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Fully Autonomous Robotic Applications Enabled by Distributed Artificial Intelligence and Fine-Tuned Large Language Models

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Abstract

Autonomous robotic systems are increasingly deployed across a wide range of domains, including manufacturing, automotive, aviation, military, healthcare, logistics, and smart cities. Traditional approaches to robotic autonomy have relied on tightly coupled perception, planning, and control pipelines using task-specific algorithms. While effective in constrained environments, these approaches often face limitations in scalability, adaptability, and high-level reasoning when applied to complex tasks, particularly in scenarios that require swarm intelligence in location-independent, dynamic, and unstructured environments.

Recent advances in Artificial Intelligence (AI), robotics, and Large Language Models (LLMs) are accelerating the transition towards fully autonomous robotic systems capable of learning continuously, coordinating, and operating in complex, dynamic, and unstructured environments. Distributed AI (DAI) and LLMs introduce new opportunities to overcome these limitations. DAI enables multiple autonomous agents to cooperate, share information, and make decisions collectively, while fine-tuned LLMs provide powerful capabilities for reasoning, planning, communication, and human-robot interaction. More specifically, fine-tuned for robotic domains deployed at the distributed edge/cloud, LLMs can i) translate high-level goals into executable action plans, ii) enable natural language interaction between humans and robots, iii) support multi-step reasoning and decision-making under uncertainty, iv) act as cognitive interfaces that integrate perception, memory, and control. Together, these technologies form a foundation for fully autonomous robotic applications that are flexible, scalable, and context-aware.

The convergence of DAI and LLMs is expected to play a central role in shaping the next generation of autonomous robotic systems. In this direction, this talk explores how DAI, combined with fine-tuned LLMs, can enable scalable, robust, and adaptive autonomous robotic applications. System architectures, learning and decision-making paradigms, communication and coordination mechanisms, and representative application domains are discussed. Future research directions, along with key challenges, including safety, reliability and ethics, are also outlined, highlighting the transformative potential of integrating DAI and LLMs in next-generation autonomous robotics.

Index Terms— Autonomous Systems, Autonomous Robotics, Artificial Intelligence (AI), Large Language Models (LLMs), Distributed Artificial Intelligence, Multi-Agent Systems, Human–Robot Interaction

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