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AI in Robotics: Advancements, Applications and Challenges

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Abstract

The development, uses, and difficulties of artificial intelligence (AI) in the field of robotics are examined in this research study. Robotics has been transformed by the use of AI approaches, which allow robots to carry out difficult tasks in an adaptive and independent manner. This article gives a general overview of the many AI methods are used in robotics, including planning/control, computer vision, natural language processing, and machine learning. The numerous uses of AI in robotics, including industrial automation, service robots, autonomous cars, space exploration, and agriculture, are further discussed. The report also discusses issues related to safety and ethics, collaboration between humans and robots, adaptation and uncertainty, data constraints, and explainability/transparency. This research study seeks to contribute to the comprehension and development of AI in robotics by highlighting the current state, prospective future directions, and opportunities in the field.

Keywords: Robotics, Artificial Intelligence, machine learning, Natural Language Processing

1. Introduction

1.1 Outline of Robots and AI

Artificial intelligence (AI), often known as machine intelligence, is the replication of human intellect in devices that are capable of inference, learning, and decision-making. It includes a broad range of methodologies, such as planning/control algorithms, computer vision, machine learning, and natural language processing. AI gives machines the ability to carry out

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tasks that would ordinarily need human intellect, like object recognition, voice understanding, making predictions, and problem solving.

On the other hand, the field of robotics deals with the creation, advancement, and use of real machines or robots. These robots can interact with and modify their environments because they are equipped with sensors, actuators, and processing power. Robotics seeks to build intelligent devices that can work on their own or help people in a variety of ways [1].

As AI technologies improve robots' capacities to detect, reason, and act in dynamic and unstructured situations, the merging of AI with robotics has proven revolutionary. Robots with AI can learn from data, make wise decisions, adjust to changing circumstances, and communicate with people more organically. Significant improvements in fields including industrial automation, service robotics, driverless cars, space exploration, healthcare, and many others have resulted from this synergy [2].

AI in robotics has enormous potential to transform a number of industries, increase productivity, improve people's lives, and pave the road for the creation of intelligent machines that can function on their own in challenging real-world situations. But in order for it to be widely used and accepted, concerns like safety, ethics, human-robot collaboration, adaptability, and the interpretability of AI decision-making must be resolved.

1.2 Significance of AI in Enhancing Robotic Capabilities

The incorporation of Artificial Intelligence (AI) methods is essential for improving the capabilities of robots in a number of ways, including:

Robots with intelligent perception may perceive and comprehend their surroundings using sophisticated computer vision algorithms. Robots can interact with their surroundings successfully because they are able to recognise and comprehend things, people, and environmental aspects. AI enables robots to learn from data and gradually enhance their performance. Robots may learn new abilities, adapt to various environments, and refine their behaviour based on feedback and experience thanks to machine learning algorithms [3].

AI algorithms give machines the ability to make complex decisions. Robots can make intelligent decisions and determine the best courses of action to efficiently accomplish certain goals by analysing large volumes of data and taking into account numerous criteria [4].

Robots can now function independently and autonomously thanks to AI. Robots can now complete jobs, navigate challenging surroundings, and react to unforeseen circumstances without constant human supervision thanks to the integration of AI technology.

AI promotes seamless communication and interaction between humans and robots through the use of natural language processing and human-robot interaction. Robot-human collaboration is facilitated by Natural Language Processing (NLP) techniques that allow robots to comprehend and respond to human commands [5].

With the aid of AI, robots are able to complete tasks faster, more correctly, and with greater tenacity than people. This boosts productivity, efficiency, and cost-effectiveness across a range of industries, including manufacturing, healthcare, logistics, and more [6].

AI contributes to the safety and risk mitigation of robotic systems by reducing hazards and raising levels of security. Robots can recognise potential dangers, evaluate risks, and take the necessary actions to ensure their own safety and the protection of others around them thanks to AI-enabled perception and decision-making [7].

Artificial intelligence (AI) endows robots with sophisticated cognitive capacities, allowing them to function more intelligently, adaptably, and effectively. Robotics with AI integration have the potential to transform industries, enhance quality of life, and open up new possibilities for automation and human-robot interaction.

1.3 Objectives

The goal of the research article "AI in Robotics: Advancements, Applications, and Challenges" is to present an in-depth analysis of artificial intelligence's (AI) function in robotics.

Examine the most recent developments in AI methods used in robotics. This comprises planning/control algorithms, computer vision, natural language processing, and machine learning. The study explores the fundamental ideas, formulas, and procedures underlying these developments.

