# Multi-Agent Oriented Programming

Introduction

# Motivation



- *Complex system* are systems composed of **many components** which may **interact with each other** and present **non-trivial relationships** between cause and effect
  - each effect > multiple causes
  - each cause > multiple effects
  - feedback loops
  - non-linear cause-effect chains

- **Complex cyber-physical social systems**
  - Smart cities
  - Smart grids
  - Manufacturing
  - Mobility systems

# Motivation – Requirements



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Explainability

# Multi-Agent System

A Multi-Agent System (MAS) is a **loosely coupled** network of problem solvers that **interact** to solve problems that are **beyond the individual capabilities** or **knowledge** of each problem solver

Durfee & Lesser, 1989

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   *pre-defined/emergent, static/adaptive, open/closed, …*

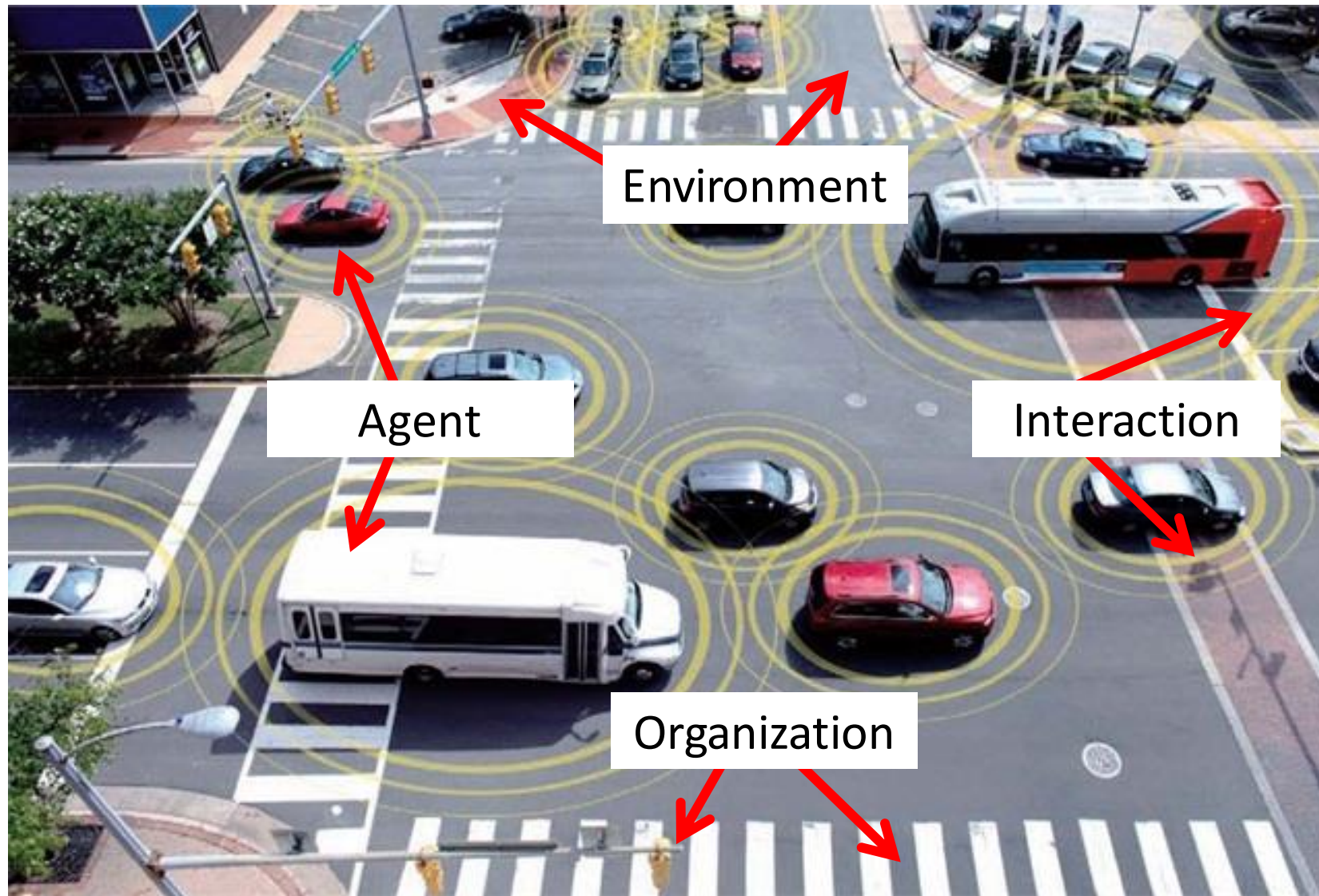   e.g., coordination and regulation activities

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<span style="color:red">A Multi-Agent System **is more than** a simple set of agents</span>

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**Multi-Agent-Based Simulation** models used to describe and simulate complex systems, either natural or artificial, to analyze their properties

- Local representations of different points of view, decisions, goals, motivations, behaviors, etc.
- Interaction between local strategies, behaviors and global and common strategies of control
- Continuous operation and evolution
- Solution is the result of interaction between local processes

**Multi-Agent-Based System Engineering** models used to design and develop systems and applications

- Multi-* (sites, expertise, domains, points of view, decisions, goals, motivations, ...)
- Incremental and collaborative development
- Continuous execution and adaptation
- Increasingly user-centric

# Multi-Agent-Based System Engineering

Separation of concerns between Autonomous and Non-autonomous entities, Modularity, Reusability

Use the right Abstraction from design to programming

Cognitive, Situated, Interactive, Social Systems

Self-* capabilities

# Multi-Agent Oriented Programming (MAOP)

- Provide first-class abstractions to model and implement Agents, Environments, Interactions and Organizations

