

CmpE 593 Multiagent Systems

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Distributed Problem Solving

Based largely on
Service-Oriented Computing: Semantics, Processes, Agents
– Munindar P. Singh and Michael N. Huhns, Wiley, 2004

Planning and Control Needed

How to maintain global coherence without explicit global control? Important aspects include how to

- Determine shared goals
- Determine common tasks across services
- Avoid unnecessary conflicts
- Pool knowledge and evidence

Coordination

A property of interaction among a set of agents performing some activity in a shared state. The degree of coordination is the extent to which they

- Avoid extraneous activity
 - reduce resource contention
 - avoid livelock
- Avoid deadlock
- Maintain safety conditions

Cooperation is coordination among nonantagonistic agents. Typically,

- Each agent must maintain a model of the other agents
- Each agent must develop a model of future interactions

Goals for Multiagent Control

Develop techniques for

- Locating and allocating capabilities and resources that are dispersed in the environment
- Predicting, avoiding, or resolving contentions over capabilities and resources
- Mediating among more agents, with more heterogeneity and more complex interactions
- Maintaining stability, coherence, and effectiveness

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Control Challenges

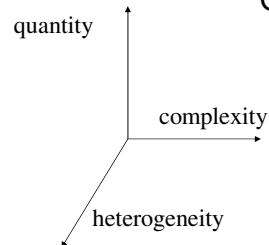
The difficulty of control depends on some major characteristics of the overall system, including:

- agents comprising the system
- problems being solved by the agents individually and/or collectively
- critical solution characteristics

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Control Challenges: Agents



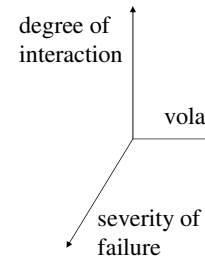
Control gets harder as agents become more:

- numerous
- complex individually (e.g., more versatile)
- heterogeneous (in capabilities, representations, languages)

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Control Challenges: Problems



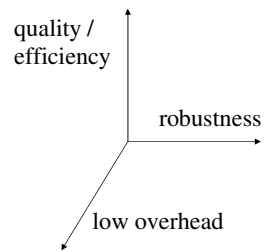
Control gets harder as the problems agents solve become more

- interrelated
- rapidly changing, or pursued in an uncertain and changing world
- unforgiving of control failures (e.g., involving irreversible actions)

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Control Challenges: Solutions



Control gets harder as solutions to agent problems are required to be more

- efficient
- robust to changing circumstances
- cheaper or faster to develop individually and in concert

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Technologies for Agent Control

- Broker-based
- Matchmaker-based
- Market-based; auctions
- BDI and commitment based
- Decision theoretic
- Workflow (procedural) based
- Standard operating procedures
- Learning / adaptive
- Coordinated planning
- Conventions / protocols
- Stochastic or physics-based
- Organizations: teams and coalitions
- Constraint satisfaction/ optimization

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Engineering Coordination

- Agents must coordinate their activities to carry out tasks
 - To improve their interest: Bid correctly in an auction
 - To satisfy group goals: Pass the ball to the available player in a soccer game
- AND/OR graph for representing goals
 - Representation of dependencies among goals
 - Resources to solve the primitive goals

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Engineering Coordination

- Define the AND/OR tree
 - Requires understanding the dependencies among goals
- Assign regions of the tree to agents
- Control decisions about which areas to explore, giving priorities to some agents when appropriate
- Traverse the graph
- Allow reporting of successful traversal

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Task Decomposition

- By the system designer
 - Must be available during implementation
 - Static
- By the agents
 - Using hierarchical planning
- Using AND/OR tree if the task decomposition is inherent
- Spatially if the layout of information sources is significant
- Functionally if expertise distribution of agents is significant

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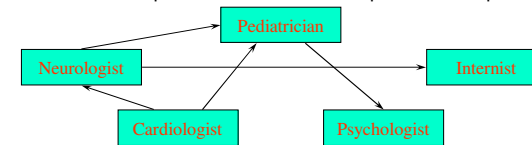
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Task Decomposition Examples

- Spatial decomposition: service is info source or decision point:



- Functional decomposition: service offers specialized expertise:



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Task Distribution Criteria

- Avoid overloading critical resources
- Engage services on tasks where expertise matches
- Make an agent with a wide view assign tasks to other agents
- Assign overlapping responsibilities to agents to achieve coherence
- Assign highly interdependent tasks to agents in spatial or semantic proximity. This minimizes communication and synchronization costs
- Reassign tasks if necessary for completing urgent tasks

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Task Distribution

- Market Mechanism
 - Task matched to agents by generalized agreement
- Negotiation
 - Task assignments are negotiated among agents
- Multiagent Planning
 - Planning agents decide the task distribution
- Organizational Structure
 - Based on roles already available in the organization

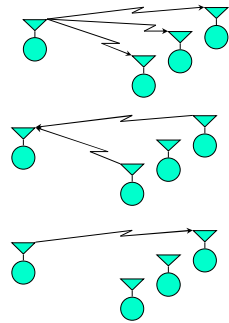
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The Contract Net Protocol

An important generic protocol

- Manager announces tasks via a (possibly selective) multicast
- Agents evaluate the announcement. Some submit bids
- Manager awards a contract to the most appropriate agent
- Manager and contractor communicate privately as necessary



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Task Announcement Message

- *Eligibility specification*: criteria that a node must meet to be eligible to submit a bid
- *Task abstraction*: a brief description of the task to be executed
- *Bid specification*: a description of the expected format of the bid
- *Expiration time*: a statement of the time interval during which the task announcement is valid

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Bid and Award Messages

- A bid consists of a *node abstraction*—a brief specification of the agent's capabilities that are relevant to the task
- An award consists of a *task specification*—the complete specification of the task

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Applicability of Contract Net

The Contract Net is

- a high-level communication protocol
- a way of distributing tasks
- a means of self-organization for a group of agents

Best used when

- the application has a well-defined hierarchy of tasks
- the problem has a coarse-grained decomposition
- the subtasks minimally interact with each other, but cooperate when they do

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Distributed Planning (1)

- **Centralized Planning for Distributed Plans**
 - Given goal description, operators, initial state
 - Generate a partial order plan (with minimal overlappings)
 - Decompose the plan
 - Add synchronization points
 - Allocate agents to subplans
 - Execute plan

Distributed Planning (2)

- **Distributed Planning for Centralized Plans**
- **Distributed Planning for Distributed Plans**
 - Plan Merging
 - Iterative Plan Formation