Journal of Artificial Intelligence and Capsule Networks (ISSN: 2582-2012)
www.irojournals.com/aicn/

Cognitive Robotics: Integrating Artificial Intelligence and Embodied Intelligence for Advanced Problem Solving

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Abstract

Artificial intelligence (AI) and embodied intelligence are combined in cognitive robotics, which marks a paradigm change in highly developed problem-solving skills. This study offers a comprehensive review of the theoretical underpinnings, practical difficulties, practical applications, and moral implications of cognitive robots. The study explores machine learning methods, natural language processing tools, and computer vision technologies after introducing the fundamental concepts. It clarifies embodied intelligence further by emphasizing the important roles that sensory data fusion, robotic actuation, and adaptive behaviours play in the cognitive capabilities of robots. The study then moves on to discuss cognitive robotics' integration difficulties, including issues in sensory data fusion, cognitive dissonance in AI-driven robotics, and human-robot interaction. Applications in autonomous cars, healthcare, manufacturing, and assistive technologies demonstrate how cognitive robotics is transforming many different industries. The ethical obligations involved in the creation and use of cognitive robotic systems are highlighted, along with ethical issues relating to employment, privacy, and ethical AI practises. In-depth analysis is done of the present and foreseeable difficulties in cognitive robotics. Along with cognitive difficulties like contextual comprehension and moral conundrums, technical obstacles linked to sensor limits and processing restrictions are also studied. The study highlights cutting-edge research projects and

DOI: https://doi.org/10.36548/jaicn.2023.4.002
Received: 17.09.2023, received in revised form: 10.10.2023, accepted: 27.10.2023, published: 09.11.2023

multidisciplinary partnerships that provide answers to these problems, paving the path for the development of cognitive robots in the future. The article envisions a future where cognitive robots would play a part in space exploration, disaster response, and personalised robotics. It also surveys integration possibilities with cutting-edge technologies like augmented reality and the Internet of Things. The study summarises the key findings and presents the implications for future research, and emphasises the important part cognitive robotics plays in resolving difficult issues. To ensure that cognitive robots continue to have an impact on a future that is smarter, more connected, and understanding, ethical issues, multidisciplinary collaboration, and responsible development practises are necessary.

Keywords: Cognitive Robotics, Artificial Intelligence, Embodied Intelligence, Machine Learning, Natural Language Processing.

1. Introduction

Cognitive robotics is a revolutionary topic that has emerged in recent years as a result of the fusion of artificial intelligence (AI) and robotics. Cognitive robots, as opposed to conventional robotic systems, have the capacity to see, reason, pick up new information, and interact with their surroundings in a way that resembles human cognition. Robotics has undergone a paradigm change as a result of the combination of AI and embodied intelligence, which allows machines to do complex problem-solving activities that were previously thought to be beyond their scope [1].

Cognitive robotics takes use of the interplay between embodied intelligence, or the robot's capacity to perceive and respond to the physical environment, and artificial intelligence, which includes machine learning, natural language processing, and computer vision. Cognitive robots can learn from experiences, adapt to complex and unexpected surroundings, and make decisions on their own by integrating these two characteristics [2]. Robots can now analyse sensory data, recognise human gestures, understand spoken language, and move items, giving them the ability to work effectively with people in a variety of contexts.

Cognitive robotics has a wide range of uses, including industry, healthcare, autonomous cars, and assistive technologies. By increasing production, efficiency, and safety, these intelligent technologies have the potential to revolutionise several sectors. For instance, in the healthcare industry, cognitive robots can help doctors with operations, patient care, and therapeutic activities. They are able to perform complex jobs with accuracy and optimise production processes in the industrial sectors [3]. Additionally, cognitive robots can safely negotiate challenging traffic situations in the world of autonomous automobiles.