- MAOP aims at engineering systems
  - as organization of autonomous agents that interact with each other within a shared environment,
  - by keeping alive, from design to execution, concepts pertaining to each of the Agent / Environment / Interaction / Organization dimensions as well as their control/life cycles

NOTE: Inspired by the VOWELS' perspective (Demazeau, 1995)

Go beyond the AOP (Shoham, 1993), EOP (Ricci et al., 2010), IOP (Huhns, 2001), OOP (Pynadath et al., 1999) approaches

# Multi-Agent Oriented Programming (MAOP)
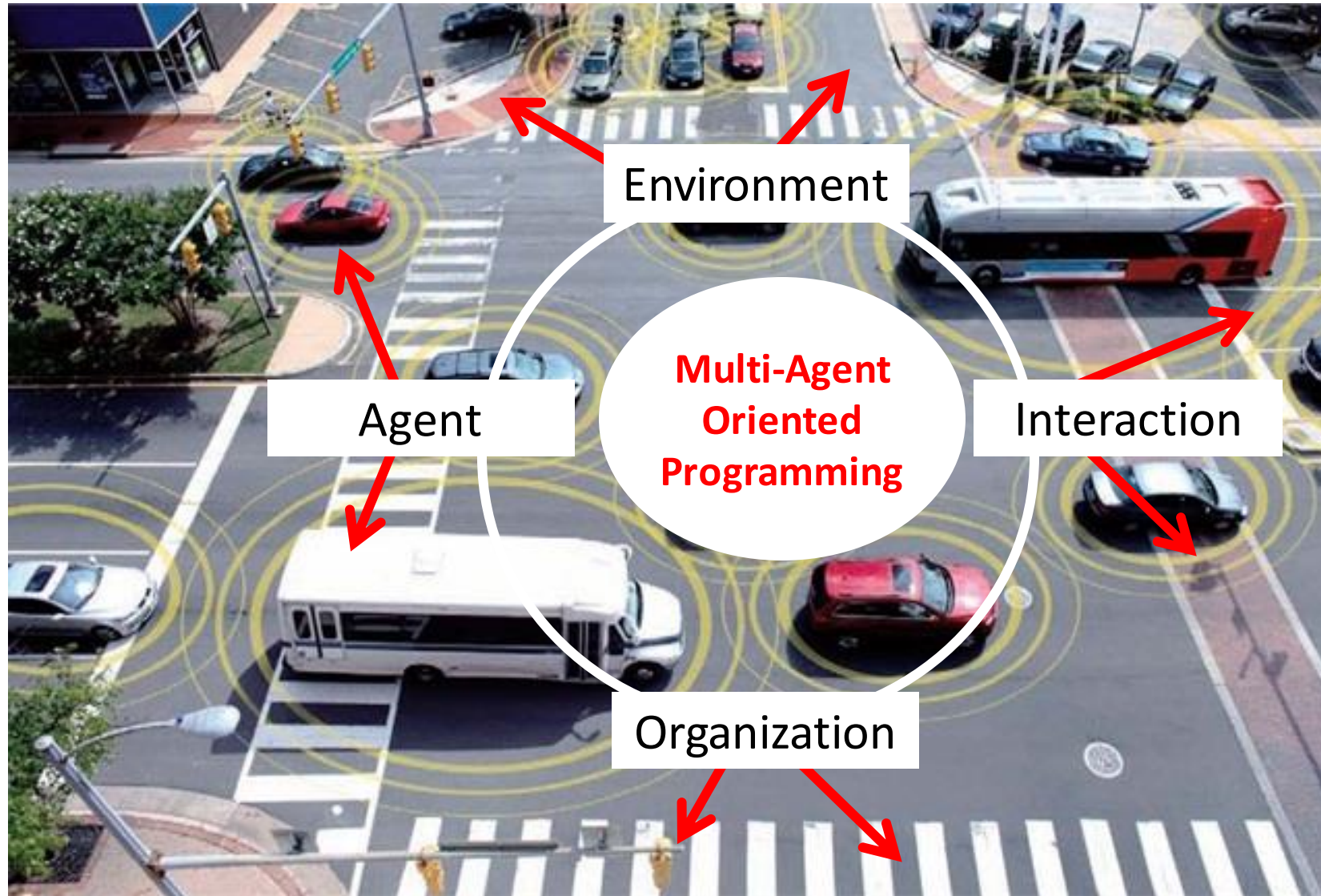
# Example: Flexible Industrial Manufacturing

**Domain problem** ("lot-size-one manufacturing"): **unique** products at **mass production costs**

- customization is **expensive**: production lines are **optimized**, **inflexible**, and have **large lifespans** (> 30yr)
    - o   we need production lines that can be **repurposed on-the-fly**
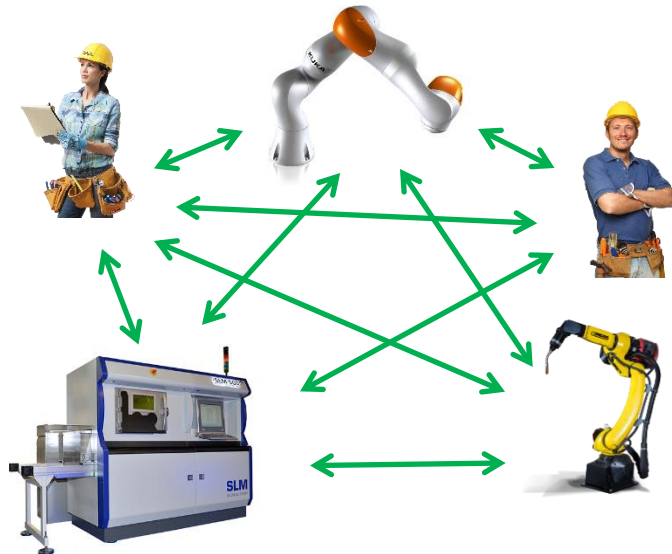