Look into the various robotics applications where AI is used. This covers robotics in industry, services, autonomous cars, space travel, medicine, and agriculture. The article looks at certain use cases and illustrates how AI improves robot capabilities in each application domain.

Identify and handle the difficulties that arise when integrating robotics and AI. These difficulties include those related to safety and ethics, human-robot interaction, adaptability and uncertainty, data restrictions, and the ability to understand and be transparent about AI decision-making. The report examines these issues and talks about various remedies and mitigating techniques [8].

By accomplishing these goals, the research paper hopes to give scholars, professionals, and decision-makers a thorough understanding of the developments, uses, and difficulties in the field of AI in robotics. It is a useful tool for comprehending the current situation, looking into new opportunities, and determining viable topics for further study and development.

2. AI Techniques in Robotics

2.1 Machine Learning

Machine learning is a branch of artificial intelligence (AI) that focuses on creating strategies and algorithms to let computers learn and anticipate the future or make decisions on their own. Supervised learning, unsupervised learning, and reinforcement learning are the three main types of machine learning.

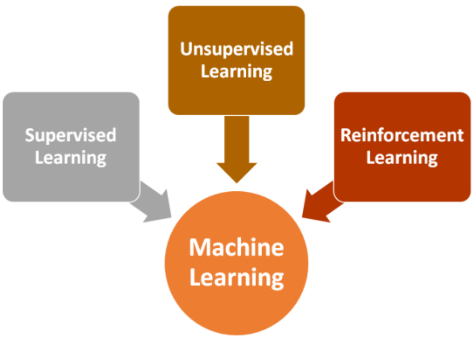

Figure 1. Machine Learning Techniques

A) Supervised Learning

The machine learning model learns using labelled training data in supervised learning, where each input sample has a corresponding target or output label. Learning a mapping function that can precisely predict the output labels for unknown input data is the aim of supervised learning. Decision trees, support vector machines (SVM), random forests, and neural networks are examples of supervised learning techniques. Applications for supervised learning include spam detection, sentiment analysis, and image categorization.

B) Unsupervised Learning

Unsupervised learning is the process of learning from unlabelled data, in which a machine learning model unearths buried structures, relationships, or patterns in the data. Unsupervised learning differs from supervised learning in that there are no predetermined target labels or outputs. Unsupervised learning algorithms search the data for relevant clusters or representations. K-means clustering and hierarchical clustering are two examples of common clustering methods. Principal component analysis is an example of a dimensionality reduction methodology. For tasks like customer segmentation, anomaly detection, and recommender systems, unsupervised learning is employed.

C) Reinforcement Learning

Through interactions with the environment, an agent can learn how to maximise cumulative rewards through reinforcement learning. The environment responds to the agent's behaviour by giving it rewards or punishments. Learning an ideal policy that maximises long-term benefits is the aim of reinforcement learning. Value iteration, Q-learning, and policy gradients are examples of approaches used by reinforcement learning algorithms. Robotics, gaming (such as AlphaGo), and autonomous decision-making systems are just a few examples of the many fields where reinforcement learning is used. These three varieties of machine learning offer various methods for addressing various kinds of issues. Unsupervised learning identifies patterns in unlabelled data, whereas supervised learning is appropriate for jobs with labelled data and well specified outputs. On the other hand, reinforcement learning is applied when an agent interacts with an environment and figures out how to maximize rewards through trial and error. Choosing the best machine learning method depends on the particular problem at hand and the data that are accessible. Each type of machine learning has unique advantages and uses [9].

2.2 Computer Vision

The goal of the artificial intelligence (AI) field of computer vision is to give machines the ability to decipher and comprehend visual data from images and videos. It entails creating algorithms and methods that give computers the ability to observe, examine, and comprehend visual input in a manner similar to that of humans.

A) Object Recognition

Identifying and classifying objects or particular attributes in an image or video is the problem of object recognition. Machine learning models must be trained to identify patterns and distinctive visual traits linked to various object categories. Applications like object identification, image classification, and facial recognition are made possible by real-time object detection and classification algorithms.

B) Scene Understanding

The ability of a computer vision system to comprehend the overall context and relationships between objects and elements within a scene is referred to as scene understanding.

It entails deriving higher-level semantics and information from visual input, such as scene categories, spatial organisation, and object interactions. Machines can analyse complicated scenes, comprehend the context, and make better decisions thanks to scene understanding algorithms.

C) Visual Perception

The ability of robots to receive and interpret visual data similarly to human visual perception is referred to as "visual perception" in computer vision.