This study explores the complex interaction between embodied intelligence and artificial intelligence in the field of cognitive robotics. This study seeks to give a thorough knowledge of how cognitive robots are transforming the future of problem-solving by presenting the theoretical underpinnings, technical breakthroughs, and practical applications. This study aims to discuss about the promise of cognitive robots while addressing the ethical, social, and technological considerations connected with this developing subject through a critical review of present research, approaches, and difficulties. Understanding the interaction between AI and embodied intelligence in cognitive robotics is essential for using the full potential of these sophisticated problem-solving systems by striving deeper into the era of intelligent machines.

2. Foundations of Artificial Intelligence

2.1 Machine Learning Techniques in Cognitive Robotics

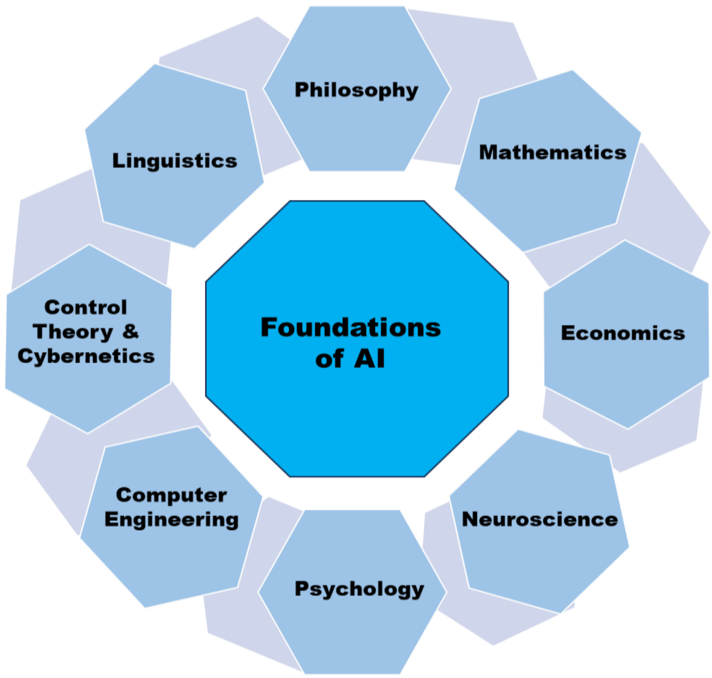

Figure 1. Foundations of Artificial Intelligence

The development of robots' cognitive skills depends heavily on machine learning (ML). The study provides detail about several machine learning methods used in cognitive robots in this area, including reinforcement learning, unsupervised learning, and supervised learning. It is essential to discuss how these methods help robots see patterns, learn from data, and make judgement calls based on past experiences. It is possible to describe how specific algorithms, such as neural networks, decision trees, and deep learning networks, might improve robotic cognition [4]. Machine learning algorithms' practical applications in fields like object identification, gesture interpretation, and autonomous navigation can give clear instances of their importance in cognitive robotics. Figure 1 depicts foundation of artificial intelligence.

2.2 Natural Language Processing Capabilities

In order to facilitate seamless communication between humans and machines, natural language processing (NLP) gives robots the ability to comprehend and respond to human language. The foundational ideas of NLP, are syntax, semantics, and pragmatics. Some of the methods used by robots to analyse human language, are tokenization, part-of-speech tagging, sentiment analysis, and named entity recognition [5]. The difficulties with NLP in robots, are processing ambiguous language and comprehending context. The practical ramifications of NLP, are addressed through the real world examples like chatbots, virtual assistants, and human-robot interaction situations.

2.3 Computer Vision and Perception in Robots

Robots can only receive and understand visual data from the environment with the help of computer vision. The fundamental ideas of computer vision, are Image recognition, object detection, and image segmentation. The visual perception systems used by robots, are cameras, LiDAR, and depth sensors [6]. The robots interpret visual input using the image processing methods including edge detection, feature extraction, and convolutional neural networks (CNNs). The use of computer vision in cognitive robotics, can be seen in real-world applications including facial recognition, autonomous driving, and robotic surveillance.

