

Multiagent systems and the societies of agents

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Learning Goals

- ▶ To analyze, describe, and design environments in which agents can operate effectively and interact with each other productively
- ▶ To learn about the communication and interaction protocols of agents used in environment infrastructure
 - a) Communication protocols enable agents to exchange messages
 - b) Interaction protocols enable agents to have conversations

Characteristics of Multiagent Environments

- ▶ Multiagent environments provide an infrastructure specifying communication and interaction protocols.
- ▶ Multiagent environments are typically open and have no centralized designer
- ▶ Multiagent environments contain agents that are autonomous and distributed, and may be self-interested or cooperative

Characteristics of environments

Property

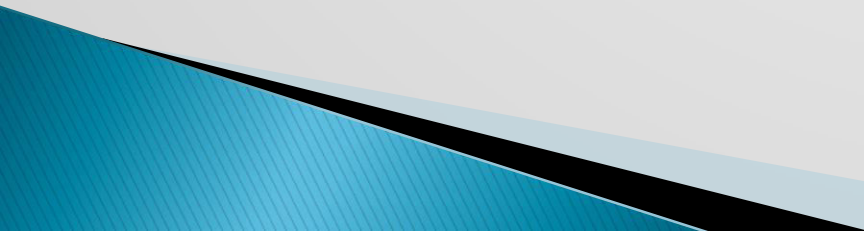
Range of Values

- | | |
|--------------------------------|--|
| ▶ Design Autonomy | ▶ Platform/Interaction Protocol/Language |
| ▶ Communication Infrastructure | ▶ Shared memory or Message-based, Connected or Connection-less (email), Point-to-Point |
| ▶ Message Protocol | ▶ KQML, HTTP, HTML or OLE |
| ▶ Operations Support | ▶ Archiving/Redundancy/Restoration |

Characteristics of Agents

Property

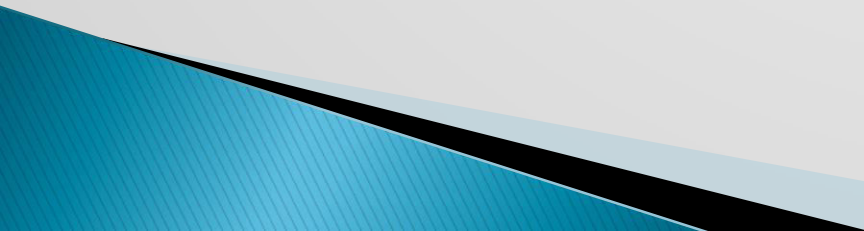
Range of Values

- | | |
|----------------|--|
| ▶ Knowable | ▶ To what extent is the environment known to the agent |
| ▶ Predictable | ▶ To what extent can it be predicted by the agent |
| ▶ Controllable | ▶ To what extent can the agent modify the environment |
| ▶ Historical | ▶ Do future states depend on the entire history, or only the current state |
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Agent Communications

- ▶ Agent is an active object with the ability to perceive, reason, and act
- ▶ Agent has the ability to communicate(the receiving and sending of messages)
- ▶ Communication can enable the agents to coordinate their actions and behavior, resulting in systems that are more coherent
- ▶ **Coordination :-**Coordination is a property of a system of agents performing some activity in a shared environment
 - a) **Cooperation:-** The coordination among nonantagonistic agents
 - b) **Negotiation:-** The coordination among competitive or simply self-interested agents
- ▶ **Coherence:-** How well a system behaves as a unit. A problem for a multiagent system is how it can maintain global coherence without explicit global control.

Dimensions of Meaning

- ▶ **Descriptive vs. Prescriptive:**-Some messages describe phenomena, while others prescribe behavior. Descriptions are important for human comprehension, but are difficult for agents to mimic.
 - ▶ **Personal vs. Conventional Meaning:**- To the greatest extent possible, multiagent systems should opt for conventional meanings
 - ▶ **Coverage:**-Smaller languages are more manageable, but they must be large enough so that an agent can convey the meanings it intends.
 - ▶ **Identity:**- When a communication occurs among agents, its meaning is dependent on the identities and roles of the agents involved
 - ▶ **Cardinality:**- A message sent privately to one agent would be understood differently than the same message broadcast publicly.
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Message Types

- ▶ The role of agent can be either active, passive, or both, allowing them to function as a master, slave, or peer, respectively.

