Development of a Modular Multi-Agent System Architecture for Enhanced Flexibility and Scalability

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Duration: April 2025 – November 2025
Programme: Master's Thesis, Chair for Dynamics, Control, Machine Learning and Numerics (FAU)

Abstract

Large Language Models (LLMs) are increasingly used in autonomous systems but face challenges in long-term reasoning, coordination, and scalability. This thesis introduces a hybrid, modular Multi-Agent System (MAS) architecture designed to overcome these challenges by combining LLM-driven planning with deterministic orchestration and real-time observability.

The proposed system integrates a **PlannerAgent** responsible for goal decomposition and workflow generation, alongside persistent **WorkerAgents** executing specialized tasks. A Redis-based communication layer enables dynamic coordination and plug-and-play scalability. The architecture supports self-evaluation, adaptive replanning, and transparent monitoring through integrated feedback loops and a Streamlit-based dashboard. This combination achieves a balance between autonomy, determinism, and explainability, paving the way for more reliable agentic systems.

Key Findings

- 96.7% planning accuracy and 38% latency reduction (parallel vs. sequential execution)
- 95% agent reuse efficiency via persistent service architecture
- 93% recovery success under failure simulation
- Fully modular, runtime-extensible design for agents and tools

Future Work

The next phase will explore:

- Distributed backends (Kafka, ROS 2, gRPC)
- Asynchronous, event-driven execution
- Collaborative memory and knowledge graph integration
- Human-in-the-loop interfaces for real-time supervision

People Involved

- Greshma Shaji – Master's Student, Data Science, FAU
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Keywords

Multi-Agent Systems · Large Language Models · Hybrid Planning · AI Orchestration · Distributed Intelligence · Transparency

Publication

Part of this research has been extended and integrated into a joint publication submitted to the *HCI International 2026* conference (Montreal, Canada), titled *"A Framework for Transparent Multi-Agent Orchestration in Enterprise Workflows: Design and Evaluation of Visibility Mechanisms for Human-Centered AI Systems."* The paper, co-authored with researchers from **Fraunhofer ISI**, explores the application of the proposed modular MAS architecture in enterprise-scale workflows, emphasizing transparency, explainability, and human-centered orchestration.