3. Key Concepts in Cognitive Robotics

3.1 Embodied Intelligence

Embodied intelligence emphasizes the importance of a robot's physical interaction with the environment. Robots with embodied intelligence learn and understand the world through their sensors and actuators [6]. This concept acknowledges that intelligence is not just about computation but also involves perception and action in the physical world.

3.2 Perception-Action Loop

The perception-action loop is a fundamental concept in cognitive robotics. It refers to the continuous cycle of perceiving information from the environment, processing the information, and taking actions based on the processed data. This loop enables robots to adapt their behaviour in response to changing environmental cues.

3.3 Sensorimotor Learning

Sensorimotor learning involves the development of robotic skills through interactions with the environment. Robots learn to manipulate objects, navigate spaces, and respond to stimuli by processing sensor data and adjusting their motor actions. Machine learning algorithms are often employed to facilitate sensorimotor learning.

3.4 Representation and Reasoning

Cognitive robots require internal representations of the external world to reason about their surroundings and make decisions. These representations can be symbolic or probabilistic, enabling robots to perform tasks such as planning, problem-solving, and decision-making.

3.5 Natural Language Interaction

Enabling robots to understand and generate human language is a significant aspect of cognitive robotics. Natural language processing techniques are employed to facilitate communication between humans and robots, allowing for more intuitive and user-friendly interactions.

4. Methodologies Used in Framing Cognitive Robotics

4.1 Machine Learning and Deep Learning

Machine learning algorithms, including supervised, unsupervised, and reinforcement learning, are used to train cognitive robots. Deep learning techniques, particularly neural networks and convolutional neural networks (CNNs), are employed for tasks such as image recognition, object detection, and language processing [8].

4.2 Computer Vision

Computer vision methods are utilized to enable robots to interpret visual information from the environment. Techniques like image segmentation, object tracking, and feature extraction are employed for tasks such as object recognition and scene understanding.

4.3 Natural Language Processing (NLP)

NLP techniques are applied to allow robots to understand and generate human language. These methods include syntactic analysis, semantic understanding, sentiment analysis, and language generation. NLP enables robots to process textual data, understand user commands, and respond appropriately.

4.4 Reinforcement Learning

Reinforcement learning algorithms are used for training robots to learn optimal actions based on rewards and penalties. Reinforcement learning enables robots to adapt their behavior through trial and error, allowing them to improve their performance over time in complex and dynamic environments.

4.5 Robotics and Control Theory

Principles from robotics and control theory are applied to design the physical structure and control mechanisms of cognitive robots. Kinematics, dynamics, and control algorithms are used to ensure robots can perform precise and coordinated movements, interact with objects, and navigate their surroundings.

4.6 Human-Robot Interaction (HRI)

HRI techniques involve the study of how humans and robots interact. This includes gesture recognition, speech processing, and emotion recognition. HRI methodologies help design robots that can communicate effectively with humans, understand social cues, and respond appropriately in various social contexts.

5. Artificial Intelligence and Embodied Intelligence for Advanced Problem Solving

5.1 Sensor Fusion and Perception

Techniques: Sensor fusion algorithms combine data from various sensors (such as cameras, LiDAR, and touch sensors) to create a comprehensive perception of the environment [9]. Bayesian methods and probabilistic models are often employed for accurate sensor fusion.

Importance: Integrating sensor data allows the robot to perceive the physical world, identify objects, and understand spatial relationships, forming the foundation for decision-making.

5.2 Machine Learning Algorithms

Techniques: Machine learning algorithms, including supervised learning, unsupervised learning, and reinforcement learning, are employed. Deep learning techniques like convolutional neural networks (CNNs) are used for tasks like image recognition and object detection.

Importance: Machine learning enables robots to recognize patterns, make predictions, and learn from experience, allowing them to adapt to new situations and solve complex problems.