Factory workers and artificial agents working
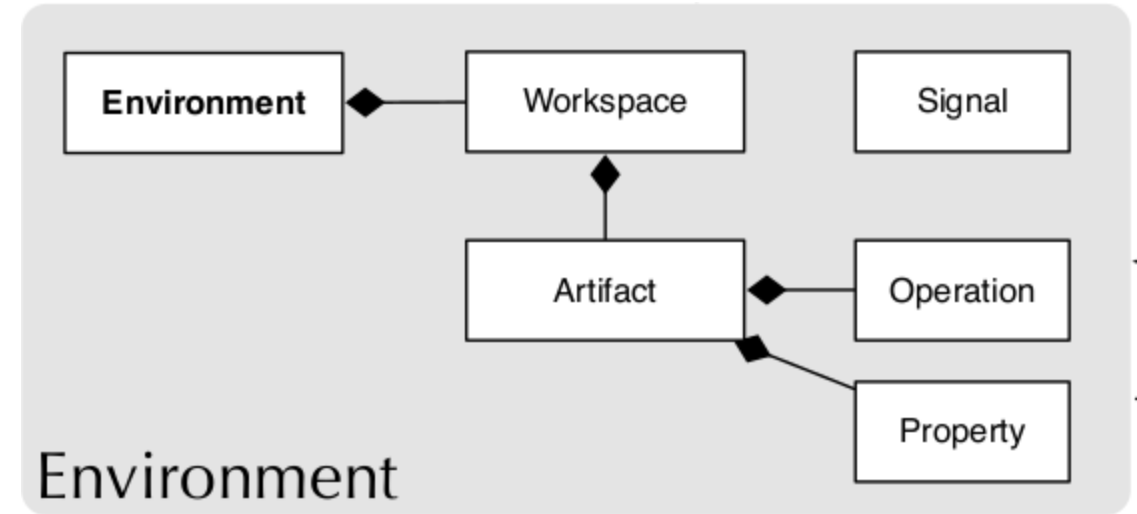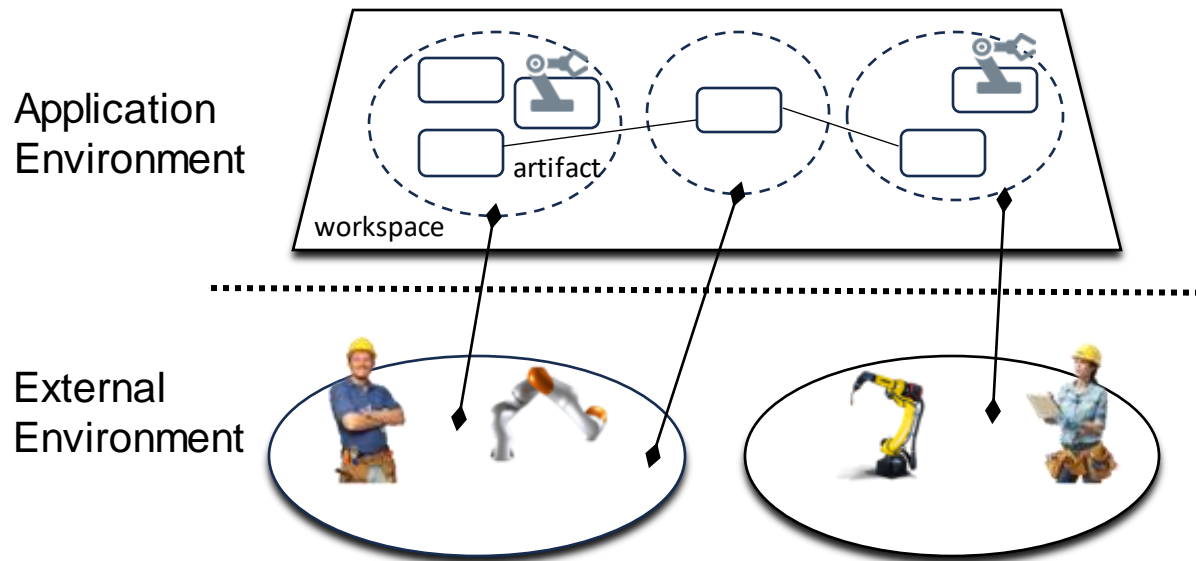towards shared goals
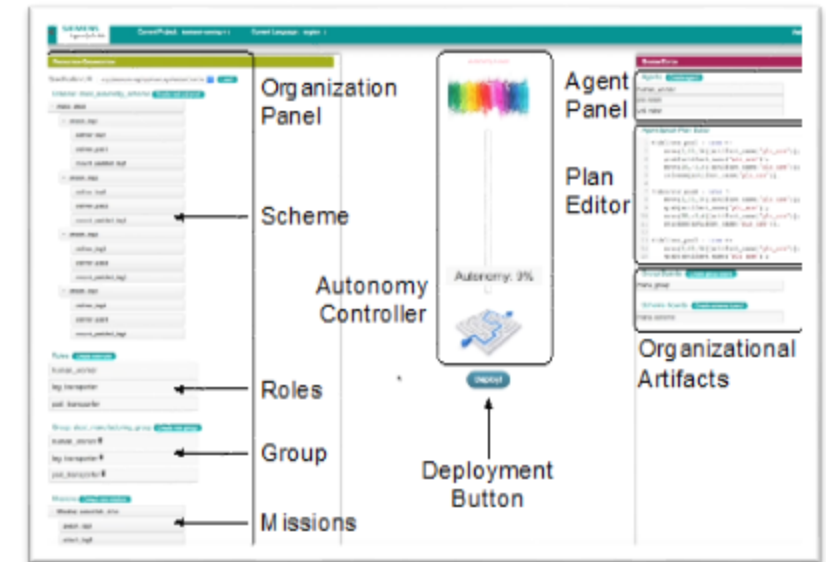
End-user programming for production engineers

