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Robotics and Artificial Intelligence: Applications of AI in Robotic Technologies

K.Y. Rokde[1] & S. S. Shende[2]

[1]*Assistant Professor, Department of Electronics, Dr. Ambedkar College, Nagpur, India*

[2]*Assistant Professor, Department of Electronics, Sharadchandra Pawar Mahavidyalaya, Lonand, India*

Corresponding Author – K.Y. Rokde

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Abstract:

Artificial Intelligence (AI) focuses on enabling machines to exhibit intelligence, allowing them to perform tasks that traditionally required human cognitive abilities. AI-driven systems are rapidly advancing in terms of functionality, adaptability, processing efficiency, and overall capabilities. These systems possess the ability to plan, learn reason, solve problems, and make decisions, enabling machines to handle an increasing number of non-routine tasks. AI can be characterized as the process of selecting an appropriate decision at the right moment, whereas human intelligence is often described as the ability to arrive at an optimal decision at the appropriate time. Since their inception, robotic systems have evolved through multiple developmental stages. Early robots were designed primarily to execute predefined, repetitive tasks. During this phase, machine learning and AI served as the foundational technologies supporting robotic functions. Robotics has since progressed to enhance machine intelligence by incorporating elements of human-like perception, particularly vision, enabling systems to recognize and interpret complex inputs. Achieving robotic vision comparable to human vision requires extensive algorithms and large volumes of data. While many robotic systems can operate without AI, it is theoretically possible to develop robots that demonstrate intelligent behaviour. This study examines the distinctions between artificial intelligence and robotics and explores the role of AI in advancing robotic technologies.

Keywords: Artificial intelligence, Robotics, Robots, AI.

Introduction:

Robotics is a discipline within computer science and engineering that focuses on the development of machines capable of performing pre-defined tasks autonomously, without continuous human intervention. Robots are commonly employed in operations that are either highly repetitive or physically demanding for humans, such as handling extremely heavy components on industrial assembly lines. Unlike humans, robots can repeatedly execute the same complex task with consistent efficiency on a daily basis. Robotics is closely associated with artificial intelligence and is often considered a subdomain of AI, covering a wide range of robotic technologies and applications. AI-driven systems are able to generate results within relatively short time frames while significantly reducing the need for repetitive human effort [1]. Most contemporary AI research is classified under "Narrow AI," which focuses on solving specific, well-defined problems. Robotics involves the design, construction, and programming of robots to perform particular tasks or functions effectively. Some of the places where AI has been deployed in the field of Robotics are as follows:

A. Assemble: Artificial intelligence has a wide range of applications in robotic assembly processes. When combined with advanced vision systems, AI enables real-time monitoring and

correction, which is particularly critical in aerospace manufacturing and other complex industrial production environments.

B. Package: Robotic packaging systems employ multiple artificial intelligence techniques to achieve cost savings, enhanced efficiency, accurate packaging, and various other benefits. In addition, AI supports continuous improvement in robotic motion control, contributing to better system performance and maintenance. This capability also simplifies the configuration, operation, and relocation of robotic equipment for technical experts [2].

C. Customer Service: In many hotels and retail establishments, customer service operations are increasingly managed by robotic systems. These robots commonly employ artificial intelligence and Natural Language Processing (NLP) techniques to interact with customers in a manner that closely resembles human communication.

Literature Review:

A. Artificial Intelligence:

Artificial Intelligence (AI) is a branch of computer science and engineering that enables machines to exhibit behavior similar to that of humans. Through the use of programming languages and specialized technologies, robotic systems are designed to mimic human actions and decision-making processes. In modern society, AI has become an essential component of daily life, with a significant portion of the population relying heavily on AI-driven technologies. AI applications are prevalent across numerous domains, including self-driving vehicles, strategic games such as chess, artistic activities like painting, and medical imaging. In the healthcare sector, AI tools are widely used in medical imaging technologies such as CT scans, X-rays, and MRI systems. Artificial intelligence focuses on developing machines capable of performing tasks that typically require human intelligence, ranging from basic pattern recognition to more complex activities such as autonomous driving or gameplay. AI is generally classified into two primary categories.[3]

1. Narrow or Weak AI: This category of artificial intelligence is developed to carry out specific, well-defined tasks such as speech recognition, image classification, and recommendation systems.[5] These systems are trained using large datasets and rely on machine learning algorithms to continuously learn and enhance their performance.

