Thesis Project Proposal: Multi-Agent Reinforcement Learning for Cloud Resource Allocation

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July 2, 2025

This document outlines the thesis project proposal on Multi-Agent Reinforcement Learning (MARL) for Cloud Resource Allocation, detailing its alignment with the MSc in Artificial Intelligence and Machine Learning, scope, dataset, outcomes, activities, beneficiaries, novelty, and timeline targeting completion by mid-August 2025.

Alignment with MSc in Artificial Intelligence and Machine Learning

This project aligns with the MSc in Artificial Intelligence and Machine Learning by applying advanced MARL techniques, such as Q-learning and Multi-Agent Deep Deterministic Policy Gradient (MADDPG), to optimize cloud resource allocation. It leverages core curriculum topics like reinforcement learning and multi-agent systems to address a real-world challenge, showcasing technical proficiency and research innovation suitable for a master's thesis.

Project Overview

The project develops AI agents to manage cloud computing resources efficiently, akin to smart traffic lights optimizing city traffic. Each agent, trained using algorithms like Proximal Policy Optimization (PPO) and MADDPG, allocates server resources, learns from dynamic workloads, and balances cooperation (system-wide efficiency) with competition (individual performance), outperforming static industry methods.

Dataset Requirements

The project uses a simulated cloud environment generating:

- Workload traces mimicking real-world cloud usage (e.g., Google Cluster Data).
- System metrics like server utilization and latency.

- Agent decision logs for training and evaluation.

Built with Python (Gym, Stable-Baselines3), the simulation ensures realistic, scalable testing.

Expected Outcomes

The project will deliver:

- Novel MARL algorithms, extending Q-learning and MADDPG for cooperative-competitive resource allocation.
- Improved efficiency (reduced energy waste, enhanced throughput) compared to industry baselines.
- Scalable framework for large-scale cloud systems.
- Publishable results for AI conferences (e.g., NeurIPS).
- Practical solutions for cloud providers.

Project Activities

The project involves:

- Building a cloud simulation environment.
- Developing MARL agents using PyTorch/TensorFlow with PPO and MADDPG.
- Integrating cooperative-competitive algorithms.
- Evaluating performance against baselines.
- Documenting findings for thesis and publication.

Beneficiaries

The project benefits:

- **Cloud Providers**: Reduced costs and improved service quality.
- **Researchers**: New MARL insights from hybrid algorithms.
- **Users**: Faster, reliable cloud services.
- **Society**: Energy-efficient computing for sustainability.

Novelty and Innovation

The project introduces a novel hybrid MARL framework combining cooperation and competition, extending algorithms like Q-learning and MADDPG. Unlike single-focus approaches, it offers real-time adaptability and scalability to large systems, addressing research gaps and providing innovative, industry-relevant solutions for resource efficiency.

Timeline

The project is structured over 7 weeks to meet the mid-August 2025 deadline (July 1 to August 15, 2025):

- **Week 1 (Jul 1-7)**: Set up simulation environment and implement baseline methods.
- **Week 2 (Jul 8-14)**: Develop single-agent MARL models using PPO.
- **Week 3 (Jul 15-21)**: Benchmark single-agent models and refine algorithms.
- **Week 4 (Jul 22-28)**: Implement multi-agent framework with MADDPG.
- **Week 5 (Jul 29-Aug 4)**: Integrate cooperative-competitive dynamics and optimize algorithms.
- **Week 6 (Aug 5-11)**: Evaluate performance against baselines and analyze results.
- **Week 7 (Aug 12-15)**: Finalize thesis and prepare for submission.

Conclusion

This project aligns with MSc objectives, delivering academic and practical impact through innovative MARL solutions. Feedback to refine its scope is welcome.