(Ciortea et al., 2018)

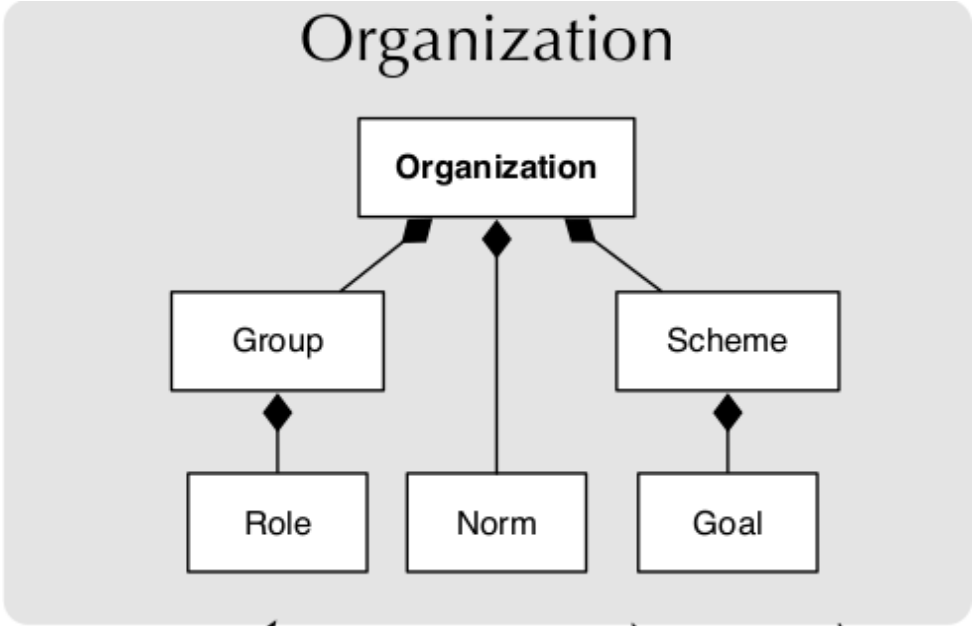# Flexible Industrial Manufacturing

External
