Multi-agent systems applied in manufacturing

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INTRODUCTION

- An approach in the intelligent factory direction could consist in interconnecting two major research fields:
  - Computer integrated manufacturing (CIM)
  - Multi-agent systems (MAS)

- A multi-agent system implementation involves two different intelligent behavior sources:
  - The agent internal reasoning mechanism
  - Interaction between the designed agents

INTRODUCTION

- **Using industrial robots in CIM environments leads to flexible manufacturing systems**
- **Flexibility creates the context for task splitting and sharing:**
  - **Machine flexibility – easier adaptation to new product types**
  - **Routing flexibility – the possibility of using different machines for the same operation**

INTRODUCTION

- Manufacturing a wide range of products leads to the following operations:
  - Part processing
  - Manipulation
  - Assembly
  - Palletization
- Each product requires an initially specified sequence involving one or more of the above operations

INTRODUCTION

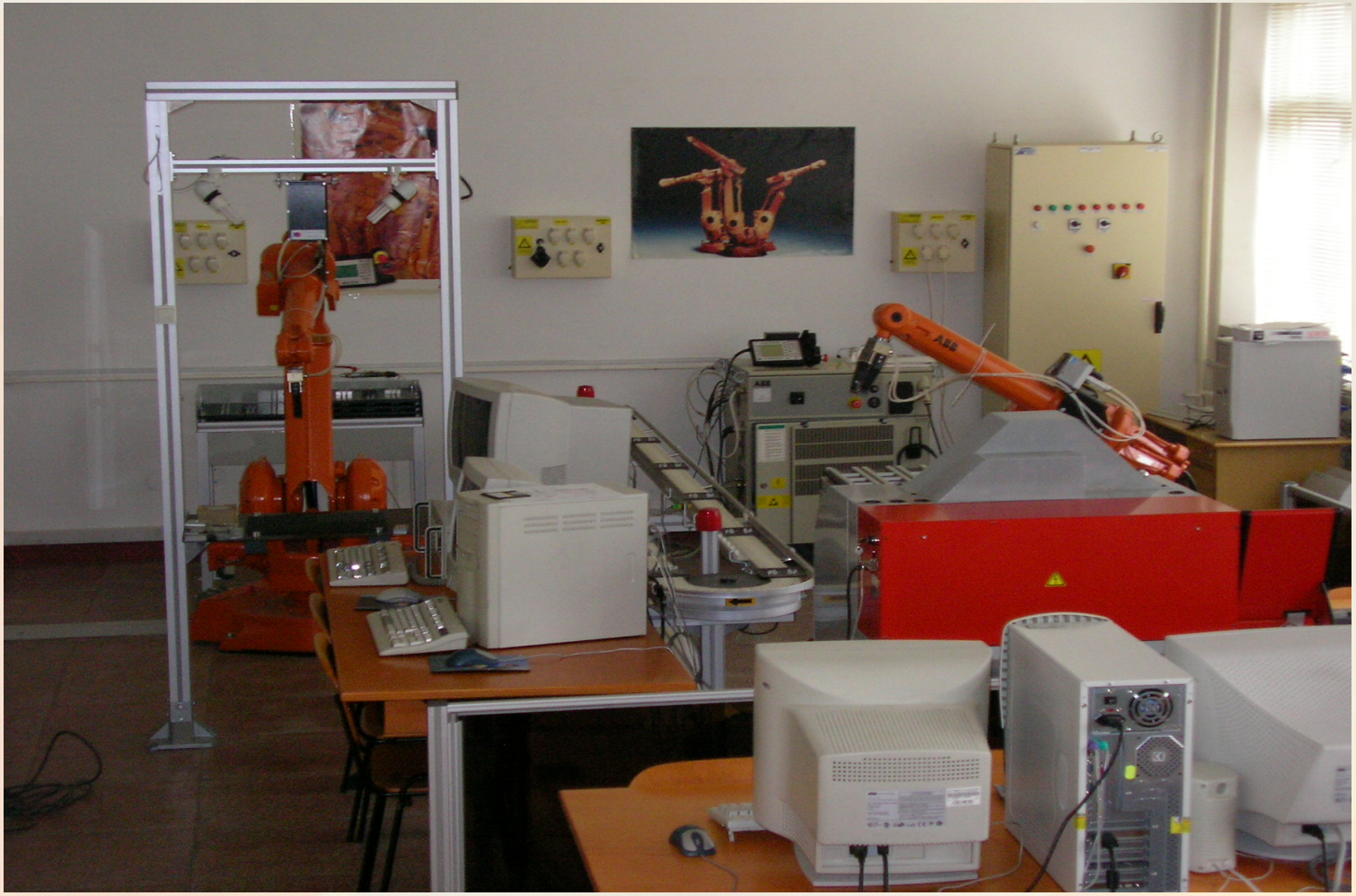

Figure 1. A flexible manufacturing system

INTRODUCTION

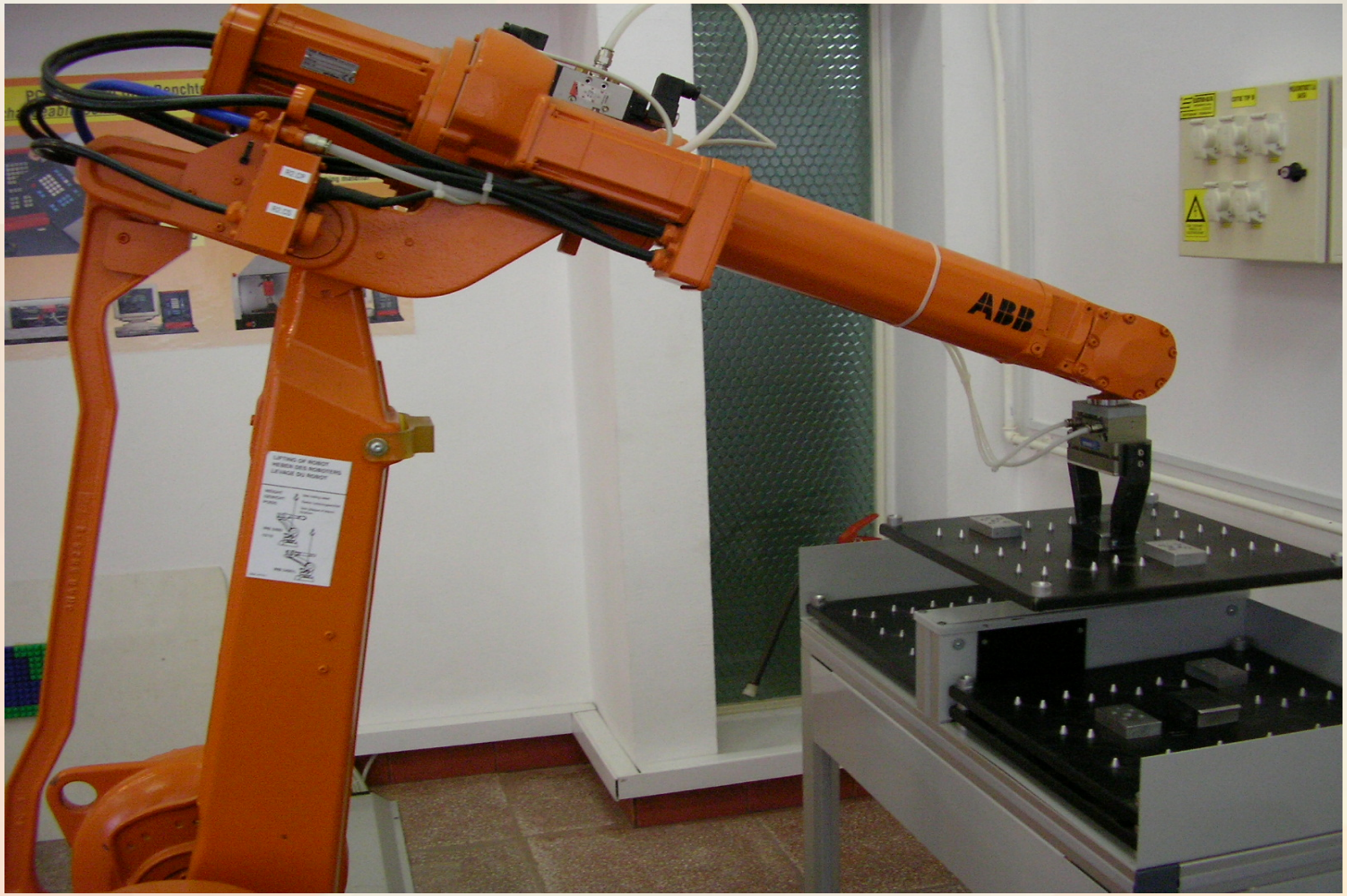

Figure 2. ABB IRB 2400 Robot

INTRODUCTION

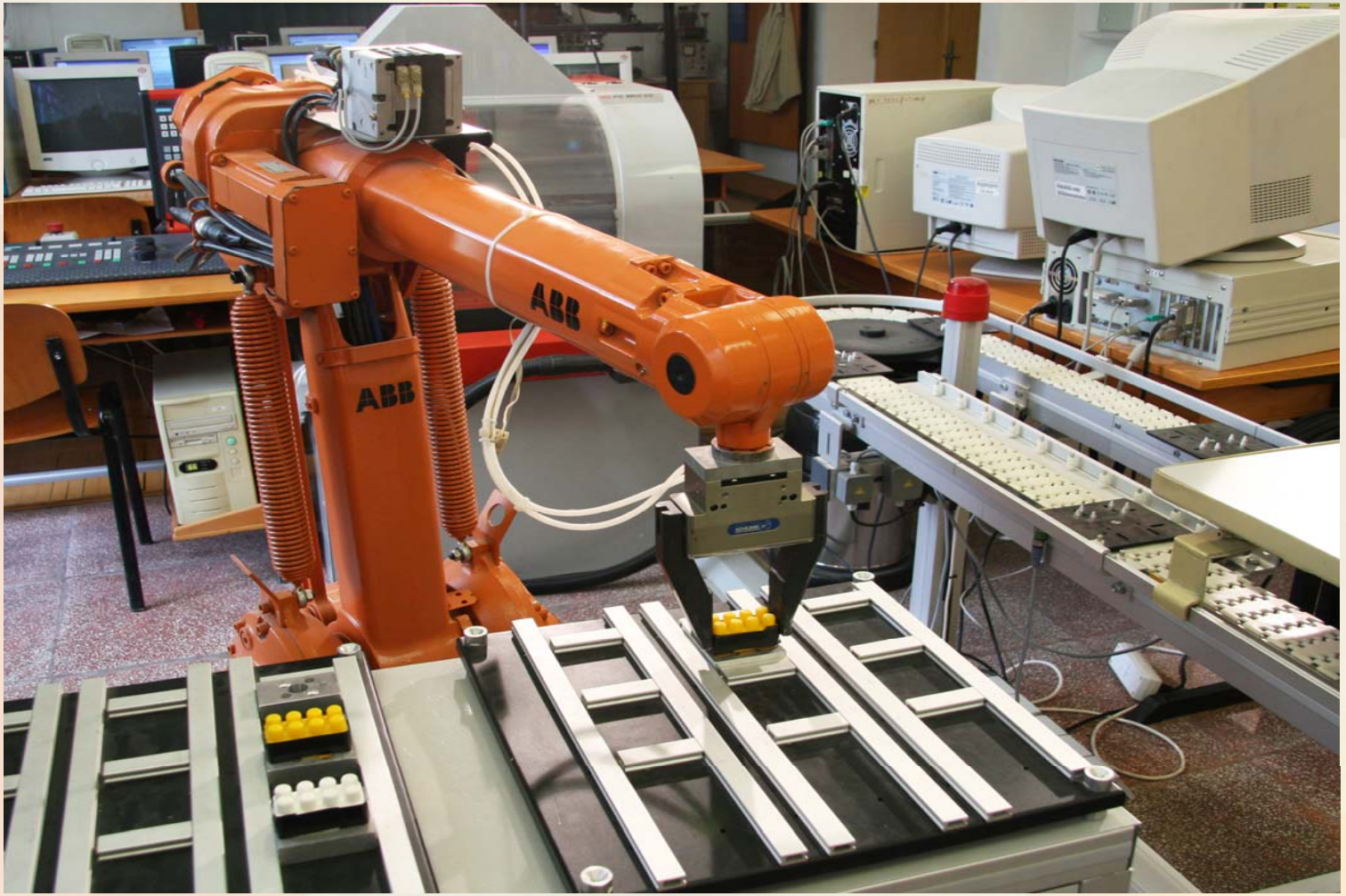

Figure 3. ABB IRB 1400 Robot

MULTI-AGENT SYSTEMS IN INDUSTRY

- **FMS are linked with MAS considering:**
  - **Each robot being coupled with a software agent**
  - **Product operation sequences are dynamically determined by the agents – distributed planning mechanism**
  - **Robot interaction in the manufacturing process relies on agent coordination and negotiation**

MULTI-AGENT SYSTEMS IN INDUSTRY

- **Multi-agent systems:**
  - **Dynamic systems**
  - **Shared environment**
  - **Planning mechanism**
    - **Centralised**
    - **Distributed**
  - **Coordination protocols**
    - **Cooperative**
    - **Competitive**
  - **Communication layer**
    - **Peer-to-peer**
    - **Broadcast**

