

# Role Analysis, Design, and Implementation of Large Language Model (LLM)-Enhanced Multi-Agent Systems (MAS)

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## TÜBİTAK

### Abstract

This project aims to systematically address the analysis, design, and implementation of the role concept in Large Language Model (LLM)-enhanced Multi-Agent Systems (MAS) through a structured engineering approach. The concept of “role,” which is traditionally treated as an analysis/design-time abstraction in Agent-Oriented Software Engineering (AOSE) methodologies, will be transformed into a first-class runtime entity by integrating it with the dynamic and contextual capabilities of LLMs. Within this scope, the methodological limitations of existing LLM-based MAS tools and frameworks will be examined, and the gap between the formal, modular, and reusable structures of AOSE and the flexible reasoning and natural language interaction capabilities of LLM-based systems will be identified and bridged. The project’s contribution lies in proposing a role-based hybrid MAS architecture that integrates roles with local code, web services, LLM actions, tool-based LLM utilization, and Model Context Protocol (MCP)-based integrations, as well as in developing a Java-based software development framework and structured prompt templates to support this architecture. The project activities include role definition and classification, hybrid architecture design, the development of dynamic prompt generation mechanisms, the implementation of a software framework based on the hybrid architecture, and evaluation through use cases in different domains. At the end of the project, it is expected to deliver a role model for LLM-enabled MAS engineering, an applicable hybrid architecture, a reusable software framework, and validated use case specifications as its main outcomes.

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