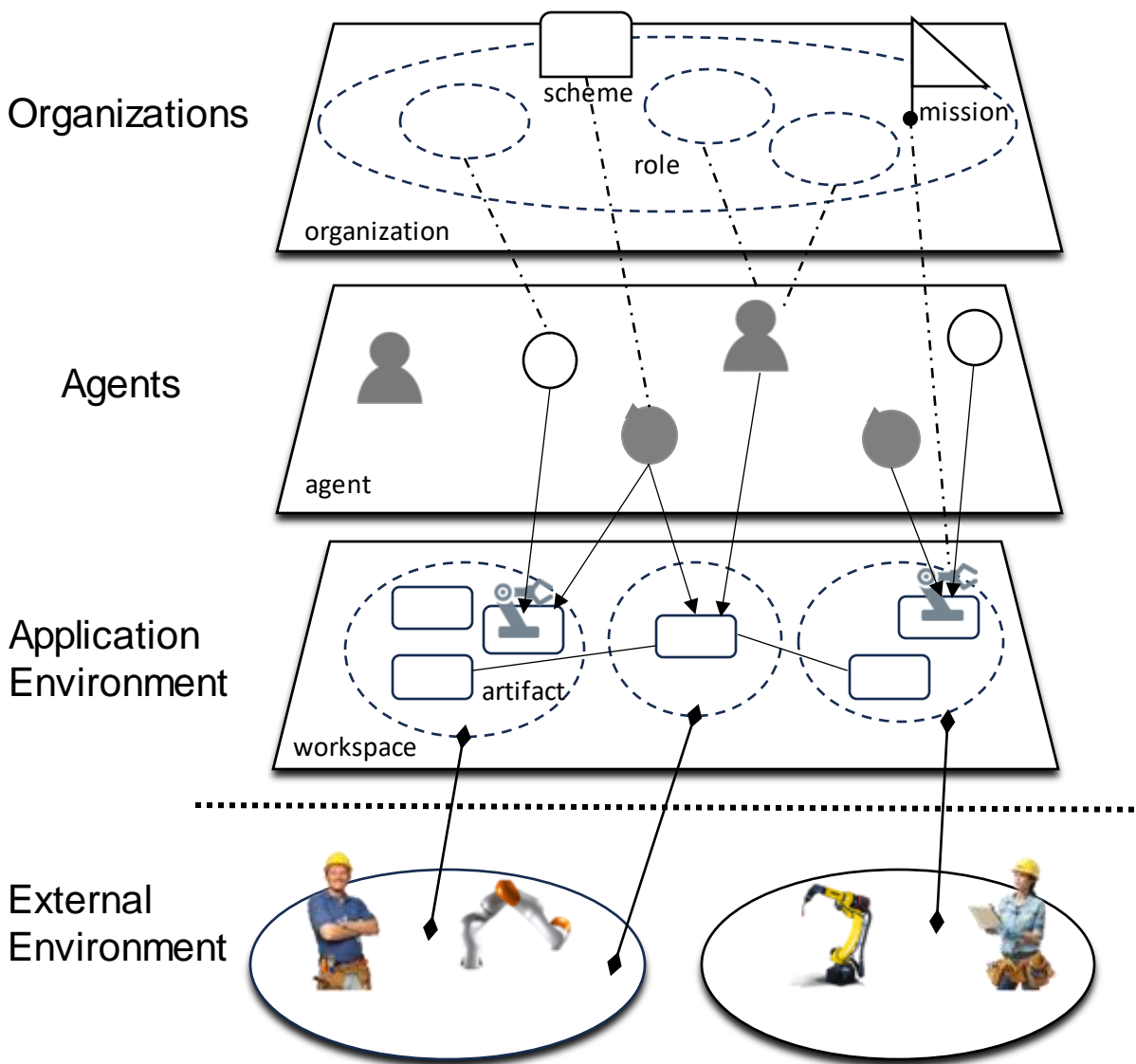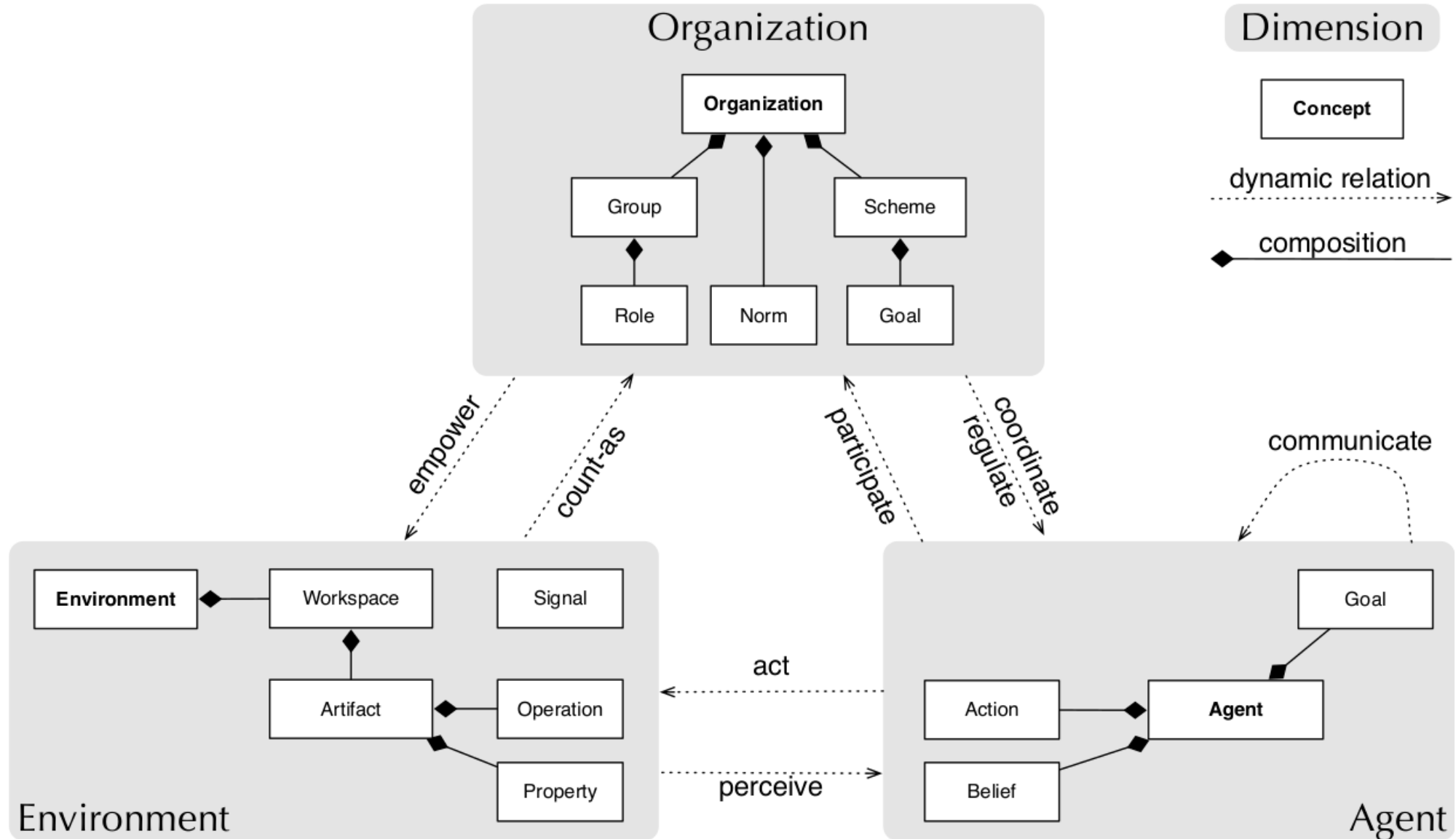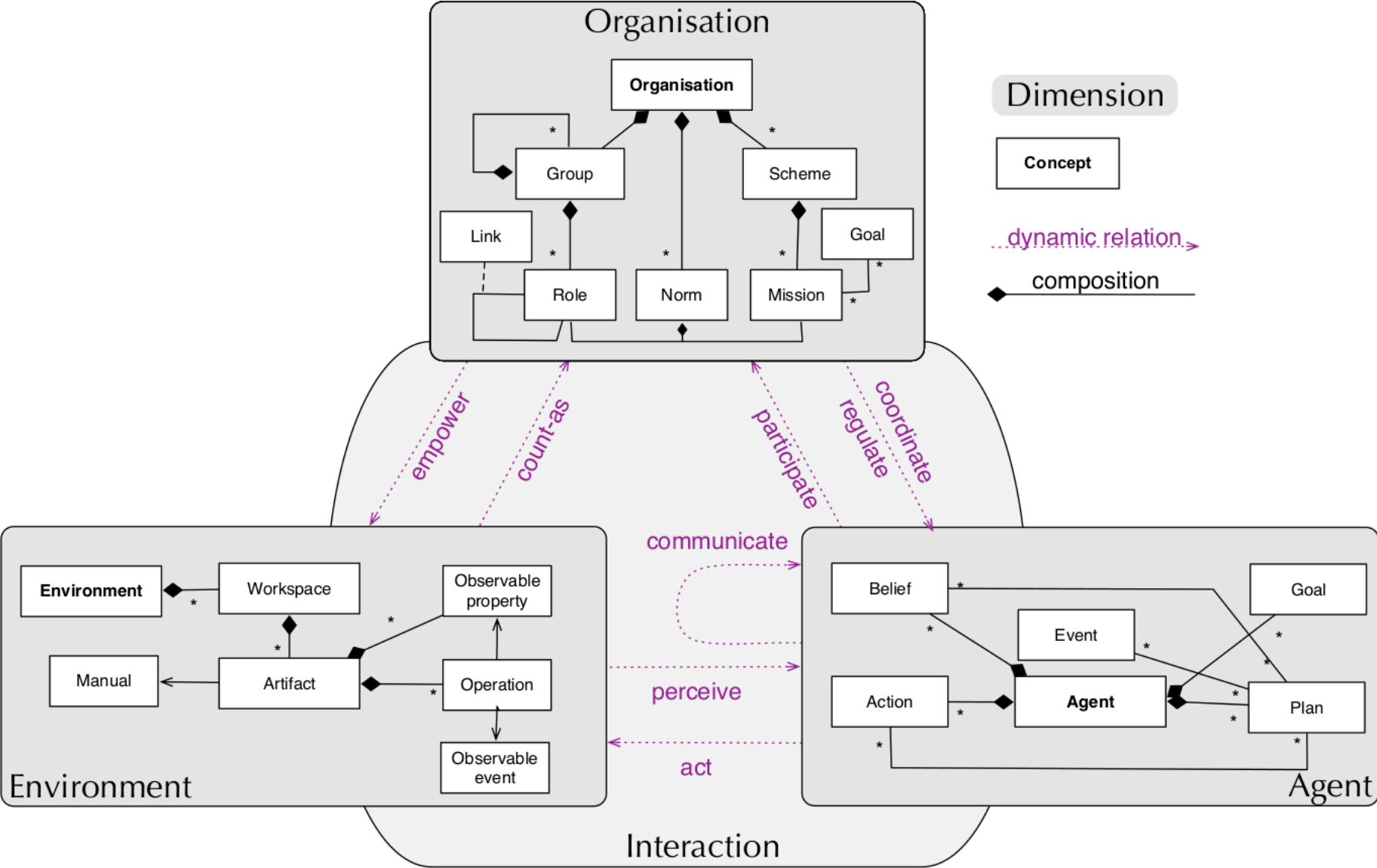Environment

