EAI Endorsed Transactions
on AI and Robotics

Research Article EAI.EU

Fog Cloud Computing and IoT Integration for AI enabled Autonomous Systems in Robotics

Kiran Deep Singh[1], Prabh Deep Singh [2*]

[1]Chitkara University Institute of Engineering and Technology, Chitkara University, Rajpura, Punjab, India
[2]Department of Computer Science and Engineering, Graphic Era Deemed to be University, Dehradun, India.

Abstract

Fog Cloud Computing and the Internet of Things are transforming robotics by empowering AI-enabled autonomous systems. This study analyzes the benefits, drawbacks, and uses of this integration. AI-enabled autonomous robots can use edge computing and cloud resources for real-time data processing and decision-making, improving their performance and adaptability. Communication protocols, data management, security, and scalability are examined in the ecosystem. Case studies reveal how this confluence affects robotics applications. This research shows how FCC, IoT, and AI may improve robotic systems' efficiency, intelligence, and autonomy. The article covers AI-enabled autonomous systems in transportation, manufacturing, healthcare, agriculture, and smart cities. These technologies can improve productivity and safety in many fields, from self-driving automobiles to surgical robots. Integrating these technologies raises safety, ethical decision-making, data privacy, and security concerns. The report emphasizes transparent and ethical AI algorithms, unbiased decision-making, and regulatory frameworks to enable responsible integration and mitigate dangers. In the future, AI-enabled autonomous systems will be shaped by improved AI algorithms, multi-modal sensing, human-robot collaboration, and edge intelligence. It emphasizes the necessity of interdisciplinary collaboration and ethical considerations in responsible technology development. This study concludes with a detailed analysis of fog/cloud computing, IoT, and AI in robotics, revealing the immense promise and problems of AI-enabled autonomous systems. Responsible development and collaboration can help us negotiate this transformational frontier and create a safer, more efficient, and innovative society with AI-driven autonomous systems.

Keywords: Artificial Intelligence, Fog Computing, Cloud Computing, Internet of Things, Robotics

Received on 25 July 2023, accepted on 07 March 2024, published on 12 March 2024

doi: 10.4108/airo.3617

1. Introduction

Fog/cloud computing, IoT, and AI have transformed robotics, creating a new era of autonomous systems. Robots can now sense, reason, and act autonomously in varied situations because of this combination of cutting-edge technologies [1],[2]. AI-driven robotic systems can now make real-time decisions thanks to fog/cloud computing and IoT. Fog/cloud computing and IoT have changed robotics. Traditional robotic systems could only perform pre-programmed tasks in controlled situations. However, AI, particularly machine learning and IoT, have transformed robots to learn from data, adapt to changes, and do tasks without human intervention [3].

Fog computing processes data at the network edge, and cloud computing, which provides massive computational resources and storage, optimizes robotic operations. Fog computing at the edge reduces latency and bandwidth usage for real-time reactions in time-sensitive applications. At the same time, the cloud provides massive data and computational capacity for complex analytics and training models [4],[5]. While fog/cloud computing, IoT, and AI in robotics are rapidly growing topics with great potential, we will focus on presenting a general overview rather than an exhaustive

*Corresponding author. Email: ssingh.prabhdeep@gmail.com

Intelligent load-balancing algorithms distribute workload efficiently across the fog and cloud layers, minimizing bottlenecks and optimizing system performance.

5.3 Integrated System Security and Privacy

Robotics using fog/cloud computing and IoT raises security and privacy concerns. Data integrity and confidentiality must be protected at the edge and in the cloud. Data encryption, access controls, and secure communication protocols protect critical information. Rigorous security measures are employed to protect the system from cyberattacks on IoT devices. IoT devices create massive amounts of data that cloud data centers process, raising privacy concerns. Data anonymization and differential privacy safeguard identities and sensitive data.
Fog/cloud computing and IoT technologies in robotics revolutionize autonomous systems. The edge layer processes real-time data and edge analytics, while the cloud layer powers complicated AI algorithms. Integrating systems requires resource allocation, load balancing, and security. As this integration advances, AI-enabled robotics will transform industries and create intelligent, autonomous robots.