	Basic Agent	Passive Agent	Active Agent	Peer Agent
Receives assertions	⊙	⊙	⊙	⊙
Receives queries		⊙		⊙
Sends assertions		⊙	⊙	⊙
Sends queries			⊙	⊙

Communication Levels

- ▶ Communication protocols are typically specified at several levels
- ▶ lowest level:- specifies the method of interconnection
- ▶ Middle level:- specifies the format, or syntax, of the information being transferred
- ▶ Top level:- specifies the meaning, or semantics, of the information
- ▶ A protocol is specified by a data structure with the following five fields
 - ▶ Sender
 - ▶ receiver(s)
 - ▶ language in the protocol
 - ▶ encoding and decoding functions
 - ▶ actions to be taken by the receiver(s).

Knowledge Query and Manipulation Language (KQML)

- ▶ A fundamental decision for the interaction of agents is to separate the semantics of the communication protocol (which must be domain independent) from the semantics of the enclosed message (which may depend on the domain).
- ▶ The communication protocol must be universally shared by all agents
- ▶ The elegance of KQML is that all information for understanding the content of the message is included in the communication itself.
- ▶ Basic Protocol Structure:- (KQML-performative
 - :sender <word>
 - :receiver <word>
 - :language <word>
 - :ontology <word>
 - :content <expression>...)
- ▶ KQML wraps a message in a structure that can be understood by any agent

KQML(2/3)

- ▶ KQML assumes asynchronous communications and to explain structure
- ▶ Example:- For example, in a Blocks-World ontology, if the concept of a wooden block of a given size is represented by the unary predicate Block, Then the fact that block A is on top of block B could be communicated as follows

(tell

:sender Agent1

:receiver Agent2

:language: KIF

:ontology: Blocks-World

:content (AND (Block A) (Block B) (On A B))

- ▶ KQML-speaking agents appear to each other as clients and servers

KQML(3/3)

Issues in KQML: –

- ▶ The sender and receiver must understand the agent communication language.
- ▶ KQML must operate within a communication infrastructure that allows agents to locate each other
- ▶ The infrastructure is not part of the KQML specification, and implemented systems use custom-made utility programs called routers or facilitators to perform this.
- ▶ KQML is still a work in progress and its semantics have not been completely defined

Knowledge Interchange Format (KIF)

- ▶ Agents need descriptions of real-world things. The descriptions could be expressed in natural languages.
- ▶ KIF, a particular logic language, has been proposed as a standard to use to describe things within expert systems, databases, intelligent agents, etc.
- ▶ KIF is a prefix version of first order predicate calculus with extensions to support nonmonotonic reasoning and definitions

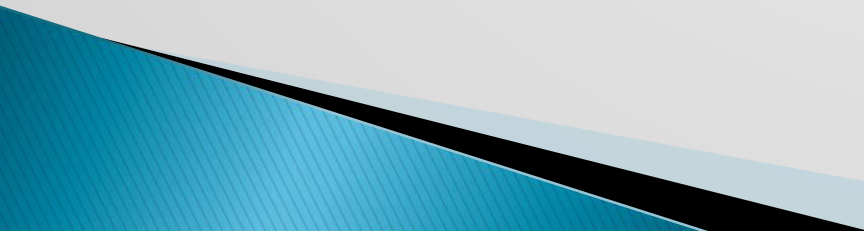
KIF 2/2

- ▶ The language description includes both a specification for its syntax and one for its semantics. KIF provides for the expression of simple data
- ▶ For Example:-one chip is larger than another can be presented as :
 $(> (* (\text{width chip1}) (\text{length chip1}))$
 $(* (\text{width chip2}) (\text{length chip2})))$
- ▶ KIF includes a variety of logical operators to assist in the encoding of logical information, such as negation, disjunction, rules, and quantified formulas.
- ▶ The semantics of the KIF core (KIF without rules and definitions) is similar to that of first-order logic
- ▶ There is a restriction that models must satisfy various axiom schemata