# Environment Dimension

# Agent Dimension
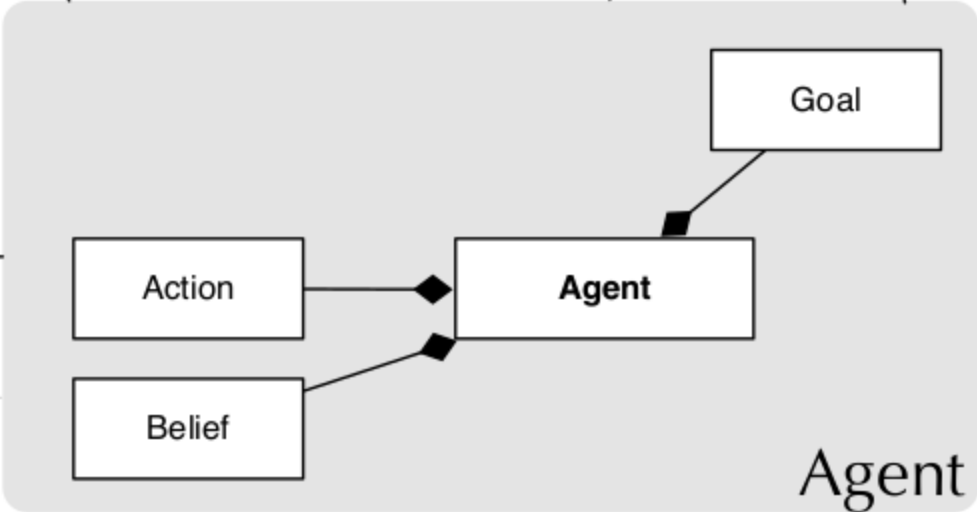