# Collective Problem Solving with Multi-Agent Systems Training

Duration: **5 Day**

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## Overview

**Collective Problem Solving with Multi-Agent Systems Training** is an advanced program exploring how multiple autonomous artificial intelligence agents can interact within a shared environment to address complex problems.

In **Multi-Agent Systems (MAS)**, agents with different roles and capabilities can communicate, exchange information, negotiate, and cooperate to achieve shared objectives. Depending on the environment, they may also compete to pursue individual goals.

The course begins with the fundamental characteristics of **Intelligent Agents** and progresses through **BDI (Belief–Desire–Intention)** architectures, **Game Theory**, **Distributed Problem Solving**, and mechanisms governing interactions between agents.

Participants examine communication protocols such as **FIPA-ACL** and **KQML**, alongside coordination approaches including **Auctions**, **Contract Net**, **Stigmergy**, **Negotiation**, and **Coalition Formation**.

The program also introduces **Multi-Agent Reinforcement Learning (MARL)** algorithms such as **Independent Q-Learning, CTDE, QMIX, and MADDPG**, simulations using **PettingZoo**, and **LLM-powered generative agent systems** developed with frameworks such as **AutoGen** and **LangChain**.

The training aims to equip participants with the knowledge needed to design adaptive and resilient distributed AI solutions for applications including **supply chain optimization**, **logistics networks**, **financial market simulations**, and **robotic systems**.

## Prerequisites

There are **no mandatory prerequisites** for attending this training.

## Who Should Attend

- **Robotics Engineers** working on **Swarm Robotics** and multi-robot coordination
- **Simulation Specialists** modeling economic markets, social systems, and supply chains
- **Quantitative Analysts**
- **Blockchain and Systems Architects** developing solutions for **DAO** and **Web3** ecosystems
- **Game AI Developers** creating dynamic virtual environments
- **Senior AI Engineers** developing complex and distributed artificial intelligence systems
- **AI Researchers**

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## What You Will Learn

Upon completing this training, you will be able to:

- Explain the characteristics of **Intelligent Agents** and identify different agent classes.
- Model agent behavior using **BDI architectures** and **Game Theory**.
- Understand and apply communication protocols such as **FIPA-ACL** and **KQML**.
- Evaluate coordination mechanisms including **Auctions**, **Contract Net**, and **Stigmergy**.
- Develop **Negotiation** and **Coalition Formation** strategies.
- Apply **MARL algorithms** such as **Independent Q-Learning, CTDE, QMIX, and MADDPG**.
- Conduct multi-agent simulations using **PettingZoo**.
- Design **LLM-powered generative agent systems** with **AutoGen** and **LangChain**.
- Develop an end-to-end project based on a **decentralized logistics network** scenario.
- Evaluate the **ethical, security, and research** considerations associated with **Multi-Agent Systems**.

## Outline

### 1. Philosophy and Theoretical Foundations of Multi-Agent Systems

#### Agent Concepts and Fundamental Characteristics

- Understanding **Intelligent Agents**
- Fundamental agent characteristics:
  - **Autonomy**
  - **Reactivity**
  - **Proactivity**
  - **Social Ability**
- Evolution from **Simple Reflex Agents** to reasoning-based **Deliberative Agents**
- Classification of agents
- Exploring different **Environment** types

#### Agent Theory and Cognitive Architectures

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- Fundamental concepts of **Agent Theory**
- **BDI (Belief–Desire–Intention)** architecture
- Modeling agent behavior through beliefs, goals, and intentions

**Game Theory**

- Analyzing strategic interactions between agents using **Game Theory**
- **Normal Form Games**
- **Extensive Form Games**
- **Nash Equilibrium**
- **Prisoner's Dilemma**
- Evaluating cooperation and competition between agents

**Distributed Problem Solving**

- Understanding **Distributed Problem Solving**
- Breaking complex tasks into smaller subtasks
- Combining results produced by different agents
- Collective problem-solving processes

## 2. Agent Architectures and Communication Protocols

This section explores agent architectures and the communication approaches that enable information exchange between autonomous agents.

- Examining **Agent Architectures**
- Architectural considerations for **BDI** and other agent behavior models
- Inter-agent communication
- **FIPA-ACL (Foundation for Intelligent Physical Agents – Agent Communication Language)**
- **KQML (Knowledge Query and Manipulation Language)**
- Messaging and information sharing in multi-agent environments

## 3. Coordination, Negotiation, and Organizational Mechanisms

- **Coordination** between autonomous agents
- **Auction-based** task and resource allocation

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- **Contract Net** mechanisms
- Indirect coordination through **Stigmergy**
- **Negotiation** strategies
- **Coalition Formation**
- Cooperative and competitive organizational structures

## 4. Multi-Agent Reinforcement Learning (MARL)

This section focuses on **Multi-Agent Reinforcement Learning (MARL)** methods that enable multiple agents to learn within cooperative or competitive environments.

- Introduction to **Multi-Agent Reinforcement Learning**
- **Independent Q-Learning**
- **CTDE (Centralized Training, Decentralized Execution)**
- **QMIX**
- **MADDPG (Multi-Agent Deep Deterministic Policy Gradient)**
- The impact of agent interactions on learning processes
- Hands-on multi-agent simulations using **PettingZoo**

## 5. LLM-Based Agent Simulations and Generative Agents

- Agent systems powered by **Large Language Models (LLMs)**
- **Generative Agents**
- Developing multi-agent structures with **AutoGen**
- Agent-based applications using **LangChain**
- Cooperation and task execution in LLM-based agent systems
- Evaluating multi-agent simulations

## 6. Practical Project and System Evaluation

Practical and evaluation topics identified in the source learning outcomes:

- **Decentralized logistics network simulation**
- Collaborative task execution involving multiple agents
- Developing an **end-to-end multi-agent project**
- **Ethical** and **security** considerations in agent systems

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- Future research directions in multi-agent systems