Artificial Intelligence and Robotics: Integrated Systems and Applications

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To Cite This Chapter

Göktepe, Y. E., & Uzun, Y. (2024). Artificial Intelligence and Robotics: Integrated Systems and Applications. In F. Zerrin Saltan, H. Arıkan & Y. Uzun (Eds.), *Current Studies in Basic Sciences, Engineering and Technology 2024* (pp. 82-91). ISRES Publishing.

Introduction

Since the beginning of the 21st century, technology and innovation have advanced rapidly, transforming every aspect of our lives. Among the pioneers of this transformation are artificial intelligence and robotics technologies. Artificial intelligence (AI) is a collection of algorithms and techniques that enable machines to exhibit human-like intelligence, while robotics deals with autonomous or semi-autonomous machines that perform physical tasks. The combination of these two disciplines has gone beyond the future seen only in science fiction works and turned into today's realities(Flasiński, 2016).

Integrating artificial intelligence and robotics technologies has enabled various applications, from industrial automation to medical devices, and the agriculture service sector. This integration increases the environmental perception and decision-making capabilities of machines, allowing for the development of more flexible, efficient, and intelligent systems (Brunette et al., 2009). For example, AI-powered robotic arms can perform precise surgical interventions and provide quality control on production lines. At the same time, applications such as autonomous vehicles and drones are concrete examples of how artificial intelligence and robotics technologies are transforming our lives (Jackson, 2019).

This book chapter addresses the integration of artificial intelligence and robotic systems, aiming to examine the key components, application areas, and challenges of these technologies. First, the historical development and basic principles of the concepts of artificial intelligence and robotics will be discussed, then how these two fields come together and how integrated systems are created will be examined. This section will also discuss the opportunities presented by integrated systems and the technical and ethical challenges faced. Developing artificial intelligence and robotics technologies not only transforms the industrial and service sectors but also deeply affects the general structure of society and the daily lives of individuals. Understanding the dimensions of this transformation and its possible future impacts is of great importance for those working in academia and industry. In this regard, this book chapter aims to provide readers with a comprehensive understanding of the integration of artificial intelligence and robotics.

Integration of Artificial Intelligence and Robotic Systems

Technological Components

Sensors

Sensors are devices that enable robotic systems to collect information from their surroundings. Different types of sensors are available, and each one detects different data. Image sensors cameras and devices such as LiDAR (Light Detection and Ranging) collect visual information about the environment (Voges & Wagner, 2021). Touch and pressure sensors enable robots to sense touch and pressure. Among the motion sensors, accelerometers and gyroscopes are used to track the movement and position of a robot. Proximity sensors help robots detect objects around them and avoid collisions (Tu et al., 2019).

Actuators

Actuators are components that allow robots to perform physical movements. They provide mechanical movement using electric, hydraulic, or pneumatic power. Electric motors are generally used for smaller, precise movements. Hydraulic actuators are used in applications that require more force, such as lifting heavy loads. Pneumatic actuators are preferred in situations requiring fast and powerful movements (Conrad et al., 2024).

Processors

Processors serve as the "brains" of robotic systems. By running artificial intelligence algorithms, it processes the data from the sensors and sends the appropriate commands to the actuators. Processors used in robotic systems generally must have high processing capacity and low energy consumption. For this purpose, general-purpose microprocessors (CPUs), graphics processing units (GPUs), and chips specialized for artificial intelligence (TPU and NPU) are used (Putra et al., 2024).

Software

Software is one of the most critical components that determine the functionality of robotic systems. This software processes sensor data, executes decision-making processes, and controls the robot's movements. Real-time operating systems (RTOS) enable robots to operate reliably and quickly (Putra et al., 2024). Artificial intelligence algorithms such as image processing, object recognition, path planning, and decision-making enable robots to exhibit intelligent behaviors. Control systems are software modules that precisely control the movements of robots.