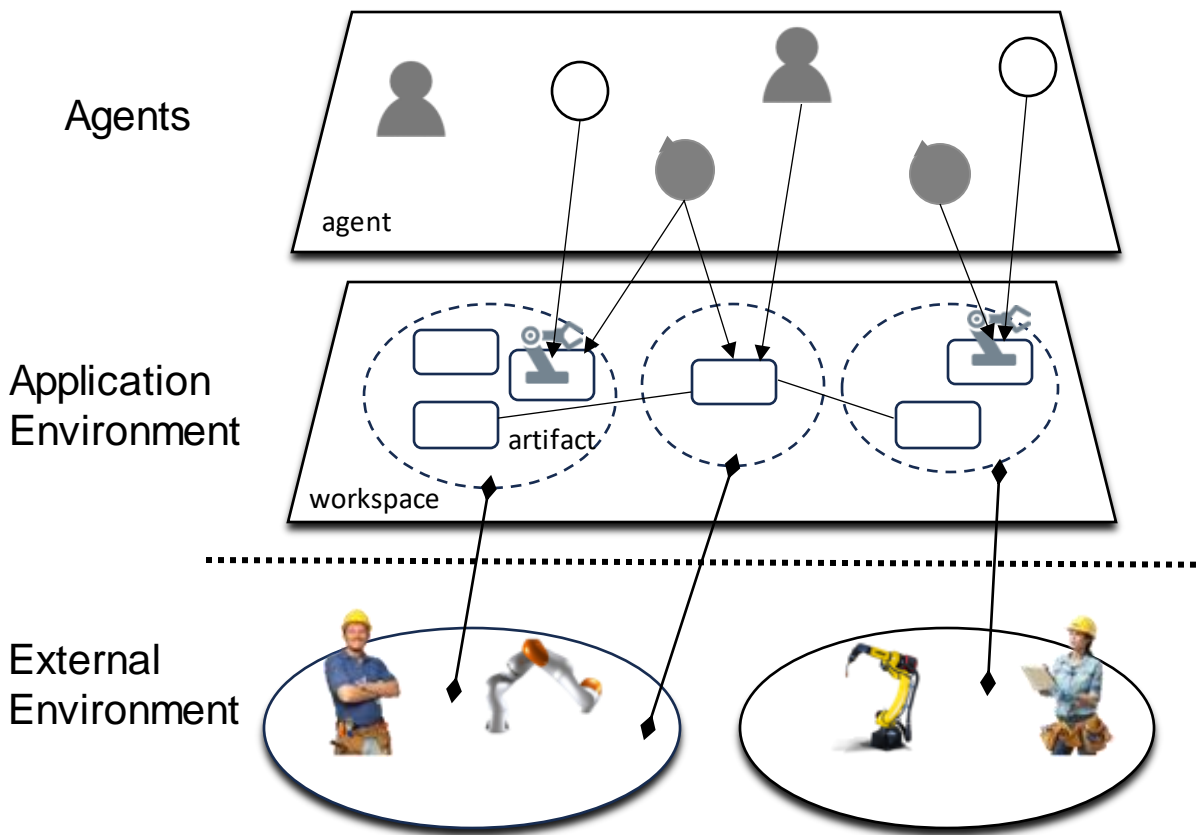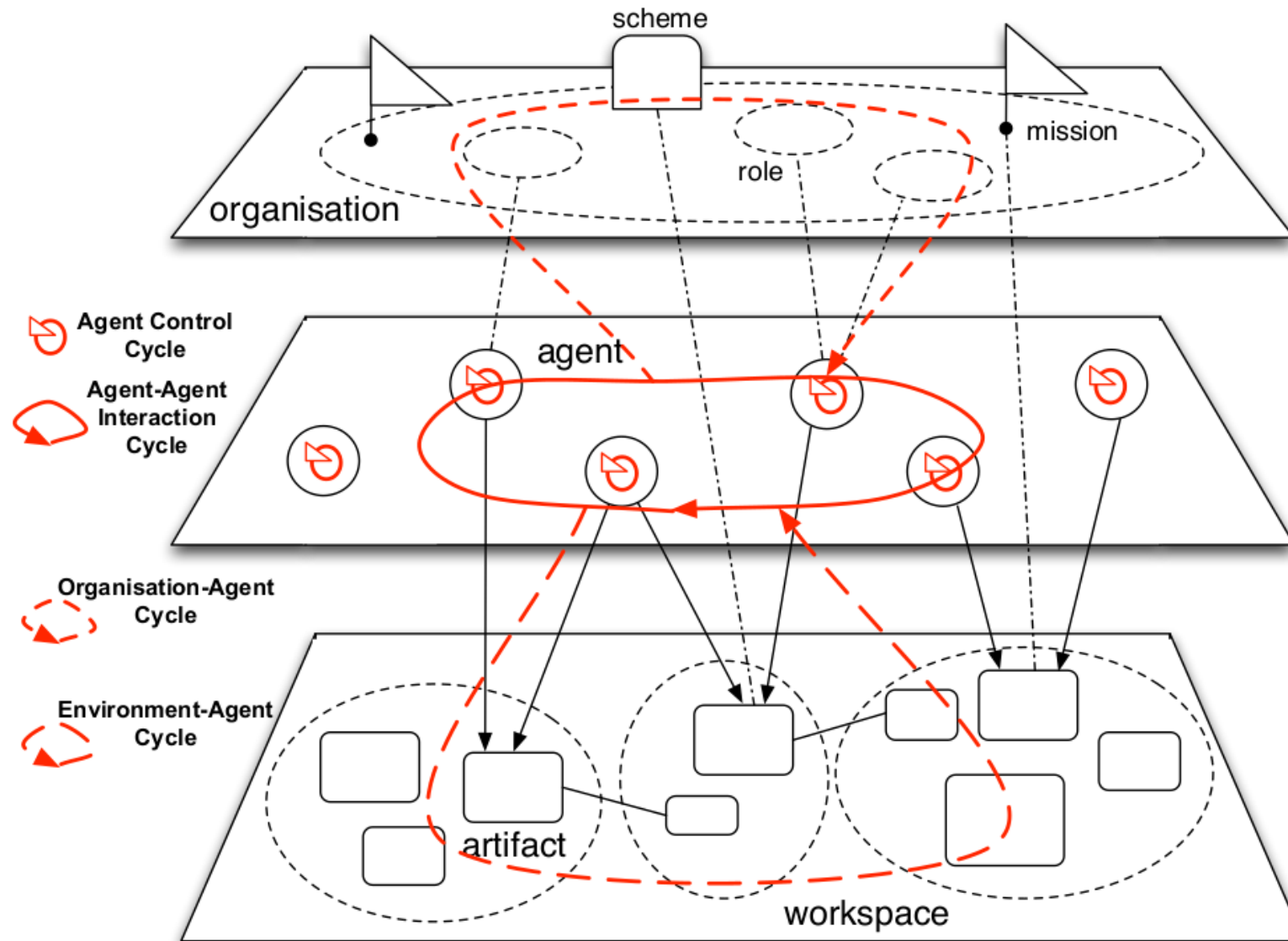
# Organization Dimension

