Adaptive Multi-Agent Systems for Disaster Response

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Abstract

This thesis proposes an adaptive multi-agent system designed to enhance coordination and decision-making in post-disaster response operations. Current approaches to disaster management often rely on centralized control systems that struggle to adapt to dynamic and unpredictable environments. The proposed system leverages agent-based modeling, reinforcement learning, and decentralized communication protocols to enable autonomous coordination among agents representing rescue teams, drones, and resource hubs. The expected outcome is a scalable, resilient platform that supports faster response times and better allocation of critical resources.

Thesis Overview

The research focuses on improving disaster response efficiency by enabling adaptive, intelligent coordination between heterogeneous agents. Traditional systems lack flexibility and fail under communication breakdowns or sudden task changes. The proposed framework introduces adaptive learning capabilities that allow agents to update their behavior in real-time. This work addresses the knowledge gap in integrating AI-driven adaptability into multi-agent coordination systems.

Background

Multi-agent systems (MAS) have been used in various domains, including logistics, robotics, and simulation. However, their use in large-scale disaster response remains limited. Machine learning, especially reinforcement learning, offers the potential to improve decision-making and adaptability, yet its integration in MAS for dynamic, high-risk environments is underexplored. This research builds on agent cooperation theories and distributed AI principles.

Related Work

Prior studies in emergency response simulation (e.g., RoboCup Rescue, CrisisSim) provide partial solutions but often rely on static rule-based systems. Recent work in adaptive swarm robotics (Nguyen et al., 2023) shows promise for decentralized adaptation, though scalability remains a challenge. My work extends these efforts by combining adaptive communication and distributed learning to enable cooperative behavior under partial observability.

Contributions

This thesis aims to:

1. Develop a simulation-based adaptive MAS framework for disaster response.
2. Implement decentralized learning protocols for coordination.
3. Evaluate the system's resilience and performance under various disaster scenarios.

Thesis Question / Hypothesis

Hypothesis: Introducing adaptive reinforcement-based coordination among agents will improve overall task efficiency and reduce mission completion time in dynamic disaster environments.

Research Goal and Methodology

The main goal is to build a decentralized MAS prototype integrating learning-based adaptation. The methodology involves designing agent architectures, implementing learning mechanisms using RL algorithms (e.g., Q-learning, PPO), and evaluating them in simulated disaster environments using the GAMA or Unity ML-Agents framework.

Evaluation and Validation Criteria

Validation will rely on comparative benchmarks with rule-based systems. Metrics include task success rate, coordination latency, and adaptability to new conditions. Statistical significance will be tested using ANOVA and t-tests.

Expected Outcomes and Significance

The expected result is an intelligent multi-agent platform that adapts autonomously to dynamic disaster scenarios. This work contributes to research on distributed AI and offers potential real-world impact for emergency planning and resilience systems.