These components play a critical role in the integration of artificial intelligence and robotic systems. While the sensors collect environmental data; processors process this data, software analyzes it, and actuators perform the necessary physical movements because of these analyses. In this way, robotic systems can perform complex tasks autonomously.

Algorithms and Learning Methods

Machine Learning

Machine learning aims to develop models that can make decisions by learning from data and discovering patterns. In robotic systems, machine learning is used to develop autonomous behaviors. For example, it is possible with machine learning algorithms for a robot to recognize objects in its environment, plan its motion paths, or optimize tasks. Basic machine learning methods include supervised learning, unsupervised learning, and reinforcement learning (Zhou, 2021).

Deep Learning

Deep learning creates multi-layered learning models using artificial neural networks. These models can extract meaningful information from large and complex data sets.

Deep learning in robotic systems is widely used, especially in tasks such as image processing and object recognition. For example, deep learning makes it possible for an autonomous vehicle to recognize pedestrians or other vehicles on the road. It is also used for learning robotic dexterity and manipulation tasks (Janiesch et al., 2021).

Natural Language Processing

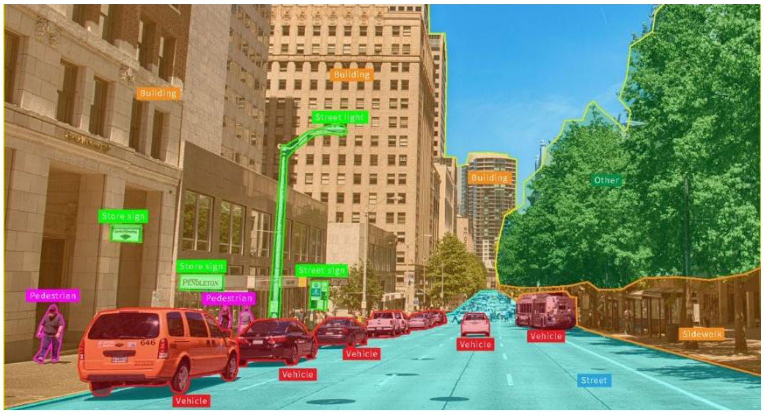
Natural language processing (NLP) is a sub-branch of artificial intelligence used by robots to understand and generate human language. NLP involves text and speech analysis, giving robots the ability to interact with users naturally. For example, a robotic assistant in a home can use NLP techniques to understand and execute the user's voice commands. In addition, NLP algorithms can also be used for robots to answer questions and share information with humans (Galassi et al., 2020).

Computer Vision

Computer vision is the process of extracting meaningful information from image and video data. This technology allows robots to see and interpret the world around them. Computer vision techniques are used in tasks such as facial recognition, object detection, motion tracking, and 3D modeling. For example, an industrial robot can use computer vision techniques to detect defects on the production line. Computer vision is also critical for autonomous navigation and mapping (Xu et al., 2021). An example of a computer vision image is shown in Figure 1.

Figure 1.

Computer vision (Computer Vision, 2023)



These algorithms and learning methods allow robotic systems to understand, learn, and make decisions based on environmental data. Machine learning and deep learning enable robots to make data-driven decisions and optimize tasks, while methods such as natural language processing and computer vision help robots interact with humans and increase their environmental awareness. In this way, robotic systems become more flexible, intelligent, and autonomous.

Data Management and Analysis

Data Collection

For robotic systems to function successfully, they must constantly collect data from their environment and operations. Data collection is carried out through various sensors. For example, devices such as cameras, radars, LiDAR sensors, accelerometers, and microphones collect visual, spatial, motion, and audio data. This data helps robots understand their surroundings and gain situational awareness. In the data collection process, the accuracy and consistency of the data are of paramount importance because this data influences the robot's decisions (Mazhar et al., 2021).