MULTI-AGENT SYSTEMS IN INDUSTRY

Contract NET

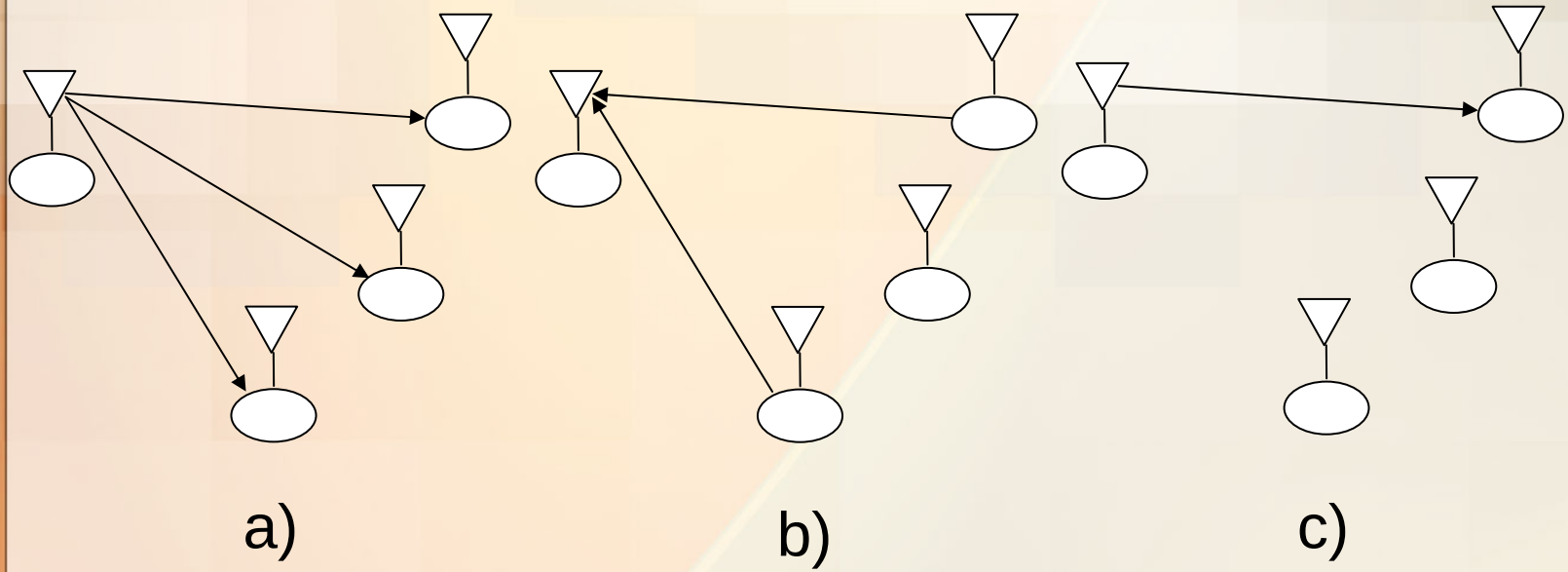

Figure 4. Contract NET protocol steps

a) Broadcast a task; b) Receive offers; c) Award contract

MULTI-AGENT SYSTEMS IN INDUSTRY

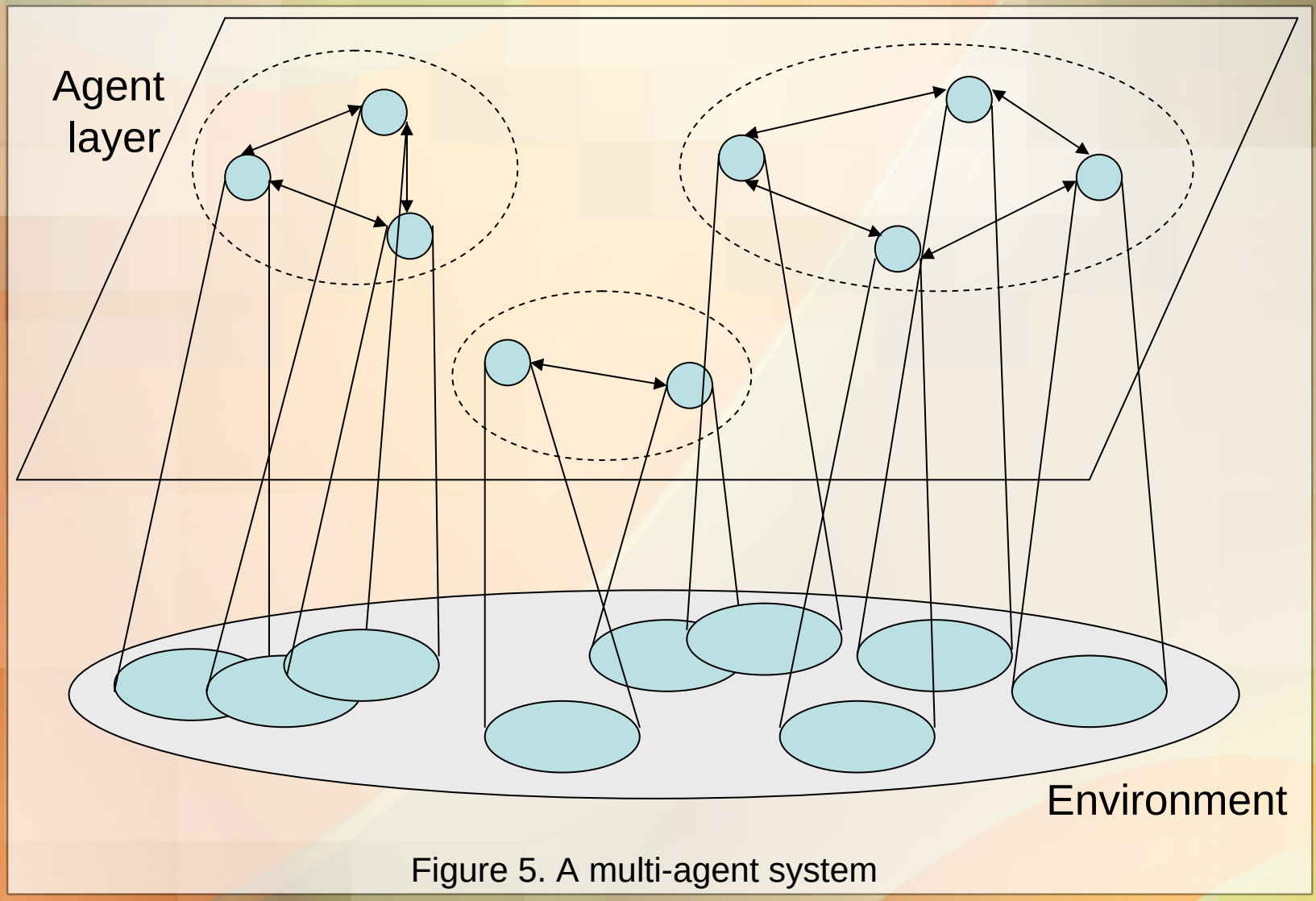

Figure 5. A multi-agent system

HOLONIC SYSTEMS

- Model – biological systems
  - Organizational structures
  - Whole – Part paradigm
  - Recursivity
- Factory
  - Collection of specialized sub-systems
  - Autonomous character
  - Cooperativity

HOLONIC SYSTEMS

- New concept: Holon ≠ Agent
  - Agent - part of a holon
- Holon - composite entity:
  - Software Agent
  - Communication Middleware Interface
  - Structural component
    - Physical device
    - Holarchy, by concatenation

HOLONIC SYSTEMS

- Recursive structure
  - Double holon role:
    - Part
    - Whole
  - Semi-heterarchical organization
  - The aggregation phenomena