5.3 Natural Language Processing (NLP) Capabilities

Techniques: NLP techniques involve tokenization, part-of-speech tagging, and sentiment analysis. Natural language understanding (NLU) algorithms enable robots to comprehend spoken or written language.

Importance: NLP enables seamless communication between humans and robots, allowing robots to process and respond to commands, questions, and instructions.

5.4 Computer Vision and Object Recognition

Techniques: Computer vision techniques, such as edge detection and feature extraction, help robots interpret visual information. Object recognition methods, including template matching and CNNs, allow robots to identify and classify objects [10].

Importance: Computer vision enables robots to "see" and understand the environment, supporting tasks like navigation, manipulation, and interacting with objects.

5.5 Reinforcement Learning and Adaptive Behaviours

Techniques: Reinforcement learning algorithms involve reward-based learning, where robots receive feedback based on their actions. Adaptive behaviors involve updating robot responses based on environmental feedback and learning from unexpected outcomes.

Importance: Reinforcement learning and adaptive behaviors enable robots to learn from trial and error, adjusting their actions in real-time to maximize efficiency and effectiveness.

5.6 Human-Robot Interaction (HRI) Techniques

Techniques: HRI techniques include gesture recognition, speech recognition, and emotion recognition. Collaborative robotics methods involve shared control algorithms and safety mechanisms for effective cooperation between humans and robots.

Importance: HRI techniques facilitate natural and intuitive interaction between humans and robots, enabling collaborative problem-solving and enhancing user experience. Figure 2 shows the artificial intelligence and embodied intelligence for advanced problem solving.

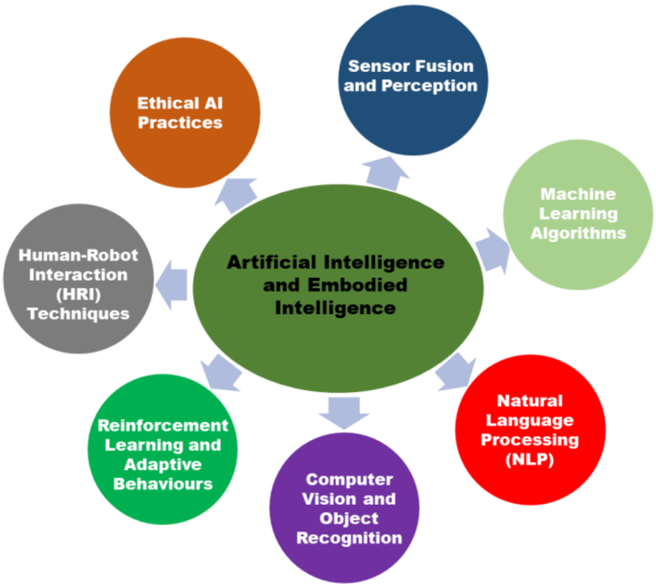

Figure 2. Artificial Intelligence and Embodied Intelligence

5.7 Ethical AI Practices

Techniques: Ethical AI practices involve implementing fairness-aware algorithms, bias mitigation techniques, and explainable AI (XAI) methods. Ethical guidelines and regulations ensure robots operate within ethical boundaries.

Importance: Ethical AI practices are essential for ensuring robots make fair and unbiased decisions, respect privacy, and adhere to ethical norms, promoting responsible problem-solving.

6. Integration Challenges and Solutions in Cognitive Robotics

6.1 Sensory Data Fusion and Interpretation

Challenges:

- Diverse Data Sources: Integration of data from different sensors with varying formats and accuracy levels.
- Noise and Interference: Sensor noise, interference, and calibration issues leading to inaccurate interpretations.

Solutions:

- Sensor Fusion Algorithms: Implement algorithms (e.g., Kalman filters) for accurate fusion of diverse sensor data.
- Calibration Techniques: Develop calibration methods to ensure consistency among sensor readings.
- Machine Learning Models: Employ machine learning models to interpret noisy data and distinguish meaningful patterns.