To comprehend the visual content, it entails capturing and processing low-level visual cues like colour, texture, shape, and motion. Automated tasks like image segmentation, picture reconstruction, and depth estimation are made possible by visual perception algorithms, which allow machines to extract useful information from images or movies. Several algorithms and techniques, such as image processing, feature extraction, pattern recognition, deep learning, and neural networks, are used in computer vision techniques. By enabling machines to process and interpret visual input, these techniques enable a wide range of applications across sectors, including robots, augmented reality, autonomous cars, surveillance systems, and medical imaging [10].

Computer vision is essential for bridging the gap between the digital and physical worlds by enabling machines to receive and comprehend visual data in a way that is comparable to human vision.

2.3 Natural Language Processing

A branch of artificial intelligence (AI) called "natural language processing" (NLP) is concerned with how computers and human language interact. It entails creating algorithms and methods that allow machines to comprehend, translate, and produce natural language text or speech. NLP is essential for enabling seamless and natural communication between humans and robots in the context of human-robot interaction and communication. A description of how NLP facilitates human-robot interaction is given below:

A) Speech Recognition

Robots can now translate spoken language into text using NLP thanks to speech recognition software. Robots can understand and process vocal commands or inquiries from people by properly transcribing spoken language [11].

a) Learning Natural Language

Robots can comprehend the intent and meaning underlying human language thanks to NLP techniques. To extract pertinent information, Natural Language Understanding (NLU) algorithms examine the syntactic and semantic structure of sentences. Robots can now understand user instructions, queries, or statements and deduce their underlying meaning thanks to this technology.

B) Dialog Systems

Robots can now translate spoken language into text using NLP thanks to speech recognition software. Robots can understand and process vocal commands or inquiries from people by properly transcribing spoken language. Robots can comprehend the intent and meaning underlying human language thanks to NLP techniques. To extract pertinent information, Natural Language Understanding (NLU) algorithms examine the syntactic and semantic structure of sentences semantic structure of sentences. Robots can now understand user instructions, queries, or statements and deduce their underlying meaning thanks to this technology [12].

C) Sentiment Analysis

Robots can now analyse the mood and emotions represented in human language thanks to NLP techniques. Robots can detect user emotions and respond appropriately thanks to sentiment analysis algorithms that categorise text or speech as positive, negative, or neutral.

The quality of interaction and communication between humans and robots is improved by NLP, which enables robots to comprehend and respond to human language in a more natural and human-like manner. This makes it easier to deploy robots in a variety of settings, including those requiring successful human-robot interaction, such as customer service, healthcare, education, and collaborative robotics [13].

3. Applications of AI in Robotics

3.1 Industrial Robotics: Automation of Manufacturing Processes

Industrial robotics is the use of robotic devices to automate various processes in manufacturing and industrial settings. It entails the use of robots and automation technology to complete jobs that have historically been completed by human workers in an effort to increase manufacturing operations' productivity, efficiency, and quality [14].

Figure 2. Industrial Robotics

Industrial robots can automate manufacturing operations and has the following benefits:

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A) Productivity Growth

Industrial robots' ability to operate constantly and precisely results in faster cycle times and higher production output. Robots are more productive than humans because they can complete repetitive jobs quickly and accurately [15].

B) Higher Quality

Robots constantly complete jobs precisely, reducing mistakes and deviations. This results in higher-quality products, fewer flaws, and more consistent manufacturing procedures.

C) Increased Effectiveness

Robotic operations can move more quickly and efficiently, which reduces waste and increases resource efficiency. They may also labour in risky or difficult conditions when people's safety may be in danger [16].

D) Adaptability and Flexibility

Industrial robots can be trained to carry out a variety of activities and can be changed to meet shifting production demands. Manufacturers may now swiftly swap between various product lines, sizes, and configurations thanks to this.

E) Cost Reduction

Even while the initial investment in industrial robotics can be substantial, there are long-term advantages such as lower labour costs, less material waste, and increased overall operational efficiency that allow enterprises to save money.

F) Ergonomics and Safety

The risk of worker injury and repetitive strain is eliminated when physically demanding or dangerous operations are automated. Robots ensure the safety and well-being of workers by handling big loads and working in hazardous conditions [17].Automotive, electronics, pharmaceuticals, food processing, and other manufacturing industries all use industrial robotics. Industrial robots frequently carry out material handling, assembling, welding, painting, packaging, and inspection jobs. The capabilities of industrial robots are further improved by the incorporation of cutting-edge technology like computer vision, artificial intelligence, and machine learning. These innovations provide robots the ability to work with people, adapt to complex and unstructured situations, and carry out more difficult tasks.