Data Processing

The raw data collected is often not directly available in its raw form; This data needs to be processed to be converted into meaningful information. The data processing process includes filtering, noise reduction, feature extraction, and data transformation. For example, an image processing system can recognize objects by analyzing camera data, or a voice recognition system can convert spoken words into text. Data processing is a critical step for robots to make sense of the information they perceive and to make logical decisions using this information (Pansara, 2022).

Decision-Making Processes

After data collection and processing, robotic systems decide to act using this information. The decision-making process is driven by artificial intelligence algorithms and machine learning models. In this process, robotic systems choose the most appropriate action to achieve specific goals. For example, an autonomous vehicle can identify traffic signs and other vehicles and decide to proceed at the appropriate speed, or a manufacturing robot can decide which products need to be re-inspected for quality control. Techniques such as optimization, path planning, task assignment, and control strategies are often used in decision-making processes (Langfeldt, 2022).

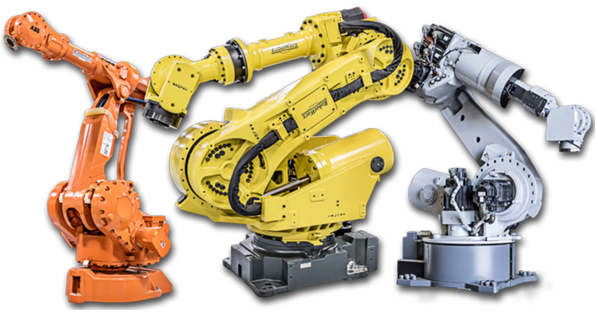
Data management and analysis ensure that robotic systems operate accurately, reliably, and effectively. Effective data management improves system performance, reduces errors, and ensures security. Furthermore, continuous data analysis allows systems to learn and improve over time, which contributes to robotic systems becoming more intelligent and autonomous.

Application Areas

Artificial intelligence and robotic technologies are used very effectively, especially in the field of industry. Robots are used to perform repetitive and precise jobs such as assembly, welding, and painting on production lines. Industrial robots operate at high speed and accuracy, optimizing production processes and reducing costs. Automation systems make production processes efficient by minimizing human intervention. Robots can automatically perform tasks such as material handling, packaging, and palletizing. In quality control processes, robots equipped with image processing and sensor technologies detect errors by checking the quality of the products and ensuring that quality standards are maintained (Arents & Greitans, 2022). An example of an industrial robot image is shown in Figure 2.

Figure 2

Industrial robot (Industrial robot, n.d.)



Recently, artificial intelligence and robotic systems have been used effectively in the field of medicine and health. Robotic surgical systems allow surgeons to perform precise and minimally invasive operations. Robotic surgery systems, such as da Vinci's, enable complex surgeries to be performed with small incisions. AI-powered medical imaging systems accelerate diagnostic processes and improve accuracy by analyzing

MRI, CT scans, and X-ray images. Rehabilitation robots help patients with the physical therapy process. These robots help paralyzed or injured patients regain their mobility (Han et al., 2022).

The agricultural sector has also been affected by these rapid technological advances. Agricultural robots increase efficiency by automating fruit and vegetable picking processes. These robots use sensors to determine plant maturity and optimize the harvesting process. Agricultural drones are used to monitor the condition of crops, perform spraying, and optimize irrigation plans. High-resolution images and data improve agriculture management. Agricultural robots and sensors analyze the chemical and physical properties of the soil. This data helps optimize fertilization and irrigation strategies (Cheng et al., 2023).

Another sector that attracts attention is the service sector. Robotic assistants used in homes and hotels help people by providing cleaning, food preparation, and other services. Customer service robots are used in banks, stores, and other service points. These robots perform tasks such as providing information to customers, giving directions, and performing simple actions (Graf & Eckstein, 2023).