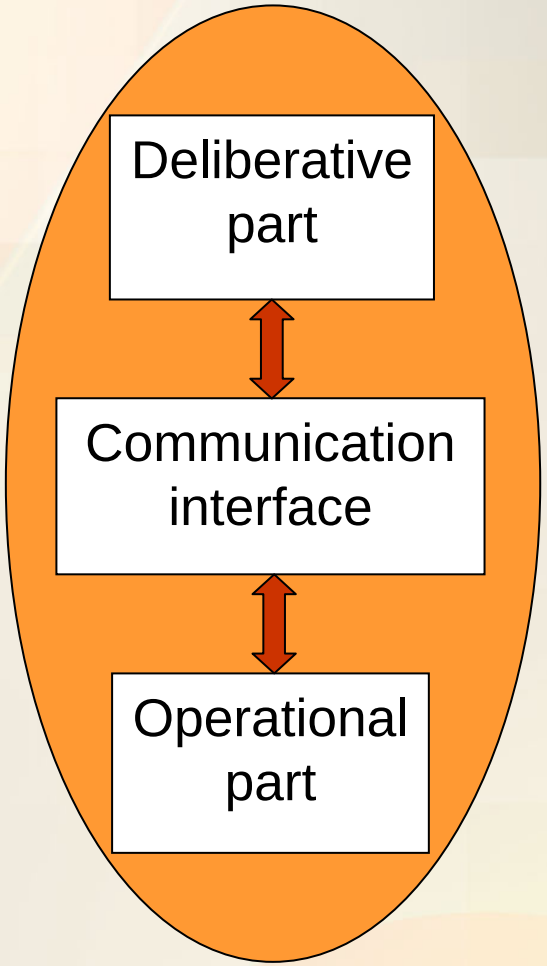

Figure 6.The generic holon

THE STARTING POINT: PROSA

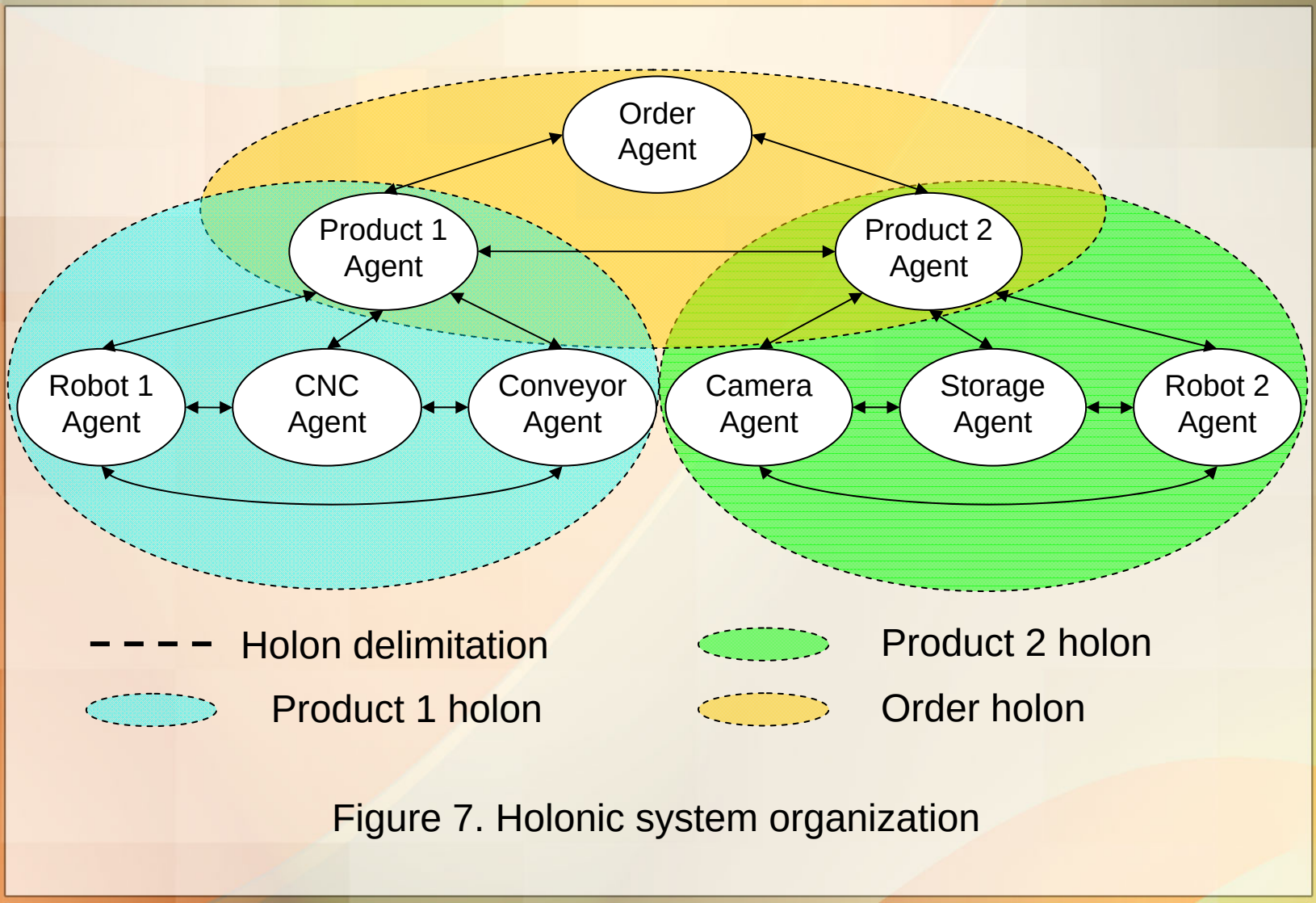

Figure 7. Holonic system organization

THE STARTING POINT: PROSA

- Holon types
  - Temporary
    - Order
    - Product
  - Permanent
    - Resource
      - Specific functionality
        - Physical devices
        - Specialized software

THE STARTING POINT: PROSA

- Coordination protocol
  - Planning
    - Plan propagation
      - from Order agent to Resource agents
  - Monitoring
    - Event propagation
      - From Resource agents to Order agent

EXTENDING PROSA

- Coordination protocol
  - Contract Net
    - Manager
    - Contractors
    - Open auction mechanism
  - Recursive context
  - Temporary bids support
  - Global goal
  - Auto-organization