Industrial robots transform manufacturing processes by automating work, boosting output, enhancing quality, and establishing safer, more effective working conditions. By allowing them to organise their businesses more effectively, cut costs, and more quickly bring high-quality products to market, it gives manufacturers a competitive edge [18].

3.3 Autonomous Vehicles: Self-driving Cars and Drones

Cars that can navigate and operate without any direct human input are known as autonomous cars. To sense the environment, make judgements, and regulate their movements, they use a combination of cutting-edge technology, including sensors, computer vision, artificial intelligence, and control systems. Drones and self-driving cars are the two main types of autonomous vehicles.

A) Self-Driving Cars

Self-driving cars, sometimes referred to as autonomous cars or driverless cars, are autos that can sense their environment and drive themselves without a driver. In order to sense their surroundings and receive real-time information about the road, traffic, and obstacles, they use a variety of sensors, including cameras, LiDAR (Light Detection and Ranging), radar, and GPS. The processing of the sensor data by sophisticated computer vision and AI algorithms enables the car to make decisions regarding lane changes, speed adjustments, and obstacle avoidance. Self-driving cars are designed to improve traffic safety, boost transportation productivity, and give people who are unable to drive themselves mobility options. Self-driving automobile technologies are currently being actively developed and tested by businesses and academic institutions, with an emphasis on obtaining high levels of autonomy, where no human involvement is necessary [19].

B) Drones

Drones are autonomous or semi-autonomous aircraft that can fly without an on board human pilot, often known as unmanned aerial vehicles (UAVs).Drones can sense their surroundings and navigate in the airspace by using a variety of sensors, including cameras, GPS, altimeters, and inertial measurement units (IMUs).To stabilise the aircraft, change altitude, and carry out manoeuvres, they make use of sophisticated control systems and flying algorithms. Aerial photography, videography, surveillance, package delivery, search and rescue missions, agricultural, and infrastructure inspections are just a few of the many uses for drones. The development of autonomous drone technology aims to enhance flying stability, obstacle recognition and avoidance, and autonomous mission planning. Drones and autonomous vehicles both represent important breakthroughs in the field. They rely on complex hardware and software systems to see, comprehend, and respond to their environment in real-time, enabling them to function safely and effectively without the need for human interaction. In order to significantly enhance the capabilities, safety, and integration of autonomous vehicles into our daily lives, research, development, and regulatory frameworks must continue [20].

4. Challenges in AI-Enabled Robotics

4.1 Safety and Ethics

When it comes to the creation and use of AI-powered robots, safety and ethics are important factors to take into account. To safeguard human well-being, uphold trust, and avert potential harm, it is crucial to ensure that these robots behave in an ethical and reliable manner. Key elements of safety and ethics in robots powered by AI are as follows [17]:

A) Safety

The main focus of safety issues is preventing robot-related mishaps, injuries, and damage. This covers both cyber security and physical safety. To reduce the danger of malfunctions or failures, safety measures include designing robots with sturdy hardware, fail-safe systems, and redundancy. To promote safe interactions between humans and robots, especially in collaborative contexts, safety rules should be put in place. To detect and reduce potential safety issues, robot systems must undergo routine testing, verification, and validation.

B) Ethical Behaviour

Ensuring that AI-powered robots behave morally when interacting with people and the environment is a concern for ethical issues. Robots should treat personal information and sensitive data with care, respecting privacy, secrecy, and data protection. Avoiding bias, discrimination, or unfair treatment based on racial, gender, or socioeconomic considerations is a component of ethical behaviour. It's critical for AI algorithms to be transparent and understandable in order for people to be able to comprehend and have faith in robot decision-making. To ensure appropriate deployment, it is important to take into account how robots will affect jobs, societal standards, and human autonomy.

C) Governance and Regulation

Setting norms, guidelines, and legal criteria for the creation and use of AI-powered robots requires effective governance structures and regulations. Establishing codes of conduct and enforcing adherence to ethical and safety standards should be a joint effort of governments, industry groups, and organisations. Robots can be guaranteed to adhere to the necessary ethical and safety standards by routine audits, inspections, and certifications. To promote knowledge and acceptance of AI-powered robots and their possible effects on society, public awareness and education initiatives are essential.