2. General or Strong AI: This form of artificial intelligence seeks to develop machines capable of performing any intellectual activity that a human can accomplish. At present, this remains largely a theoretical concept, as existing AI systems are restricted to specialized tasks and do not possess the versatility and adaptability characteristic of human intelligence. Artificial intelligence has a wide range of practical applications across various sectors, including healthcare, finance, transportation, and entertainment. For instance, AI-driven chatbots assist customers by responding to routine inquiries, while image recognition systems are utilized in medical diagnostics to detect diseases from clinical images. Despite its advantages, AI also presents ethical challenges, such as the risk of bias in automated decision-making and the potential effects on employment as machines increasingly undertake tasks traditionally performed by humans.[4]

Artificial Intelligence (AI) has become a major technological innovation with the capability to transform the domain of robotics. In recent years, increasing attention has been directed toward the incorporation of AI methodologies into robotic systems, enabling them to operate autonomously and adjust to dynamic environments. Machine learning approaches, including supervised, unsupervised,

and reinforcement learning, are widely applied in robotics to allow robots to learn from data and make informed decisions based on observed patterns and prior experiences. In addition, computer vision, a prominent subfield of AI, has significantly enhanced robotic perception by enabling robots to interpret and understand their environment through visual inputs. Natural Language Processing (NLP) further contributes to improved human–robot interaction by allowing robots to comprehend and generate human language for effective communication and cooperation. NLP techniques are commonly employed in applications such as personal assistant robots, service robots, and social robots, enhancing their ability to engage with humans in a more natural and intuitive way. [5]

Deep learning, which focuses on training artificial neural networks using large-scale datasets, has achieved notable success in a wide range of robotic applications, including object detection, speech recognition, and motion planning. Reinforcement learning, another important machine learning approach, has been employed to enable robots to develop optimal decision-making strategies through trial-and-error interactions with their environments. Beyond technical developments, ethical considerations related to the application of AI in robotics have attracted increasing attention. Key ethical concerns such as safety, transparency, accountability, and bias in automated decision-making must be addressed to ensure the responsible and ethical implementation of AI-enabled robotic systems across various sectors. Despite rapid advancements, several challenges persist, including the difficulty of AI algorithms in managing uncertain and dynamic environments, as well as issues concerning system safety, robustness, and interpretability. Furthermore, the social and economic consequences of widespread AI-driven robotic adoption, particularly its potential impact on employment and societal structures, require careful evaluation. Nonetheless, the scope of AI applications in robotics remains extensive and diverse. The continued integration of AI and robotics is expected to further advance automation, presenting both new opportunities and emerging challenges for researchers, engineers, policymakers, and society at large.[6]

B. Robotics:

Robotics is a domain within artificial intelligence that focuses on the development of automated, multifunctional, and reprogrammable machines. Due to their versatile capabilities, robots are increasingly utilized to replace human labour in demanding environments, such as space exploration, prolonged underwater operations, and strategic applications within military forces.[7]

Robots are widely employed in industries and manufacturing units for the assembly of products such as automobiles, machinery, and hardware systems, as well as for controlling mechanical and technical processes. Their use significantly reduces human involvement in hazardous operations, enabling the safe execution of tasks that are either risky or impractical for humans to perform.

Robots can work as: -

Automatic machine sweeper, space exploration, under water, in military, security, and in entertainment.