HOLONS AND SERVICES

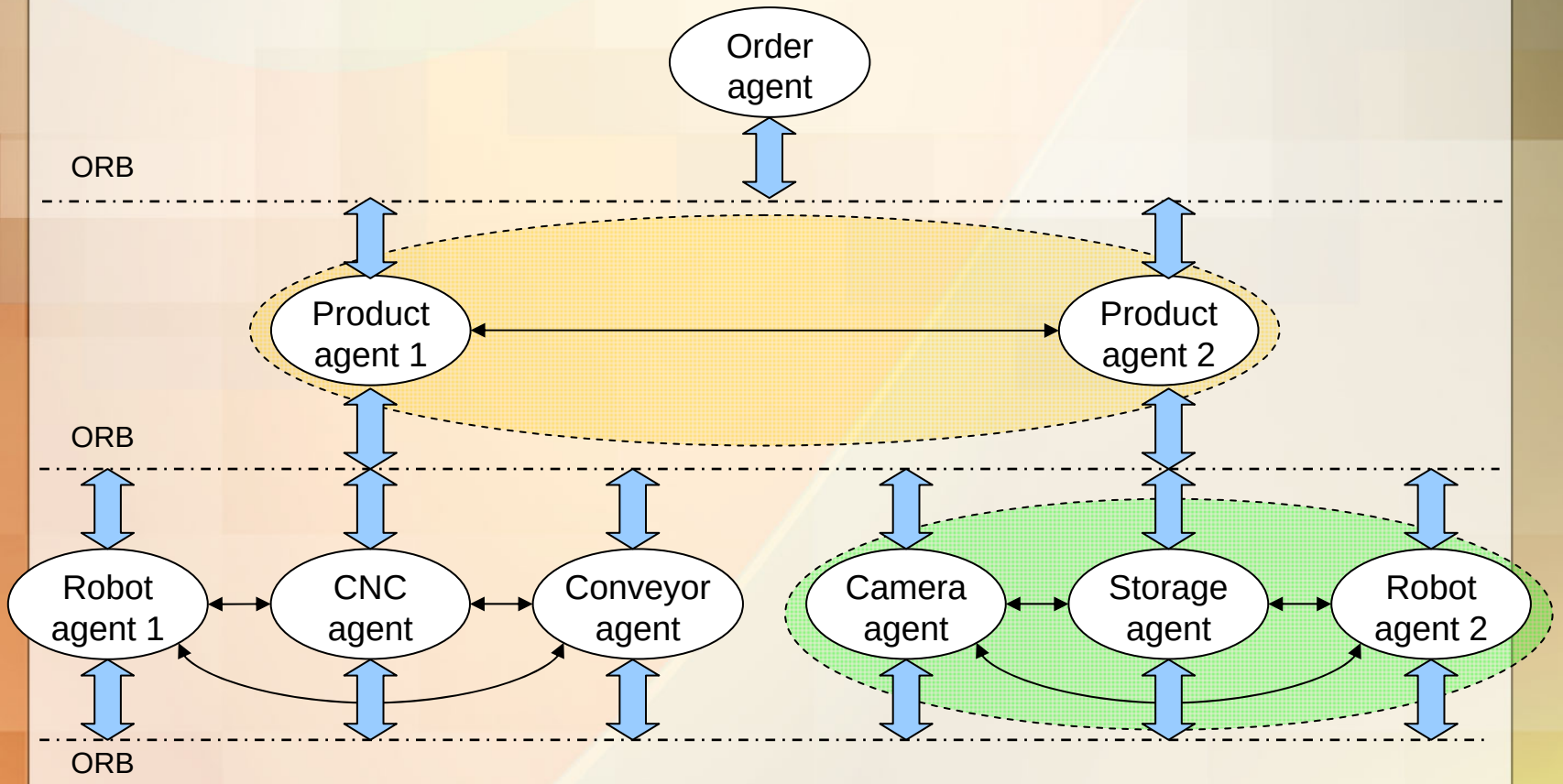

Figure 8. Decoupling the holonic system with services

HOLONS AND SERVICES

- Services
  - Loose coupling
  - Robust communication mechanism
- Dynamic service composition
  - A service call made by an upper level agent might require several service calls on a lower level
  - Auto-organization