6.2 Addressing Cognitive Dissonance in AI-Driven Robotics

Challenges:

- Conflicting Data Inputs: Conflicting information from different sensors leads to decision-making dilemmas.
- Unexpected Sensor Readings: Sudden and unexpected sensor readings causing inconsistencies in robot behavior.

Solutions:

- Anomaly Detection: Implement anomaly detection algorithms to identify and flag conflicting or unexpected sensor readings.
- Adaptive Learning Techniques: Use adaptive learning algorithms to dynamically adjust the robot's behavior based on real-time sensor inputs.

6.3 Human-Robot Interaction and Collaboration

Challenges:

- Language Understanding: Difficulty in understanding complex human language, including idiomatic expressions.
- Interpreting Non-Verbal Cues: Challenges in interpreting human gestures, facial expressions, and emotions accurately.

Solutions:

- Natural Language Processing (NLP) Algorithms: Utilize advanced NLP algorithms, including semantic analysis and sentiment recognition, for accurate language understanding.
- Gesture Recognition Systems: Implement sophisticated gesture recognition systems using computer vision techniques to interpret non-verbal cues effectively.

6.4 Integration Challenges in Autonomous Vehicles

Challenges:

- Real-Time Decision Making: Complex decision-making processes in real-time scenarios, such as intersections or sudden obstacles.
- Sensor Redundancy: Redundant sensor data leads to confusion and decision-making conflicts.

Solutions:

- Advanced Decision Algorithms: Develop AI-driven decision algorithms that weigh multiple factors and predict potential outcomes to make informed driving decisions.
- Sensor Data Filtering: Implement filtering techniques to eliminate redundant or conflicting sensor data, ensuring accurate interpretation.

6.5 Integration Challenges in Healthcare Robotics

Challenges:

- Patient Safety: Ensuring robots make safe decisions in sensitive healthcare environments, especially during surgeries.
- Data Privacy: Protecting patient data collected and processed by healthcare robots.

Solutions:

- Safety Protocols: Implement safety protocols, including fail-safes and emergency stop mechanisms, to prevent harm to patients.
- Data Encryption and Access Control: Apply encryption and strict access control measures to safeguard patient data, ensuring privacy and compliance with healthcare regulations.

6.6 Integration Challenges in Educational Robotics

Challenges:

- Adaptability to Learning Styles: Adapting robotic teaching methods to diverse student learning styles and needs.
- Teacher Training: Ensuring educators are proficient in using educational robots effectively.

Solutions:

- Personalized Learning Algorithms: Develop adaptive algorithms that customize learning experiences based on individual student progress and preferences.
- Educator Training Programs: Conduct training programs to educate teachers about the optimal use of educational robots, enabling them to integrate robots into their teaching methodologies effectively.

7. Applications of Cognitive Robotics

Table 1. Applications of Cognitive Robotics

Application	Uses	Limitations
Autonomous Vehicles and Intelligent Navigation	Safe and efficient transportation. Real-time obstacle detection and avoidance. Improved traffic flow and reduced accidents.	Limited performance in extreme weather conditions. Ethical and legal challenges in decision-making.

		High development and maintenance costs.
Healthcare: Robotics in Surgery and Patient Care	Precision in surgical procedures. Minimally invasive surgeries. Assistive tools for rehabilitation. Patient monitoring and care.	Complex surgeries require skilled supervision. High initial costs and maintenance. Ethical concerns in decision-making.
Manufacturing: Automation and Precision Tasks	High-precision manufacturing. Repetitive tasks and assembly. Collaborative robots working alongside human workers.	Initial setup and programming can be time-consuming. Limited adaptability for new tasks. Cost of implementation.
Assistive Technology: Enhancing Human Lives	Mobility assistance for individuals with disabilities. Robotic prosthetics and exoskeletons. AI-driven devices for the visually impaired. Emotional support and companionship.	Customization challenges for individual needs. Affordability and accessibility issues. Social acceptance and user adaptation.
Autonomous Drones and UAVs	Aerial surveillance and monitoring. Search and rescue operations. Environmental monitoring. Package delivery services.	Limited battery life and flight range. Airspace regulations and safety concerns. Vulnerability to weather conditions.
Retail and Customer Service Robots	Customer interaction and assistance. Inventory management. Guiding customers within stores. Data collection for customer preferences.	Limited ability to handle complex inquiries. Initial setup costs. Privacy concerns with data collection.

