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TOWARDS AUTONOMOUS EDGE INTELLIGENCE: INTEGRATING GENERATIVE AI, AGENTIC AI, AND EDGE COMPUTING

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Abstract

Edge computing has been recognized as an important technology for efficient data processing and decision making at the edge. Most existing edge computing solutions, however, are mainly designed for static model inference and are heavily dependent on cloud infrastructure for model updates, training, and decision making. This paper presents an integrated framework for Autonomous Edge Intelligence, which leverages the capabilities of Generative AI, Agentic AI, and Edge Computing to enable intelligent systems with capabilities such as local reasoning, data generation, and autonomous decision making. Generative AI allows edge devices to generate synthetic data, which helps in efficient data usage and preserves the privacy of the data. Agentic AI extends the capabilities of edge devices with goal-oriented decision making, which enables the devices to sense their environment, plan, and execute actions autonomously. This integrated framework, therefore, enables the development of more responsive, efficient, and scalable intelligent systems for various distributed intelligent systems, such as smart manufacturing, autonomous driving, healthcare monitoring, and drone swarms, among others.

Keywords

Edge Computing, Generative AI, Agentic AI, Autonomous Systems, Edge Intelligence, Multi Agent Systems, Distributed AI

1. Introduction

With the proliferation of Internet of Things (IoT) devices, a tremendous amount of data is being generated at the edge of the network. Cloud-based solutions are not able to meet the growing demand for low latency, privacy, and real-time processing. Edge computing solves this problem.

However, most of today's edge devices are only able to perform pre-trained models to perform static inference tasks. They are not able to create new information or autonomously adapt to changing environments without depending on

centralized cloud-based solutions.

Recent breakthroughs in Generative AI and Agentic AI provide a promising opportunity to create a new class of decentralized intelligent systems that are able to operate autonomously. Generative AI can create new information, and Agentic AI can perform goal-based decision making.

This paper proposes a novel Autonomous Edge Intelligence architecture that combines Generative AI and Agentic AI to create decentralized intelligent systems that are able to operate autonomously.

2. Literature Review

Edge computing is extensively used to solve the latency and bandwidth issues of distributed systems. Research literature proves that computation offloading from cloud to edge devices greatly improves response time and data privacy. Also, Generative AI technologies like transformers and diffusion models have shown tremendous potential in generating synthetic data like text and images. Nevertheless, its implementation is only feasible in cloud environments due to its computational needs. Agentic AI is a new framework for designing autonomous AI systems that use perception-planning action loops for decision-making and action. These systems can set goals and assess outcomes to change behavior accordingly.

New research is being conducted to integrate intelligent agents with edge computing. Nevertheless, few frameworks integrate all three technologies: Generative AI, Agentic AI, and edge computing. This is where the need for designing an autonomous edge intelligence framework arises.

3. Proposed Architecture

Generative AI models, Agentic decision systems, and hybrid edge-cloud infrastructures are combined in this proposed architecture to facilitate autonomous edge intelligence.

Key Components

1. Edge Perception Layer

- Gathers information from various sources such as sensors, cameras, and IoT devices
- Performs preprocessing and feature extraction

2. Generative Intelligence Module

- Generates artificial data
- Supplements existing information
- Generates predictions or simulations

3. Agentic Decision Engine

- Executes tasks that require planning and reasoning
- Executes tasks that are goal oriented
- Executes perception-action feedback

4. Distributed Edge Network

- Enables collaboration between edge agents

• Supports decentralized communication

5. Hybrid Edge Cloud Layer

• Executes tasks that require intensive computation

• Synchronizes models and updates **4.**

Methodology

The system is based on a three-step autonomous workflow:

Step 1: Edge Data Perception

In this step, data is collected from real-time situations using sensors. The relevant features are extracted to eliminate unnecessary data transmission.

Step 2: Local Generative Processing

In this step, generative AI models are used to generate additional data or simulate possible situations. This helps in enriching the training data and conducting predictive analysis.

Step 3: Agentic Decision and Action

In this final step, agentic AI models are used to evaluate the data obtained from the previous steps and create a decision plan using planning algorithms such as heuristic search and reinforcement learning. The actions are then executed by the device.

5. Results / Use Cases

Smart Manufacturing

Generative models can be used to simulate the failure of equipment, which can be used for predictive maintenance. Agentic AI can be used to control robotic systems to optimize the production process.

Autonomous Vehicles

Edge AI can be used to process sensor data and detect obstacles, navigate, and make decisions without the need for cloud communication.

Collaborative Drone Swarms

Multiple drones can be used as agents, which can be coordinated to carry out tasks such as search and rescue operations with local communication protocols.

Healthcare Monitoring

Generative models can be used to generate trends for patients' health, and agentic AI can be used to detect abnormalities.

6. Future Work

The future of AI is focused on several directions:

• Developing Energy-Efficient AI Hardware for Running Generative AI Models at Edge Devices

• Designing Self-Improving Edge Agents for Continuous Learning

• Developing Scalable Multi-Agent Coordination Frameworks

• Designing Neuromorphic Computing Architectures

These future directions will further improve the scalability of distributed AI systems.

7. Conclusion

This paper introduced a framework for Autonomous Edge Intelligence by integrating Generative AI, Agentic AI, and

Edge Computing. The proposed architecture for Autonomous Edge Intelligence is decentralized and can perform data generation, decision-making, and action execution locally.

The proposed framework reduces dependence on centralized cloud computing, which improves system efficiency, data privacy, and system performance. The potential applications of Autonomous Edge Intelligence are vast, ranging from manufacturing to healthcare, transportation, and robotics.

Future directions in AI hardware, decentralized learning, and multi-agent coordination will further improve the adoption of Autonomous Edge Intelligence in real-world applications.

8. References

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