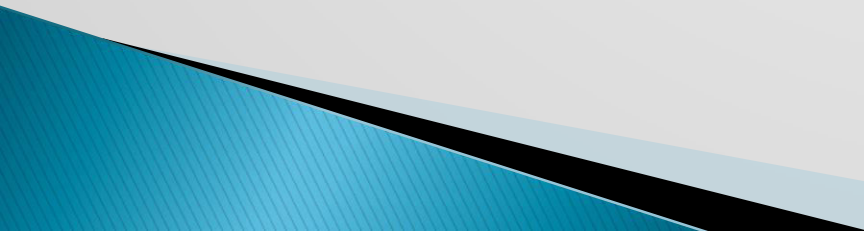
Agent Interaction Protocols

- ▶ Interaction protocols govern the exchange of a series of messages among agents—a conversation
- ▶ where the agents have similar goals or common problems, as in distributed problem solving (DPS), the objective of the protocols is coherent performance of the agents without violating autonomy.
- ▶ Important aspect to consider for coherence:-
 - 1) Determine shared goals
 - 2) Determine common tasks
 - 3) Avoid unnecessary conflicts
 - 4) Pool knowledge and evidence.

Coordination Protocols

- ▶ In an environment with limited resources, agents must coordinate their activities with each other to further their own interests or satisfy group goals.
 - ▶ The actions of multiple agents need to be coordinated because there are dependencies between agents' actions, there is a need to meet global constraints.
 - ▶ To characterize both global and local problems, distributed goal search formalism has been used frequently and the key agent structures are commitment and convention
 - ▶ Commitments are viewed as pledges to undertake a specified course of action, while conventions provide a means of managing commitments in changing circumstances.
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Coordination Protocols(2/3)

- ▶ Commitments provide a degree of predictability so that agents can take the future activities of others into consideration when dealing with interagent dependencies, global constraints, or resource utilization conflicts
 - ▶ Agents must evaluate whether existing commitments are still valid in case of situation change
 - ▶ Conventions constrain the conditions under which commitments should be reassessed
 - ▶ Conventions help an agent manage its commitments, but they do not specify how the agent should behave towards others if it alters or modifies its commitments
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Coordination Protocols (3/3)

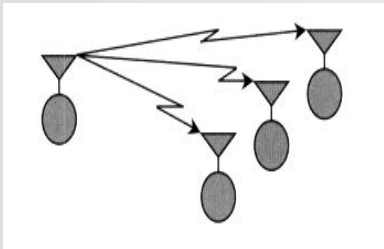
- ▶ The minimum information that a team of cooperating agents should share when they jointly commit to a common goal
 - 1) The status of their commitment to the shared objective.
 - 2) the status of their commitment to the given team framework.
- ▶ If an agent comes to believe that a team member is no longer jointly committed, it also needs to reassess its own position with respect to the joint action.
- ▶ Commitments and Conventions are the cornerstones of coordination: commitments provide the necessary structure for predictable interactions and Social convention provide the necessary degree of mutual support

Cooperation Protocols

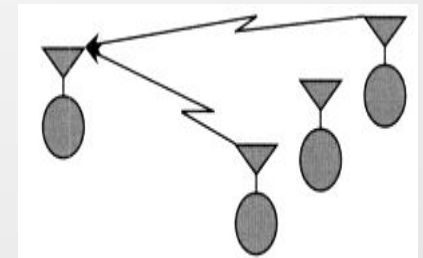
- ▶ A basic strategy shared by many of the protocols for cooperation is to decompose and then distribute tasks.
- ▶ Such a divide and conquer approach can reduce the complexity of a task: smaller subtasks require less capable agents and fewer resources.
- ▶ Once tasks are decomposed, they can be distributed according to the following criteria:
 - 1) Avoid overloading critical resources
 - 2) Assign tasks to agents with matching capabilities
 - 3) Make an agent with a wide view assign tasks to other agents
 - 4) Assign overlapping responsibilities to agents to achieve coherence
 - 5) Assign highly interdependent tasks to agents in spatial or semantic proximity. This minimizes communication and synchronization costs