Agricultural Robotics	Precision farming and crop monitoring. Automated harvesting. Pest control and weed management. Soil analysis and crop optimization	Limited adaptability to diverse farm environments. Initial investment costs. Maintenance challenges in agricultural settings.
Educational Robots	Interactive learning experiences. Programming and STEM education. Special education support for children with learning disabilities	Limited emotional intelligence and empathy. Dependency on internet connectivity. Ethical concerns in student-robot interaction

8. Ethical and Social Implications

8.1 Ethical Considerations in Cognitive Robotics

Given the possible influence on society, ethical issues in cognitive robots are of the utmost importance. This section dives into moral conundrums including permission, data security, and privacy. It explores topics relating to robot autonomy and responsibility for mistakes, as well as robot rights and obligations [11]. It investigates the ethical ramifications of deploying cognitive robotics in healthcare applications like robotic surgery and geriatric care. The study also addresses issues with biases in AI systems and how they affect judgement. The real case studies of ethical difficulties businesses and academics have encountered in the field of cognitive robotics, emphasising the significance of ethical frameworks and rules for directing responsible development and deployment. Figure 3 shows the ethical and social implications.

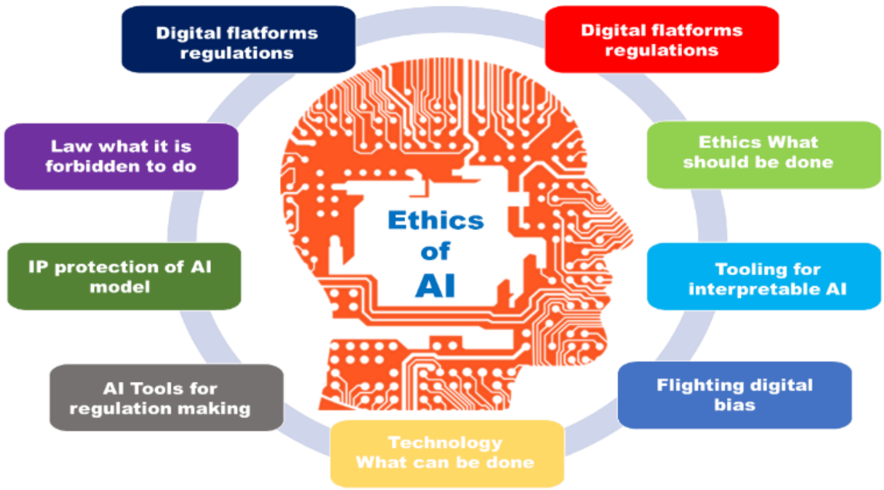

Figure 3. Ethical and Social Implications

8.2 Impact on Employment and Society

Concerns regarding the effects on employment and society institutions have been raised by the broad use of cognitive robots. This idea of technological unemployment and how automation and robots powered by AI may displace some occupations. In a variety of industries, such as manufacturing, transportation, and customer service, it may assess the likelihood of job displacement. In order for the workforce to be able to adapt to a technologically enhanced environment, it is essential to know how AI has changed the job market [12]. Exploring societal effects such as altered income distribution and economic inequality is possible. Analysing actual cases of communities or businesses impacted by automation and the steps taken to lessen its social effects can offer a nuanced view.