D) Human Oversight and Responsibility

When using AI-powered robots in important or high-risk applications, it is the duty of humans to monitor their behaviour. To ensure accountability for their activities, humans should be able to intervene or override robot judgements as necessary. The creation and decision-making processes of AI-powered robots must engage a variety of stakeholders, including ethicists, subject matter experts, and end users. Collaboration between academics, engineers, policymakers, and society at large is necessary to address persistent safety and ethical issues. To ensure that new technologies serve humanity while reducing potential hazards and ethical quandaries, it is essential to strike a balance between innovation and responsible application of AI-powered robots.

4.2 Human-Robot Collaboration: Addressing the Social Implications and Acceptance

The term "human-robot collaboration" describes the interaction and teamwork between humans and robots in a variety of contexts, including the workplace, the healthcare industry, and private situations. It entails utilising the skills and capacities of both humans and robots to accomplish common objectives. For human-robot collaboration to be successfully integrated and widely adopted, it is essential to address the societal ramifications and ensure acceptance [21]. Here are some crucial things to keep in mind:

A) Acceptance and Faith

Effective collaboration between people and robots requires the development of trust. Robots should be capable and trustworthy, and humans should feel at ease working alongside them.To build trust and acceptance, robot behaviour must be transparent, judgements must be comprehensible, and clear communication is essential. Programmes for education and awareness can assist people understand the advantages, restrictions, and potential effects of human-robot collaboration while allaying any fears or misconceptions.

B) User-Centred Design

For acceptance and usability, robots must be designed with an emphasis on user needs, preferences, and usability. Robotic systems can be made intuitive, simple to use, and in line with human capabilities and expectations by involving end users in the design and development process. Humans and robots should be able to communicate and interact clearly thanks to user interfaces that are intuitively developed.

C) Social and Emotional Intelligence

The ability to comprehend and react correctly to human emotions, expressions, and social cues is made possible by the development of social and emotional intelligent robots. Robots should show empathy, respect for others' personal space, and cultural sensitivity to promote pleasant relationships with humans [22].

5. Future Development

5.1 Enhancing Human-Robot Interaction and Collaboration

Enhancing human-robot interaction and collaboration means continually working to make it easier for people and machines to communicate, comprehend, and cooperate. In order to develop seamless and natural interactions that maximise the capabilities of both humans and robots, this entails leveraging technology, design concepts, and user-centred methods. In order to achieve common goals, it is desired to establish a harmonious and effective relationship between people and robots.

A) Natural Language Processing and Speech Recognition

Robots can already comprehend and interpret human language thanks to developments in speech recognition and natural language processing, enabling more fluid and intuitive communication.

B) Multimodal Interaction

The complexity and adaptability of human-robot interaction is increased by giving robots the ability to recognise and react to a variety of communication cues, including speech, gestures, touch, and visual cues. As a result, a wider variety of communication channels that suit human tastes and talents are made possible.

C) Context Awareness

Robots that are context-aware have sensors and algorithms that allow them to comprehend their surroundings and guess at human intentions. Robots can change their behaviour and give humans the help they need by making use of context information like location, time, and task-specific facts. By enabling robots to foresee human requirements, make proactive suggestions, and modify their actions accordingly, this improves collaboration.

By constantly advancing the communication and collaboration capabilities of robots, the full potential of the Robots can be unlocked as collaborative partners in various domains, ranging from manufacturing and healthcare to personal assistance and entertainment. This advancement will lead to improved human-robot interaction and collaboration, which requires a multidisciplinary approach, combining expertise in robotics, human-computer interaction, cognitive sciences, and artificial intelligence.

6. Conclusion

AI has fundamentally changed the field of robotics by facilitating important developments, extending applications, and posing particular difficulties. Robotic capabilities have been substantially improved by the incorporation of AI technologies, such as machine learning, computer vision, natural language processing, planning, and control, making them more intelligent, flexible, and autonomous. Robots with AI capabilities have found use in a number of industries, including healthcare, autonomous driving, and industrial automation. Manufacturing processes have been revolutionised, transportation efficiency and safety have been increased, precise and personalised healthcare has been made possible, and new forms of human-robot interaction and cooperation have been made possible. The use of AI in robotics has changed view of how it is related to machines. It has widened the scope of automation, autonomy, and teamwork. The creation, use, and adoption of AI-powered robots for the benefit of society must ensure appropriate development, deployment, and acceptance despite the impressive developments.

References

[1] Mihret, Estifanos. (2020). Robotics and Artificial Intelligence. International Journal of Artificial Intelligence and Machine Learning. 10. 10.4018/IJAIML.2020070104.