HOLONS AND SERVICES

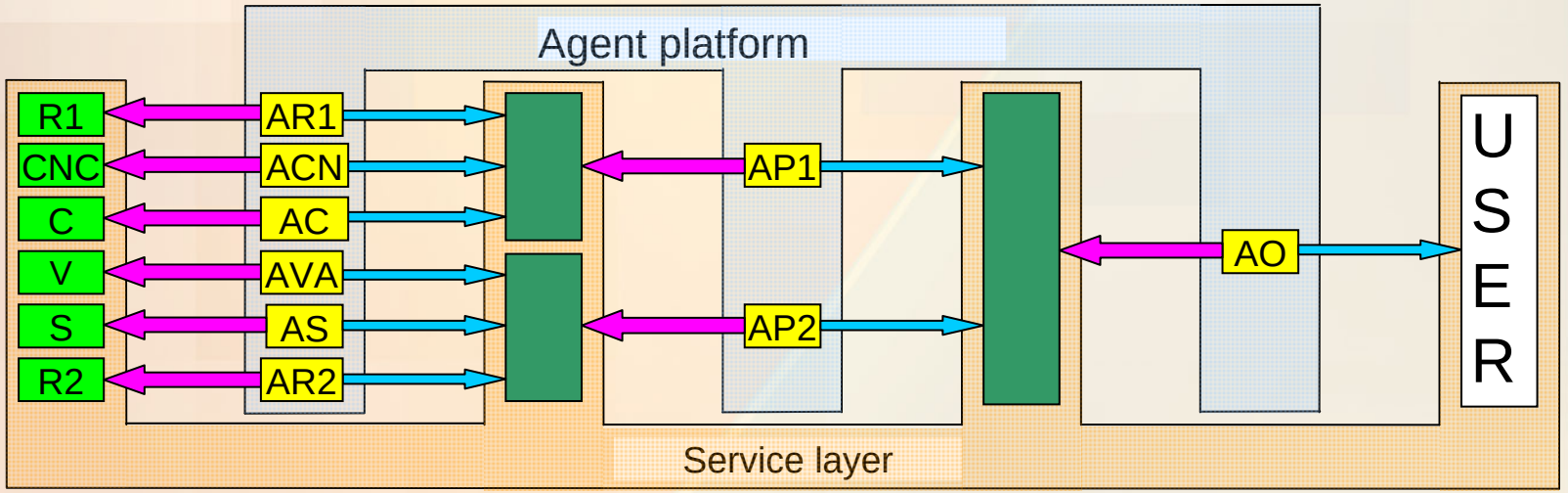

Figure 9. Service composition in the holonic system

RESOURCE HOLON IMPLEMENTATION

- **Functional components**
  - **Execution device**
  - **Driver application**
  - **Communication middleware**
  - **Software Agent**

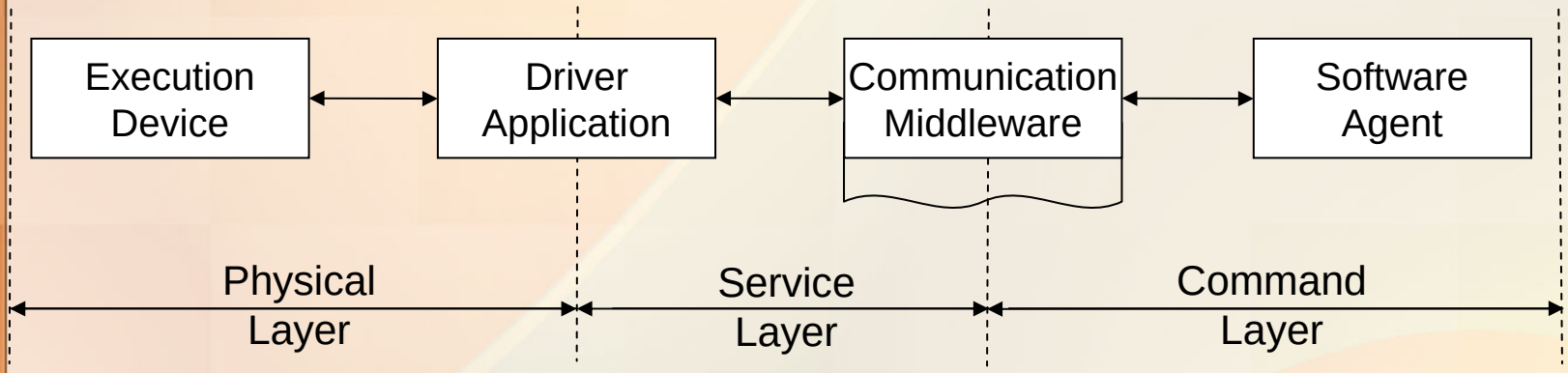

Figure 10. Typical resource holon architecture

RESOURCE HOLON IMPLEMENTATION

- Driver application
  - Connected to a physical device
  - Exporting its functionality
  - High specificity
- Communication middleware
  - CORBA compatible
  - Unifying communication channels for distributed and heterogeneous systems

COMMUNICATION MIDDLEWARE

- **CORBA - Common Object Request Broker Architecture**
  - **Communication layer**
  - **Language specific interfaces**
  - **Standardized by the Object management group (omg.org)**
  - **Mechanism for remote procedure call**
    - **Servant applications**
    - **Object references**
    - **Remote method invocations**
    - **Client applications**
  - **Support layer for SOA**

COMMUNICATION MIDDLEWARE

- CORBA Services
  - Name service – a CORBA dns
  - Trader service – open auction system
  - Event service
    - Event channels
    - Event producers/consumers
- Object Request Broker (ORB)
  - Platform independent - Mico
  - Platform dependent
    - Java RMI
    - IIOP.NET

PRELIMINARY CONCLUSIONS

- **The holonic system advantages**
  - **Increased adaptability**
  - **Goal driven auto-organization**
  - **Minimum fault impact**
- **Holon implementation advantages**
  - **Modular architecture**
  - **Plug & Play functionality**
  - **Quick integration of legacy devices**

PRELIMINARY CONCLUSIONS

- Middleware benefits
  - Distributed event handling
  - Knowledge separation
  - Communication transparency
- SOA benefits
  - Decoupled agent system
  - Increased robustness

FUTURE WORK

- Communication middleware support for higher level holons
  - Dynamic service composition with CORBA
  - Implementing the auto-organization mechanism
- Validating the resulting holonic system architecture

FUTURE WORK

- Investigating the usage of Petri-Nets in validating holonic/agent based systems
- Global action spaces
  - Narrowing action chains corresponding to goal solving plans
  - Defining workflows
  - Analyzing performances and obtaining a benchmark mechanism

Thank you for your attention!