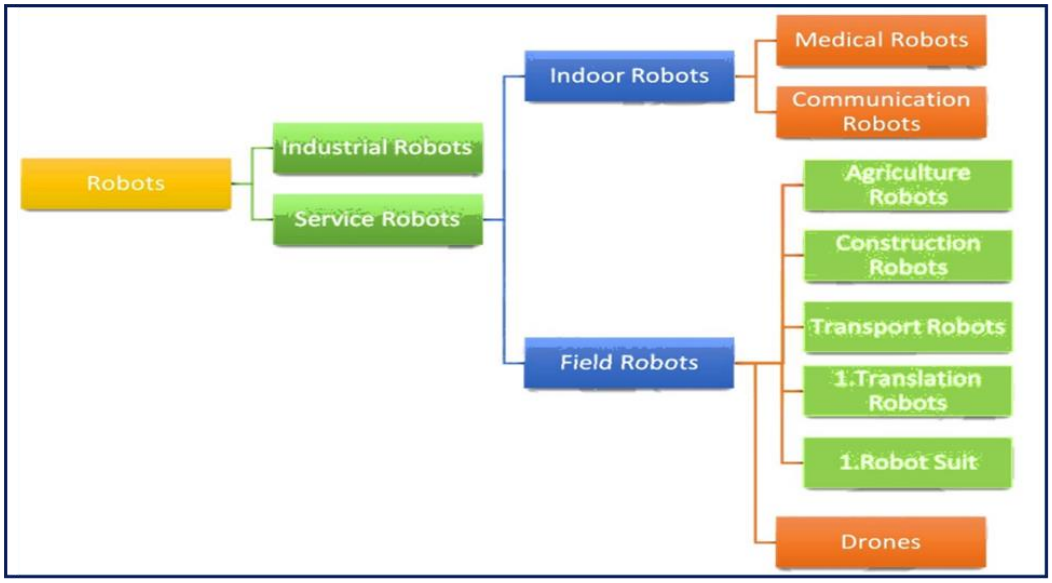

Fig 1. Types of Robots

Components of Robots:

1. Actuators
2. Electric Motors
3. Pneumatic Air Muscles
4. Sensors
5. Piezo motors &Ultrasonic motors
6. Muscle Wires
7. Power Supply

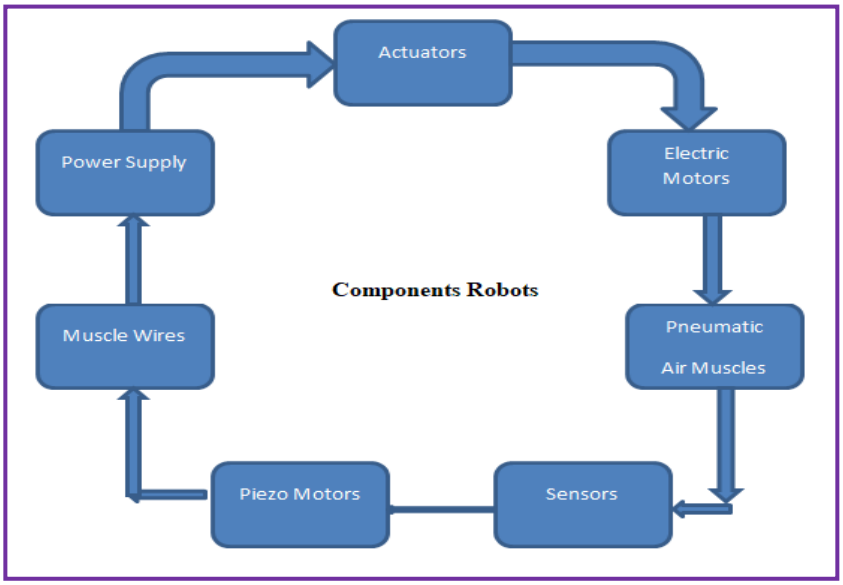

Fig 2. Components of Robots

Actuators: Actuators are components responsible for enabling movement in robotic systems and for interacting with the surrounding environment. They function by converting control signals into physical or mechanical motion through the use of an external power source.

Electric Motors: An electric motor is a device that transforms electrical energy into mechanical energy, typically producing rotational motion. Electric motors are generally classified into two main categories: alternating current (AC) motors and direct current (DC) motors.[10] AC motors are commonly preferred due to their flexible speed control and relatively lower power

requirements, while DC motors are often selected for low-power applications because of their lower initial cost when compared to AC motors.

1. **Pneumatic Air Muscles:** Air muscles are soft, inflatable devices that are well suited for use as artificial muscles in robotic systems. These muscles consist of an internal bladder, and when the bladder is pressurized, the surrounding lattice structure contracts in a manner similar to a scissor linkage mechanism.[8]
2. **Sensors:** A sensor is a device or module designed to detect physical events or environmental changes and convert them into output signals. Essentially, sensors capture information from the surrounding environment and transmit this data to another electronic processing unit, which then performs further operations based on the received information.
3. **Piezo motors:** Piezoelectric motors, including ultrasonic and piezo motors, are utilized to apply directional force to the driven surface in response to electrical signals. These motors assist robotic systems in achieving precise movement in the intended direction. [9]
4. **Muscle Wires**: Muscle wires are composed of Nitinol, a nickel-titanium alloy with a slender structure. These wires expand or contract when a controlled amount of electric current and heat is applied. Specifically, when approximately 5% of an electric current passes through them, the wires undergo contraction.
5. **Power Supply:** A power supply is an electronic device designed to convert electrical current into usable electrical energy. Its primary function is to deliver this converted power to a connected load.[10]