# Interaction Dimension

# JaCaMo Metamodel – Multi-Agent Concepts

# JaCaMo Metamodel – Multi-Agent Dynamics

# Applications

- Governance of Room Allocation in a Smart Co-working Space

- Governance of a Machine-To-Machine Management Infrastructure

- Governance of Online Forum

- Tackling Online Disinformation

- Coordination of Rover on Mars

- Coordination of Fleet of Autonomous Vehicles

# Smart Room Scenario

*Develop one room controller agent to manage a "Heating, Ventilating and Air Conditioning" (HVAC) device to reach a desired temperature based on agents' preferences acting on behalf of users*

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Separation of concerns

- Integration and interoperability with the HVAC
  - **environment** modeling

- Strategy to keep the right temperature
  - **agent** modeling

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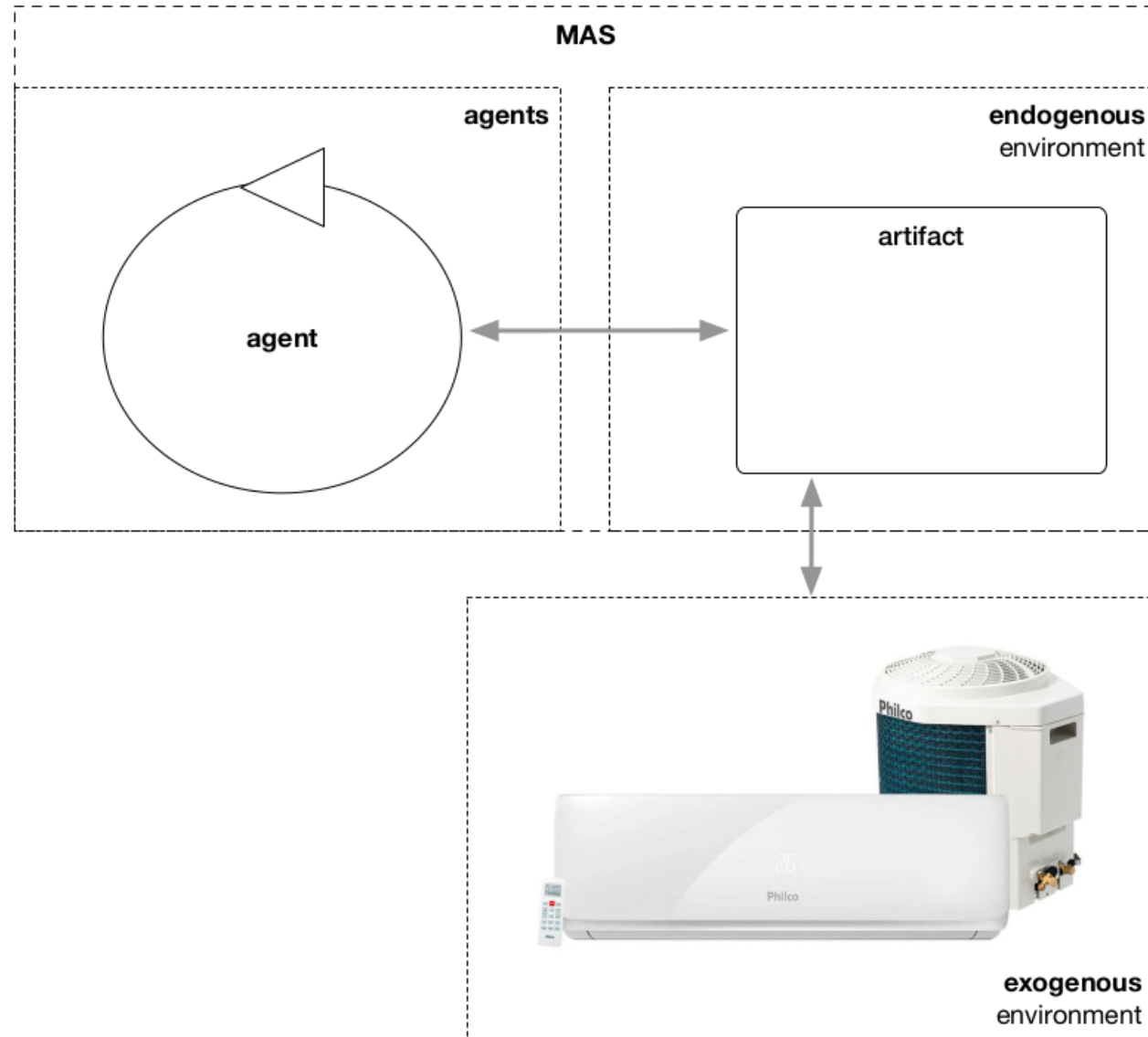
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