methods and ensures precise solutions to the navigation challenge. The proposed method provides a promising option for accurate robot navigation in various real-world circumstances by including power diagrams in the navigation process [24].

RESEARCH METHODOLOGY

The research methodology employed in this study is primarily review-based, utilizing a systematic approach to gather and synthesize existing literature on the topic. As a result, we selected 25 sources from a total of 48 while assessing the literature. Subsequently, we classified the primary findings by conducting a qualitative analysis of 21 studies. Since the goal of the study was to determine the methodological framework for robotics training, the qualitative synthesis entailed gathering information about the study's content, learning objectives, student age range, methods and tools, and assessment of learning outcomes. We used the "from particulars to generals" (bottom-up) method while accounting for the specific features and circumstances of these investigations. Researchers have studied various sources involving academic databases, journals, conference proceedings, and other pertinent sources that should be consulted in order to compile an extensive list of academic articles. The inclusion criteria involved factors such as relevance to robotics encompassing a wide range of considerations, including technological advancement, cost-effectiveness, societal acceptance, ethical implications, legal regulations, environmental impact, and the specific needs of the application or industry deploying robotics technology. These factors significantly influence the development, implementation, and integration of robotic systems across various sectors of society. Once the relevant papers were identified, researchers extracted essential information from each, including key findings, employed methodologies, identified challenges, proposed opportunities, theoretical frameworks, and the authors' conclusions.

FINDINGS

Reducing the cost of robotics involves several strategies:

1. *Design optimization:* Streamline designs to use fewer materials and simpler components without sacrificing functionality.

2. *Mass production:* Increase production volumes to benefit from economies of scale.
3. *Sourcing*: Optimize the supply chain to find affordable components and materials.
4. *Modularity:* Design robots with interchangeable parts to reduce production and maintenance costs.
5. *Automation:* Implement automation in manufacturing processes to reduce labor costs.
6. *Open source:* Utilize open-source software and hardware to lower development costs.
7. *Energy efficiency:* Design robots to be energy-efficient to reduce operating costs.
8. *Longevity:* Build robots with durable components to extend their lifespan and reduce the frequency of replacements.

Material waste is one of the main factors that can destroy production profit. Initially, materials can be costly. A manufacturer does not want to waste expensive components or materials. Manual manufacturing techniques can lead to significant material waste, which increases expenses. Errors committed by workers may lead to overuse or partial scrapping. This may result in the requirement to restart workpieces or the use of more materials to fix errors. The cost of materials increases in all scenarios. Nonetheless, implementing robotic applications is a successful way to reduce the material costs. Owing to the high repeatability and precision of the robot operation, parts are accurate for the first time. A FANUC (Factory Automation NUmerical Control) M710ic/50, for example, can precisely cut materials by adhering to a preprogrammed path. By doing this, the robot is prevented from straying and chopping too much material, which wastes energy. Expensive material prices may be outdated for robotic applications.

Increasing the Effectiveness of Operations

Exorbitant expenses can mostly be attributed to inefficient operations. Slow cycle times, subpar products, and low productivity levels are consequences of inefficient production, and these factors can raise costs and hurt profit margins. Robotic applications are made as efficient as possible. Robot applications can be completed much faster than with traditional manufacturing techniques. The quick speeds, round-the-clock functioning, and accuracy of industrial robots all contribute to shorter cycle times. An efficient process yields faster cycle times; therefore, a product costs less money to produce in less time.

Because robotic applications are efficient, they can handle a higher workload than conventional approaches, which would require more personnel. Robotic applications are more productive because of their higher throughput rates. With just one FANUC Arc Mate 120ic, a robotic welding application may have the same number of welds as two to three workers, resulting in ideal efficiency. The efficiency of robotic applications allows more products to reach more consumers in less time. Costs will decrease if the overall production process is more effective.

Over time, robotic applications have become more cost-effective, contributing to lower operating costs. Robots that operate in robotic applications do not require benefits or hourly wages. Owing to their decreasing cost and expansion of the used robot market, robots are now more accessible than ever. As prices decline, businesses can swiftly realize a return on investment, which lowers the operational costs of robotic applications relative to costly fixed machinery and labor.

CONCLUSION

Manufacturing robotics offers numerous cost-saving benefits. In education, robots, such as Makeblock mBot and Non-Autonomous Organization (NAO), foster critical thinking and creativity. Despite the initial investment of $50,000 to $80,000 for a new robot, including peripherals and programming, long-term savings outweigh the costs. Robotics minimizes material waste because robots operate with precision, reducing the need for costly do-overs. They also improve operational efficiency by completing tasks faster than manual methods, increasing productivity, and reducing cycle time. Furthermore, robotic applications have become more affordable over time, with declining prices and a growing used robot market, making them a cost-effective solution compared to fixed machines and manual labor.

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