Comparison Of Robotics With Artificial Intelligence:

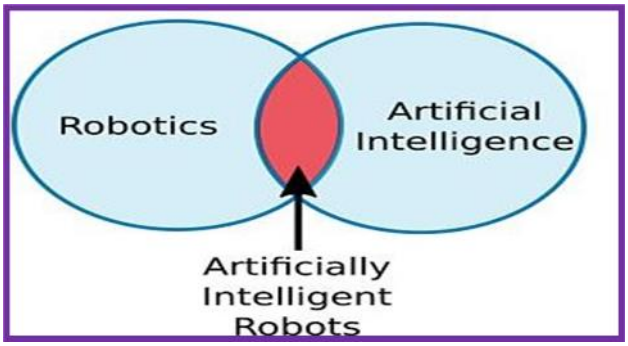

Fig. 3. Venn diagram of AI & Robotics

Artificial Intelligence (AI) and robotics are closely related fields, but they are not identical. AI focuses on enabling systems to replicate human cognitive functions such as learning, problem-solving, and decision-making without relying solely on predefined instructions. In contrast, robotics deals with the design, construction, and programming of robots to perform specific tasks. In many robotic applications, the use of AI is not essential because the assigned tasks are repetitive, structured, and predictable, requiring minimal cognitive processing. While robotics emphasizes the creation of autonomous machines, AI provides the intelligence that allows machines to simulate human reasoning and learning capabilities.

The difference between robotics and artificial intelligence are as follows:

A. AI

- They are commonly applied in computer-generated digital environments, where information is usually represented and processed using symbolic rules.
- Such systems require general-purpose computing platforms for their execution.

B. Robotics:

- In real-world environments, robots are commonly employed to carry out physical tasks.

- The input data is frequently received in analog form, such as speech waveforms.
- The operation of such systems requires specialized hardware components, including sensors and actuators.

What is the role of AI in robots?

Artificial Intelligence and robotics are integrated through the development of AI-enabled robots, where intelligent algorithms guide robotic behavior. However, many robots still operate without significant AI capabilities. Traditionally, industrial robots were limited to performing predefined, repetitive tasks. With the incorporation of AI techniques—such as object manipulation, spatial perception, computer vision, and motion planning—robots can now interpret and adapt to unfamiliar data and dynamic environments. AI-based vision systems enable robots to detect and recognize a wide range of objects with accuracy comparable to human perception. Furthermore, AI-driven robots utilize computer vision and motion control to achieve a deeper understanding of their surroundings and respond effectively to changing conditions. Through machine learning, robots can improve their performance by learning from errors, reducing the need for constant human supervision and allowing for greater operational autonomy.[11]

Applications:

There are different applications of Robotics. Some of main and important applications are as follows:

A. Robotics in Defense Sector
B. Robotics in Medical
C. Robotics in Entertainment
D. Robotics in Mining Industry
E. Robotics in Industrial sectors

A. Robotics in Defence Sector:

Robotics has assumed a progressively significant role in defence applications over the years, encompassing areas such as reconnaissance, surveillance, explosive ordnance disposal, and battlefield assistance [12]. One of the primary benefits of employing robotic systems in defence is their ability to undertake operations that are hazardous or challenging for human personnel. For instance, robots can be deployed in environments contaminated by chemical or biological agents, enabling exploration and assessment without endangering soldiers' lives. Additionally, robotic technologies contribute to enhancing the efficiency and effectiveness of military operations. Unmanned aerial vehicles (UAVs), commonly known as drones, are widely used for surveillance and reconnaissance purposes, delivering real-time intelligence to commanders and supporting timely, well-informed decision-making.