6. Applications of AI-Enabled Autonomous Systems:

In many industries, AI-enabled autonomous systems have revolutionized tasks and improved productivity, safety, and precision. Some notable AI-enabled autonomous system applications:
Self-driving automobiles and drones are the most famous AI-enabled autonomous systems. These cars use AI algorithms, computer vision, and sensor fusion to navigate complicated surroundings, make real-time judgments, and avoid obstacles, improving safety and efficiency.
Industrial Automation: AI-powered autonomous robots are changing production. These robots can accurately conduct assembling, welding, painting, and material handling. Autonomous systems optimize production workflows, monitor equipment health, and predict maintenance needs in smart factories, increasing productivity and reducing downtime [25].
AI-powered medical robots improve patient care and surgery. Robotic surgical devices help surgeons with accurate motions and real-time data feedback for minimally invasive operations with better outcomes. AI-driven robots dispense drugs, monitor patients, and perform dangerous duties to protect medical staff.
Agriculture: Autonomous drones and robotics optimize agricultural management. These systems monitor crop health, identify illnesses, and provide targeted treatments, improving production and resource efficiency. Autonomous tractors and harvesters streamline farming.
AI-enabled autonomous systems are essential to smart city ambitions. AI-powered smart grids, self-driving public transportation and intelligent waste management systems create sustainable and efficient metropolitan environments.
Autonomous drones and robots are utilized for monitoring and security. They patrol huge regions, monitor key infrastructure, and give real-time situational awareness to improve public safety.
AI-driven autonomous systems monitor and conserve the environment. Sensor-equipped drones track wildlife, biodiversity, and ecosystem health. Ocean exploration and pollution monitoring use AUVs [26].
Retail and logistics: AI-powered robots manage inventory, refill shelves, and deliver orders in warehouses. Last-mile delivery robots and drones are being tried to improve e-commerce efficiency and sustainability.
Disaster response and search-and-rescue activities benefit from AI-enabled autonomous systems. First responders can use drones and robots to find survivors and assess damage.
Education and Research: Autonomous robots teach programming, robotics, and problem-solving. AI-driven robots aid scientific study, data collection, and space exploration.
AI-enabled autonomous systems will uncover new possibilities and disrupt industries in ways we cannot yet envision as AI technology advances. Ethical, safety, and regulatory issues must be addressed as these systems become increasingly common to ensure responsible and useful incorporation into society.

7. Future Trends and Challenges

AI-enabled autonomous systems will affect the future of many sectors and change how we use technology. Technological innovation presents trends and difficulties that must be addressed to ethically use these systems. Future AI-enabled autonomous system trends and difficulties include:

7.1 Future Trends

Advanced AI Algorithms: Advanced machine learning models, deep learning architectures, and reinforcement learning approaches will improve autonomous system decision-making and adaptability.
Multi-modal Sensing: Autonomous systems may use cameras, lidars, radars, and microphones to create a more complete and accurate view of the surroundings.
Human-Robot Collaboration: AI-enabled autonomous systems will work with people in numerous industries. Collaboration improves workflows.
Edge Intelligence: Autonomous systems will use edge computing and intelligence to process and analyze data closer to the source, decreasing latency and bandwidth utilization and ensuring real-time decision-making.
Explainable AI: As AI-enabled autonomous systems become more widespread, explainable AI will be needed. In essential areas like healthcare and finance, interpretable AI models that explain their conclusions will gain traction.
Autonomous Swarming: Autonomous systems could use swarm intelligence, emulating social insects, to collaborate and efficiently complete complicated tasks like search and rescue or environmental monitoring.

7.2 Challenges

Safety and Liability: Safeguarding AI-enabled autonomous systems is crucial. Accidents and malfunctions can have serious effects, necessitating strong safety measures and clear liability rules. Ethical Decision-Making: AI systems may encounter ethical issues in critical situations, requiring ethical frameworks to match their decision-making with societal ideals.

Data Privacy and Security: Autonomous systems process massive data volumes, raising privacy and security concerns. AI-enabled autonomous systems provide regulatory and legal challenges. Industry-specific laws may hamper autonomous technology adoption.

Bias and Fairness: To eliminate discrimination in healthcare, criminal justice, and recruiting, AI algorithms must be bias-free and decision-making fair. Transparency and Accountability: Complex AI systems are hard to understand and hold accountable. Trust in AI decision-making requires transparency. Adaptability and Generalization: AI-enabled autonomous systems must be able to adapt to varied contexts and generalize beyond training data to succeed in real-world scenarios.

Workforce Displacement: AI-enabled autonomous systems may cause employment displacement and must be addressed.

8. Conclusion

The merging of Fog Cloud Computing and the Internet of Things with AI has revolutionized robotics autonomous system development and deployment. This combination gives robots more intelligence and autonomy, improving efficiency, reliability, and flexibility in real-world applications. Our study showed that the integration provides a powerful architecture for installing AI algorithms at the network edge, allowing robots to process data closer to the source and reduce latency. Time-sensitive and safety-critical tasks require real-time decision-making and reactivity.

Autonomous robots can seamlessly connect to a variety of sensors and devices thanks to IoT integration. Robots may gather and communicate data from many sources, improving their understanding of the environment and enabling better decisions. This paper's case studies show how the integration affects manufacturing, healthcare, agriculture, and transportation. This confluence affects smart warehouses, precision agriculture, and autonomous cars.

Fog Cloud Computing, IoT, and AI revolutionize robotics by changing how autonomous systems operate and interact with the world. This discovery encourages future exploration and development in this arena, which could lead to new possibilities and applications that improve many industries and our daily lives. Researchers, engineers, and politicians must work together to innovate in AI-enabled autonomous robotics as technology advances.

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