Artificial intelligence technologies, which have become an indispensable part of the field of security and defense, are developing day by day and achieving very important successes in this field. Unmanned aerial vehicles are used in reconnaissance, tracking, and unmanned missions. They are widely used in military operations to collect information and ensure security in risky areas. Autonomous ground vehicles are used in operations such as reconnaissance, material handling, and operating in hazardous areas. These vehicles increase the safety of security forces and military personnel. Security robots are used to provide security in public spaces and private properties. Thanks to cameras, sensors, and artificial intelligence algorithms, it detects and reports suspicious behavior (Araya & King, 2022).

These application areas show how artificial intelligence and robotics technologies are integrated into different areas of our lives and the potential benefits these technologies offer. Each area plays a critical role in achieving goals such as increasing efficiency, reducing costs, and ensuring human safety.

Technical and Ethical Challenges

The safe operation of robotic systems is critical for the protection of both users and the environment. In terms of physical safety, robots need to be designed and operated in a way that does not harm humans. For example, industrial robots need to be equipped with safety systems to prevent collisions with humans in their work areas. Robotic systems can exchange data over internet connections and networks. This creates a potential target for cyberattacks and malware. Cybersecurity threats make it imperative that systems are protected against unauthorized access, data leaks, and operational disruptions (Amoo et al., 2024). Vulnerabilities in critical systems such as autonomous vehicles and medical robots can have serious consequences. The proliferation of artificial intelligence and robotics technologies brings with it the automation of many manual and routine tasks. This can lead to unemployment in some lines of work and requires employees to renew their skills. It can cause economic and social imbalances in society.

Robotic systems collect and process large amounts of data. This data may include users' personal information, habits, and behaviors. Data privacy is important to ensure that this information is not misused and that users' privacy is protected. Robots and devices used in healthcare work with sensitive personal data, so strict regulations are required in this regard. Situations may arise where artificial intelligence systems may make unethical decisions. For example, an autonomous vehicle may need to decide who to hurt in the event of an accident. Such situations require reflection on how to apply ethical principles during the programming of robots (Umoga et al., 2024).

The development of artificial intelligence and robotics technologies can create gaps in existing legal systems. Legal regulations are necessary to regulate the use of these technologies and to prevent possible misuse. For example, the introduction of autonomous vehicles to traffic should be controlled by legal regulations such as liability and insurance issues. International standards have been set to ensure the safe, effective, and ethical development and use of artificial intelligence and robotic systems. These standards cover various stages from the design to the use of the systems and harmonize the applications in different countries. The standards also ensure device interoperability and user safety.

These technical and ethical challenges are important issues to consider ensuring that AI and robotics technologies are developed and used responsibly and safely. Solving these challenges requires a great emphasis on ethical principles, user safety, and international cooperation in the technology development process.

Future Perspectives

Rapid advances in artificial intelligence and robotic technologies continue. More sophisticated artificial intelligence algorithms will enable robots to learn and perform more complex tasks. Significant advances are expected in the areas of deep learning, reinforcement learning, and natural language processing. Robots will become more autonomous, and better adapting to their environment and changing conditions. This is especially critical in systems such as autonomous vehicles and unmanned aerial vehicles. Nanorobots and biomimetic designs could revolutionize fields such as medicine and environmental sciences. These technologies can be used in applications such as cellular-level therapy and environmental cleanup (Wang et al., 2022).

The development of hybrid systems, where humans and machines work together, will bring major changes in business and everyday life. Co-operative robots (Cobots) are designed to work safely and efficiently side by side with humans. These robots increase productivity by assisting human workers in factories, laboratories, and healthcare facilities. Augmented Reality (AR) and wearable technologies facilitate human-machine interaction, enabling operators to control and interact with robots. For example, maintenance personnel can monitor the condition of robots and give them instructions through AR glasses. Biomechanical implants and prostheses integrated into the human body can increase physical abilities. Such technologies can improve the quality of life of people with disabilities and support people's physical workforce (Weiss et al., 2021). An example of a cobot image is shown in Figure 3.

Figure 3

Cobot (Cobot, n.d.)