B. Robotics in Medical:

Robotics has achieved notable progress in the medical domain, with applications spanning surgical procedures, rehabilitation, diagnostic processes, and targeted drug delivery systems. The integration of robotic technologies in healthcare offers substantial benefits, including improved clinical outcomes, shorter patient recovery periods, and increased accuracy in medical interventions. A major advantage of medical robotics lies in its support for minimally invasive surgical techniques. Robotic-assisted surgical platforms enable procedures to be performed through small incisions, thereby minimizing tissue damage and reducing postoperative scarring compared to conventional open surgeries. Furthermore, these systems enhance surgeons' control by providing superior dexterity and precision, resulting in more accurate and controlled surgical movements [13].

C. Robotics in Entertainment:

Robotics is a multidisciplinary domain that integrates principles from engineering, computer science, and artificial intelligence. In the entertainment sector, robots are specifically developed to engage and amuse audiences through interactive activities, performances, games, and immersive experiences [20]. These systems are equipped with sensors, actuators, and sophisticated software algorithms that allow them to interact effectively with humans in diverse settings.

The application of robotics in the entertainment industry includes the following areas [14]:

- Theme parks and amusement attractions
- Film and television production
- Live stage performances
- Gaming and interactive media
- Personal and home-based entertainment

D. Robotics in Mining Industry:

Robotics has brought significant advancements to the mining sector by addressing many of the operational challenges traditionally faced by miners. Mining operations are inherently hazardous and technically complex, often requiring extensive human labor and substantial resources. The adoption of robotic technologies has allowed mining companies to enhance workplace safety, operational efficiency, and overall productivity, while simultaneously lowering costs and minimizing environmental impact. Key applications of robotics within the mining industry include the following:

- **Autonomous vehicles:** Mining organizations increasingly deploy self-operating equipment such as haul trucks and drilling rigs to improve efficiency and safety. These machines are capable of functioning in dangerous environments without exposing human workers to risk.
- **Drones and unmanned aerial vehicles (UAVs):** UAVs are utilized for surveying and monitoring mining sites, offering real-time insights into equipment status and environmental conditions. They also assist in mapping and modeling mining areas, enabling better planning and optimization of mining activities.
- **Robotic drilling systems:** Automated drilling technologies facilitate mineral extraction from inaccessible or hazardous locations. These systems are designed to withstand extreme conditions, thereby reducing the likelihood of injuries to personnel.
- **Automated sorting and processing:** Robotic systems are employed to separate and process ores and minerals efficiently, decreasing waste generation and lowering processing costs [15].

E. Robotics in Industrial sectors:

Robotics has significantly transformed a wide range of industrial sectors by reshaping work processes and enhancing productivity and operational efficiency. In industrial environments, robots are widely employed to automate repetitive and physically intensive tasks, leading to improved precision, speed, and workplace safety. One of the most prominent applications of robotics is in manufacturing, where robots are extensively utilized on production lines for tasks such as welding, painting, and material handling. Their ability to operate continuously without fatigue ensures uniform product quality and high production output. Furthermore, industrial robots equipped with sensors and advanced vision systems are capable of executing complex operations such as inspection and sorting, thereby strengthening quality control mechanisms [15], [16].

Conclusion:

Artificial intelligence forms a fundamental component of the present research. The discipline of AI enables machines to exhibit analytical and

conceptual reasoning capabilities. Its primary objective is to develop systems that can understand, learn, and operate in ways that align with human behaviour and decision-making. AI plays a vital role in machine learning processes and is expected to assume an increasingly significant position in the advancement of robotics. By integrating AI, intelligence can be embedded into electromechanical systems, allowing machines to perform tasks traditionally carried out by humans. On-going research in this domain is highly promising, as these techniques demonstrate considerable potential and practical value.

Artificial Intelligence (AI) and Robotics have the potential to transform society, but they also present ethical challenges. These include concerns about misuse, biases, transparency and impact on employment and human interaction. By prioritizing ethical decision-making and responsible practices, we can harness the benefits of AI and robotics for the betterment of society. The continued development and application of AI technologies are likely to have profound implications for human society in the future. While artificial intelligence offers substantial benefits and serves as a powerful technological tool for human advancement, it also presents potential risks. The misuse of AI by malicious or antisocial individuals could lead to serious consequences for humanity, the environment, and other living organisms. Therefore, responsible development and ethical use of AI are essential to ensure its positive impact on society. In conclusion, various algorithms employed in AI for robotics come with their own strengths and limitations. The selection of the appropriate algorithms depends on the task requirements, data availability and computational resources.

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