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INTRODUCTION

# Introduction to the Special Issue on Artificial Intelligence for Adaptive and Autonomous Cloud/Edge Computing Systems

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## 1 Introduction

Modern computing systems operate in increasingly heterogeneous environments that range from large-scale data centers in the Cloud to resource-constrained devices at the Edge, often jointly exploited to tradeoff latency, energy consumption, cost, reliability, and privacy. Moreover, computing applications and services rely on increasingly complex software and hardware stacks, including multiple virtualization layers. The resulting complexity is hardly manageable by humans alone, especially at runtime, and requires computing systems to autonomously take timely decisions in the face of varying working conditions, in order to guarantee Quality-of-Service requirements.

Advancements in **Artificial Intelligence (AI) and Machine Learning (ML)** have significantly impacted and fostered the development of adaptive and autonomous computing systems, providing powerful tools to cope with system complexity and uncertainty, assisting or replacing traditional methodologies. The integration of these methodologies into existing Cloud/Edge computing systems also poses several challenges, related to the accountability, accuracy, explainability, safety, scalability, and sustainability of AI-driven autonomic systems. This Special Issue explores these challenges alongside the opportunities of AI/ML integration in the design and implementation of autonomous and adaptive Cloud/Edge systems across multiple domains, from serverless computing systems to smart eye-wears.

## 2 Papers in This Special Issue

Following a rigorous review based on relevance, originality, technical novelty, and presentation quality, we selected 4 manuscripts from 20 submissions. A unifying theme emerging from this issue is the use of adaptive and learning-based techniques to optimize workload placement and execution across distributed computing resources.

Two papers focus explicitly on task offloading in edge environments, leveraging reinforcement learning to cope with uncertainty and dynamics. Gebrekidan et al. [1] propose a coordinated multiagent deep reinforcement learning architecture, where client agents estimate task requirements and a master agent orchestrates offloading decisions at the edge. By explicitly modeling server heterogeneity and coordination, the approach improves latency and energy efficiency over traditional heuristics.

Complementarily, Wamuhindo Kambale et al. [2] explore lightweight, tabular reinforcement learning strategies for offloading AI workloads in wearable systems. The evaluated methods

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effectively reduce response time and energy consumption, highlighting that learning-based adaptivity is feasible even on severely resource-constrained devices.

A second, closely related theme concerns adaptive scheduling and resource management for AI-driven workloads at the edge. Yuan et al. [4] address the growing computational demands of multimodal large language models deployed outside centralized data centers. By decomposing inference pipelines and dynamically assigning model components to heterogeneous edge devices, the proposed scheduling framework balances latency constraints and energy efficiency.

Finally, the Special Issue also addresses the system-level challenges that arise when such adaptive mechanisms are deployed in highly dynamic execution environments, particularly serverless platforms. Specifically, Wang et al. [3] focus on performance anomaly diagnosis and root-cause analysis in serverless function compositions, where ephemeral execution and complex invocation graphs complicate observability. This paper leverages multiple ML techniques for anomaly detection and also addresses issues related to fine-grained tracing.

Taken together, the papers in this Special Issue advance a common vision of intelligent Cloud–Edge systems that are autonomous, adaptive, and resilient by design, demonstrating the fundamental role of data-driven approaches in the management of complex distributed environments.

## Acknowledgments

This collection showcases the breadth of current research at the intersection of distributed systems, AI, and autonomous systems. Bridging the gap between theory and experimental implementation, these works demonstrate the evolving nature of the field. We hope that these papers will stimulate new ideas and remain a valuable reference for researchers and scholars for years to come.

The completion of this issue would not have been possible without the contributions of many individuals. We extend our sincere gratitude to all the authors who submitted their high-quality work for consideration. We also offer our deepest thanks to the reviewers. Their meticulous evaluations and commitment to excellence were indispensable in ensuring the high caliber of this special issue. Finally, we thank the Editor-in-Chief Dr. Rami Bahsoon and the editorial team of the *ACM Transactions on Autonomous and Adaptive Systems* for their guidance and support throughout this process.

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