8.3 Ensuring Ethical AI and Robotic Practices

Ensuring ethical AI and robotic practises is crucial for addressing ethical issues. The creation of moral standards and laws in the area of cognitive robots is examined in this section. It can go over efforts being made by governments, business associations, and academic organisations to create guidelines for AI and robots ethics [13]. The study explores accountability, transparency, and fairness in AI algorithms, highlighting the significance of explainable AI (XAI) and bias reduction methods. The multidisciplinary cooperation among ethicists, decision-makers, technologists, and the general public might shape moral AI practises. The significance of responsible development and deployment of cognitive robots, can be seen through the real-world examples of businesses or projects using ethical AI principles and the beneficial effects of ethical concerns.

9. Challenges and Future Directions

9.1 Current Challenges in Cognitive Robotics

Numerous obstacles prevent cognitive robots from being easily integrated into numerous fields. Technical difficulties such sensor limits, processing restrictions, and the requirement for effective algorithms to analyse enormous volumes of data in real-time is discussed. It speaks about cognitive difficulties such context understanding, common sense reasoning, and environment adaptation [14]. The study also address difficulties in human-robot interaction, such as recognising natural language and deciphering non-verbal signs. Figure 4 depicts the challenges and future directions.

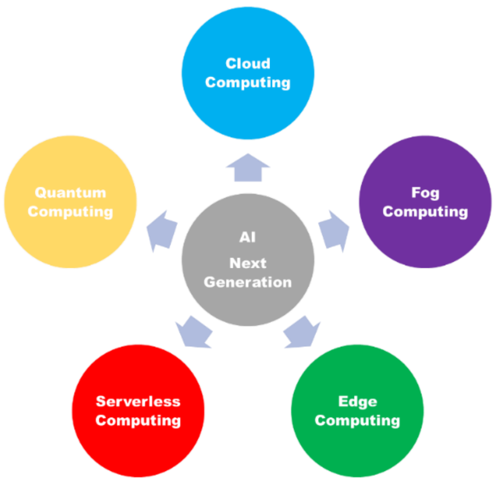

Figure 4. Challenges and Future Directions

9.2 Overcoming Limitations: Research and Innovation

The limits of cognitive robots are being aggressively addressed by scientists and entrepreneurs. In this part, the most recent studies and ground-breaking fixes for the problems mentioned before are examined [15]. The developments in robotic hardware architectures can be explored, using the machine learning techniques, and sensor technologies. The multidisciplinary research projects that combine engineering, cognitive science, and computer science can be used to improve robot perception, cognition, and interaction capabilities. Also ground-breaking techniques help cognitive robotics overcome its constraints, such as swarm robots, explainable AI, and bio-inspired robotics.

9.3 Envisioning the Future: Cognitive Robotics Beyond

Looking ahead, cognitive robots have a huge amount of promise. This section examines futuristic ideas and prospective uses that go beyond what cognitive robots are now capable of. The cognitive robots can be used with other cutting-edge technologies, including augmented reality (AR) and the Internet of Things (IoT), to build linked, intelligent ecosystems [16]. The uses of cognitive robotics extends to environmental monitoring, disaster response, and space exploration, demonstrating how robots with highly developed cognitive capacities can navigate and function in challenging and unstructured situations. It can also go over the possibilities of personalised robotics, where robots are made to suit specific tastes and requirements, improving user experience and human-robot interaction. The ethical implications are also necessary to be considered in the potential uses and the societal effects of sophisticated cognitive robots

10. Conclusion

10.1 Key Findings

The study provides a summary of the most important discoveries and learnings made throughout the course of the investigation. It summarise the key ideas covered in the study, including how cognitive robotics integrates artificial intelligence and embodied intelligence, key technologies like machine learning, natural language processing, and computer vision, difficulties cognitive robotics faces, and actual applications in various fields.

10.2 Implications for Future Research and Development

The implications of the study results on the development of cognitive robots is covered in this section. It investigates how the aforementioned issues, breakthroughs, and applications will affect the field's future study and development. Emerging technology, multidisciplinary cooperation, and the changing requirements of industry and society should all be taken into account. The study identifies possible study areas, such as improving human-robot collaboration, resolving ethical issues, and developing cognitive robot skills.