The proliferation of artificial intelligence and robotic technologies can lead to significant changes in the social structure and labor market. While automation and artificial intelligence will cause some jobs to disappear, they will also lead to the emergence of new business areas and professions. Routine and repetitive tasks will be handled by automation, while jobs that require creative and strategic thinking will continue to be done by humans. The integration of robots and artificial intelligence into everyday life could change the way society interacts with. For example, robotic assistants and smart home systems can provide seniors and people with disabilities with greater independence. At the same time, there are risks such as reduced social interactions between people. In the future, individuals will need to have skills that are compatible with technology. Education systems can be restructured to focus more on areas such as digital literacy, artificial intelligence, data science, and robotics (Tapalova & Zhiyenbayeva, 2022).

These perspectives are important for understanding the future implications and potential of AI and robotics technologies. Technological advances, human-machine collaboration, and societal impacts present both opportunities and challenges. Therefore, during the development and implementation of these technologies, it is necessary to pay attention to ethics, security, and social responsibility issues.

Conclusions and Suggestions

The integration of artificial intelligence and robotic systems has led to radical transformations in various industries in the modern world. The efficiency, accuracy and speed provided by these technologies in areas such as industry, medicine, agriculture, service sector and security have created new opportunities while improving business processes. However, significant challenges have also emerged, such as changes in the labor market, ethical issues, safety risks, and the necessity of regulatory frameworks. Future developments need to be carefully considered from an ethical and societal point of view, as well as technological innovations.

It is critical to increase R&D investments to move artificial intelligence and robotic technologies to advanced levels. Innovative solutions should be developed and implemented, especially in areas such as advanced algorithms, autonomous systems and unmanned vehicles. Training programs must be restructured to prepare the workforce of the future for these technologies. Training programs should be created in areas such as artificial intelligence, data science, robotics engineering, and cyber security, and continuing training opportunities should be offered for existing employees. In addition, digital literacy and critical thinking skills should be encouraged.

A comprehensive ethical framework should be established to ensure the ethical use of artificial intelligence and robotic systems. There should be clear and consistent regulations on data privacy, algorithmic transparency, and responsible use of AI. In addition, legal regulations should be developed at national and international levels to ensure the safe and fair use of these technologies. It is important to ensure a broad dialogue on the societal impact of artificial intelligence and robotic technologies. Raising public awareness about these technologies and listening to their concerns will facilitate social acceptance and adaptation. In addition, cooperation and dialogue between policymakers, academics, industry leaders, and non-governmental organizations should be encouraged. The safety standards of artificial intelligence and robotic systems should be strengthened. Strong defense mechanisms should be developed to protect against cybersecurity threats. In terms of physical safety, regulations should be made, and strict inspections should be carried out to ensure safe working conditions for robots.

More advanced algorithms should be developed in areas such as deep learning, explainable artificial intelligence, reinforcement learning, and hybrid AI models. This will enable artificial intelligence to be used effectively in more complex and dynamic tasks. Studies on hybrid systems that optimize human and machine collaboration should be increased. Cobots and augmented reality technologies can offer more efficient and safe solutions for human-machine interaction. Research in areas such as biomechanical implants, prosthetics, and nanorobots could offer important innovations in terms of medical treatments and augmenting human capabilities. Developments in this area can lead to major advances in the medical and healthcare industry.

Studies should be carried out on the development and implementation of artificial intelligence and robotic systems by the principles of sustainability and justice. This aims to ensure that technologies fairly benefit all segments of society and minimize their environmental impact. International cooperation in the field of artificial intelligence and robotics should be encouraged and universal standards should be set. This will ensure that technologies are used safely, ethically, and effectively on a global scale.

In conclusion, advances in artificial intelligence and robotics technologies have the potential to lead to major changes in all areas of society. To ensure that these changes are positive, great importance should be given to the principles of ethics, safety, and social responsibility in technology development processes.

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