Contract net

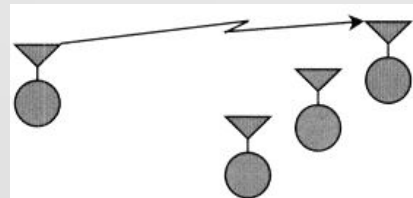
The contract net protocol is an interaction protocol for cooperative problem solving among agents for the task distribution as shown below



a) The manager announces the task via a multicast



b) Agents evaluate the announcement and submit bids

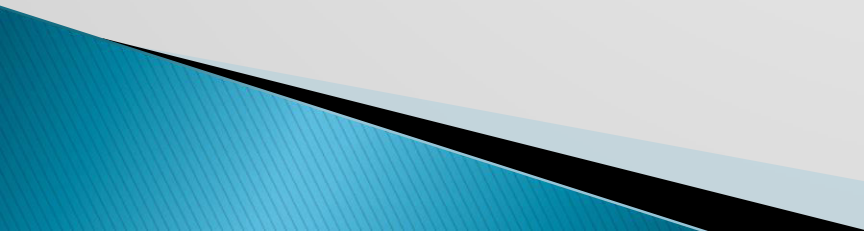


c) The manager awards the contract to most appropriate agent

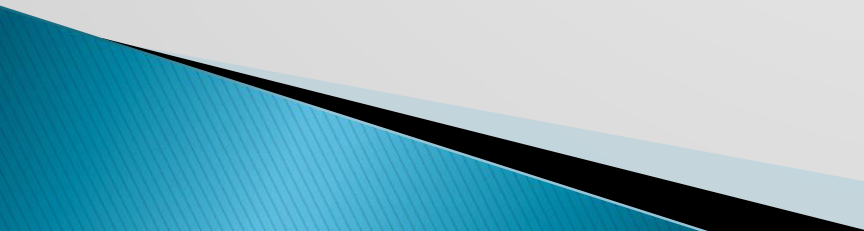
Limitations of contract net

- ▶ A limitation of the contract net protocol is that a task might be awarded to a contractor with limited capability if a better qualified contractor is busy at award time.
- ▶ A manager may not receive bids for several reason:-
 - 1) All potential contractors are busy with other task
 - 2) No contractors, even if idle are capable of working on the task.
 - 3) A potential contractor is idle but ranks the proposed task below other tasks.
- ▶ To handle these cases, a manager may request immediate response bids to which contractors respond with messages such as eligible but busy, ineligible or uninterested.
- ▶ The manager can then make adjustments in its task plan for example wait until a potential contractor is free.

Societies of Agents

- ▶ The agents not operate in isolation they work in some environment with other agents which can or can not be affected by it.
 - ▶ A group of agents can form a small society in which they play different roles. The group defines the roles, and the roles define the commitments associated with them.
 - ▶ When an agent joins a group, he joins in one or more roles, and acquires the commitments of that role.
 - ▶ Agents join a group autonomously, but are then constrained by the commitments for the roles they adopt.
 - ▶ The groups define the social context in which the agents interact
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Societies of Agents (2/3)

- ▶ The mental primitives such as beliefs, desires and intentions are appropriate for a number of applications, they are not suitable in themselves for understanding all aspect of social interactions.
 - ▶ Social commitments are the commitments of an agent to another agent
 - ▶ Social commitments are a flexible means through which the behavior of autonomous agents is constrained.
 - ▶ Social dependencies may be compound, mutual(cooperation) or reciprocal.
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Societies of agents(3/3)

- ▶ A group of agents form cooperative team when:-
 - 1) All agents share a common goal.
 - 2) Each agent is required to do its share to achieve the common goal by the group itself or a subgroup.
 - 3) Each agent adopts a request to do its share.
- ▶ Beyond social dependencies, social laws may govern the behaviors of large numbers of agents in a society

Summary

- ▶ With the elements of computational environment in which agents operate whether it is communication or cooperation they act in interest of themselves or their society

Thank you