10.3 Closing Thoughts: The Role of Cognitive Robotics in Advanced Problem Solving

The study's concluding remarks highlights the important part cognitive robotics plays in increasing problem-solving abilities. It can go over how cognitive robots improves human productivity, safety, and quality of life in addition to solving complicated challenges. The study reflects on the revolutionary potential of cognitive robots in reshaping sectors and opening up new opportunities in assistive technology, manufacturing, transportation, and healthcare. Additionally, it draws attention to how crucial moral concerns and ethical behaviour are in determining the direction of cognitive robots.

Reference

[1] Steinfeld, T. Fong, D. Kaber, M. Lewis, J. Scholtz, A. Schultz, M. Goodrich, Common metrics for human-robot interaction, in: Proceedings of the 1st ACM/IEEE International Conference on Human-Robot Interaction (HRI), Utah, USA, 2006.

[2] T. Fong, I. Nourbakhsh, K. Dautenhahn, “A survey of socially interactive robots”, Robotics and Autonomous Systems 42 (3–4) (2003) 143–166.

[3] S. Griffiths, L. Voss, F. Rohrbein, Industry-academia collaborations in robotics: Comparing Asia, Europe and North-America, in: 2014 IEEE International Conference on Robotics and Automation (ICRA), IEEE, 2014, pp. 748–753.

[4] H. J. Levesque, G. Lakemeyer, Cognitive robotics, in: G. Lakemeyer, H. J. Levesque, F. Pirri (Eds.), Cognitive Robotics, no. 10081 in Dagstuhl Seminar Proceedings, Schloss Dagstuhl - Leibniz-Zentrum fuer Informatik, Germany, Dagstuhl, Germany, 2010. URL http://drops.dagstuhl.de/opus/volltexte/2010/2633 4

[5] Breazeal, A. Takanishi, T. Kobayashi, Social robots that interact with people, in: Springer Handbook of Robotics, Springer, Heidelberg, 2008, pp. 1349–1369.

[6] Bordini, Rafael H., Lars Braubach, Mehdi Dastani, A. El F. Seghrouchni, Jorge J. Gomez-Sanz, Joao Leite, Gregory O'Hare, Alexander Pokahr, and Alessandro Ricci. "A survey of programming languages and platforms for multi-agent systems." Informatica 30, no. 1 (2006).

[7] L. A. Zadeh, "Fuzzy logic—a personal perspective," Fuzzy Sets and Systems, vol. 281, pp. 4-20, 2015.

[8] N. Spinrad, "Mr Singularity," Nature, vol. 543, pp. 582-582, 2017.

[9] E. Horvitz, "One Hundred Year Study on Artificial Intelligence: Reflections and Framing," ed: Stanford University, 2014.

[10] S. Lohr, "The age of big data," New York Times, vol. 11, 2012.

[11] M. Quigley, K. Conley, B. Gerkey, J. Faust, T. Foote, J. Leibs, R. Wheeler, A. Y. Ng, Ros: An open-source Robot Operating System, in: ICRA workshop on open source software, Vol. 3, 2009, p. 5.

[12] T. Berners-Lee, J. Hendler, O. Lassila, et al., The semantic web, Scientific American 284 (5) (2001) 28–37.

[13] A. M. Turing, Computing machinery and intelligence, Mind 59 (1950) 433–460.

[14] S. M. Shieber, Lessons from a restricted Turing test, Communications of the Association for Computing Machinery (6) (1994) 70–78.

[15] R. M. French, The Turing test: The first 50 years, Trends in Cognitive Sciences 4 (3) (2000) 115–122.

[16] S. Harnad, P. Scherzer, First, scale up to the robotic Turing test, then worry about feeling, Artificial Intelligence in Medicine 44 (2) (2008) 83–89.