[2] Soori, Mohsen &Arezoo, Behrooz&Dastres, Roza. (2023). Artificial Intelligence, Machine Learning and Deep Learning in Advanced Robotics, A Review. 10.1016/j.cogr.2023.04.001.

[3] Premebida, Cristiano & Ambrus, Rares & Marton, Zoltan. (2018). Intelligent Robotic Perception Systems. 10.5772/intechopen.79742.

[4] Phillips-Wren, Gloria & Jain, Lakhmi. (2006). Artificial Intelligence for Decision Making. 4252. 531-536. 10.1007/11893004_69.

[5] Khurana, Diksha & Koli, Aditya & Khatter, Kiran & Singh, Sukhdev. (2022). Natural Language Processing: State of The Art, Current Trends and Challenges. Multimedia Tools and Applications. 82. 10.1007/s11042-022-13428-4.

[6] Hosseinzadeh Dizaj, Mehran. (2022). The effect of artificial intelligence in robotics.

[7] Guzman Urbina, Alexander & Ishida, Shuichi & Eugene, Choi & Aoyama, Atsushi. (2016). Artificial intelligence improving safety and risk analysis: A comparative analysis for critical infrastructure. 471-475. 10.1109/IEEM.2016.7797920.

[8] Zeller, Frauke & Dwyer, Lauren. (2022). Systems of collaboration: challenges and solutions for interdisciplinary research in AI and social robotics. Discover Artificial Intelligence. 2. 10.1007/s44163-022-00027-3.

[9] Chopra, Ronit. (2023). Artificial Intelligence in Robotics: (Review Paper). International Journal for Research in Applied Science and Engineering Technology. 11. 2345-2349. 10.22214/ijraset.2023.50635.

[10] Runnova, A. & Maksimenko, Vladimir & Zhuravlev, Maksim. (2019). Use of artificial intelligence for study of the visual perception. 38. 10.1117/12.2527705.

[11] Vashisht, Vineet & Pandey, Aditya & Yadav, Satya. (2021). Speech Recognition using Machine Learning. IEIE Transactions on Smart Processing & Computing. 10. 233-239. 10.5573/IEIESPC.2021.10.3.233.

[12] Mctear, Michael. (2020). Conversational AI: Dialogue Systems, Conversational Agents, and Chatbots. Synthesis Lectures on Human Language Technologies. 13. 1-251. 10.2200/S01060ED1V01Y202010HLT048.

[13] Kawade, Dipak & Oza, Kavita. (2017). Sentiment Analysis: Machine Learning Approach. International Journal of Engineering and Technology. 9. 2183-2186. 10.21817/ijet/2017/v9i3/1709030151.

[14] Alseqyani, Abdulrahman&Alotaibi, Saud. (2022). Artificial Intelligence & Robotics – Synthetic Brain in Action. International Journal of Artificial Intelligence & Applications. 13. 49-56. 10.5121/ijaia.2022.13304.

[15] Ernst, Ekkehard. (2022). Artificial Intelligence: Productivity Growth and the Transformation of Capitalism. 10.1007/978-3-030-90192-9_7.

[16] Waltersmann, Lara & Kiemel, Steffen & Stuhlsatz, Julian & Sauer, Alexander & Miehe, Robert. (2021). Artificial Intelligence Applications for Increasing Resource Efficiency in Manufacturing Companies—A Comprehensive Review. Sustainability. 13. 6689. 10.3390/su13126689.

[17] Bezboruah, Tulshi& Bora, Abhijit. (2020). Artificial intelligence: The technology, challenges and applications. 10.14738/tmlai.85.8956.

[18] Chella, Antonio &Iocchi, Luca &Macaluso, Irene &Nardi, Daniele. (2006). Artificial Intelligence and Robotics..IntelligenzaArtificiale. 3. 87-93.

[19] Kumar, Rishabh& Sharma, Tarun& Chaudhary, Renu& Singh, Vibhor. (2022). Self-Driving Car Using Machine Learning. 10.1007/978-981-19-4193-1_69.

[20] Wang, Qing & Xu, Chenren&Leng, Supeng&Pollin, S.. (2018). When Autonomous Drones Meet Driverless Cars. 514-514. 10.1145/3210240.3210806.

[21] Soares de Lima, Edirlei & Feijó, Bruno. (2019). Artificial Intelligence in Human-Robot Interaction. 10.1007/978-3-319-96722-6_11.

[22] Schröder, Marc & Mckeown, Gary. (2010). Considering Social and Emotional Artificial Intelligence.