# Knowledge Engineering

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Lecture 12 – Agent Interaction & Communication
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# Where are we?

Last time ...

- Agent architectures
- Deliberative vs. reactive architectures
- The BDI model of agency
- Subsumption architecture
- Hybrid approaches: Touring Machines/InteRRaP

Today ...

- Agent interaction & communication

# Categories of Agent Interaction

- Non-/Quasi-communicative interaction:
  - Shared environment (interaction via resource/capability sharing)
  - "Pheromone" communication (ant algorithms)
- Communication:
  - Information exchange: sharing knowledge, exchanging views
  - Collaboration, distributed planning: optimising use of resources and distribution of tasks, coordinating execution
  - Negotiation: reaching agreement in presence of conflict
  - (Human-machine dialogue, reporting errors, etc.)

# Speech Act Theory

- Most multiagent approaches to communication based on **speech act theory**
- Underlying idea: treat communication in a similar way as non-communicative action
- **Pragmatic** theory of language, concerned with how communication is used in the context of agent activity
- Austin (1962): Utterances are produced like "physical" actions to change the state of the world
- Speech act theory is a theory of how utterances are used to achieve one's intentions

# Speech Act Theory

- A speech act can be conceptualised to consist of:
  1. Locution (physical utterance)
  2. Illocution (intended meaning)
  3. Perlocution (resulting action)
- Two parts of a speech act:
  - **Performative** = communicative verb used to distinguish between different "illocutionary forces"
    - Examples: promise, request, purport, insist, demand, etc.
  - **Propositional content** = what the speech act is about
- Example:
  - Performative: request/inform/enquire
  - Propositional content: "the window is open"

# Speech Act Theory

- Searle (1972) identified following categories of performatives:
  - assertives/representatives (informing, making a claim)
  - directives (requesting, commanding)
  - commissives (promising, refusing)
  - declaratives (effecting change to state of the world)
  - expressives (expressing mental states)
- Ambiguity problems:
  - "Please open the window!"
  - "The window is open."
  - "I will open the window."
  - ...
- Debate as to whether this (or any!) typology is appropriate (and innate to human thinking)

# Agent Communication Languages

- Agent communication languages (ACLs) define standards for messages exchanged among agents
- Usually based on speech act theory, messages are specified by:
  - Sender/receiver(s) of the message
  - Performative to describe intended actions
  - Propositional content in some content language
- Most commonly used languages:
  - KQML/KIF
  - FIPA-ACL (today de-facto standard)
- FIPA=Foundation for Intelligent Physical Agents"

# KQML/KIF

- KQML – Knowledge Query and Manipulation Language
- An "outer" language, defines various acceptable performatives
- Example performatives:
  - `ask-if` ('is it true that...')
  - `perform` ('please perform the following action...')
  - `tell` ('it is true that...')
  - `reply` ('the answer is ...')
- Message format:

```
(performative
      :sender       <word>   :receiver     <word>
      :in-reply-to  <word>   :reply-with   <word>
      :language     <word>   :ontology     <word>
      :content      <expression>)
```

# Example

```
(advertise
          :sender           Agent1
          :receiver         Agent2
          :in-reply-to      ID1
          :reply-with       ID2
          :language         KQML
          :ontology         kqml-ontology
          :content          (ask
                            :sender      Agent1
                            :receiver    Agent3
                            :language    Prolog
                            :ontology    blocks-world
                            :content     "on(X,Y)"))
```

# KQML/KIF

- KQML does not say anything about *content* of messages
  $\longrightarrow$ need content languages
- *KIF* – Knowledge Interchange Format: a logical language to describe knowledge (first-order logic with some extensions/restrictions)
- Examples:
  - `(=> (and (real-num ?x) (even-num ?n))`
    `(> (expt ?x ?n) > 0))`
  - `(interested joe '(salary ,?x ,?y ,?z))`
- Can be also used to describe ontology referred to by interacting agents

# FIPA ACL

- In recent years, FIPA started work on a program of agent standards – the centrepiece is an ACL called FIPA-ACL
- Basic structure is quite similar to KQML (performative, "housekeeping", content)
- "Inform" and "Request" basic performatives, all others (about 20) are macro definitions (defined in terms of these)
- The meaning of inform and request is defined in two parts:
  - Pre-condition, i.e. what must be true in order for the speech act to succeed
  - "Rational effect", i.e. what the sender of the message hopes to bring about
- Example:

```
(inform      :sender agent1 :receiver agent5
             :content (price good200 150)
             :language sl :ontology hpl-auction)
```

# ACL Semantics

- One possibility to define semantics of speech acts is through constraints on mental states of participants
- A possible semantics for request $request(s, h, \phi)$
  - Pre-conditions (before utterance):
    - $s$ believes $h$ can do $\phi$
      (you don't ask someone to do something unless you think they can do it)
    - $s$ believes $h$ believe $h$ can do $\phi$
      (you don't ask someone unless they believe they can do it)
    - $s$ believes $s$ want $\phi$
      (you don't ask someone unless you want it!)
  - Post-conditions (after utterance):
    - $h$ believes $s$ believe $s$ wants $\phi$
      (the effect is to make them aware of your desire)

# Problems

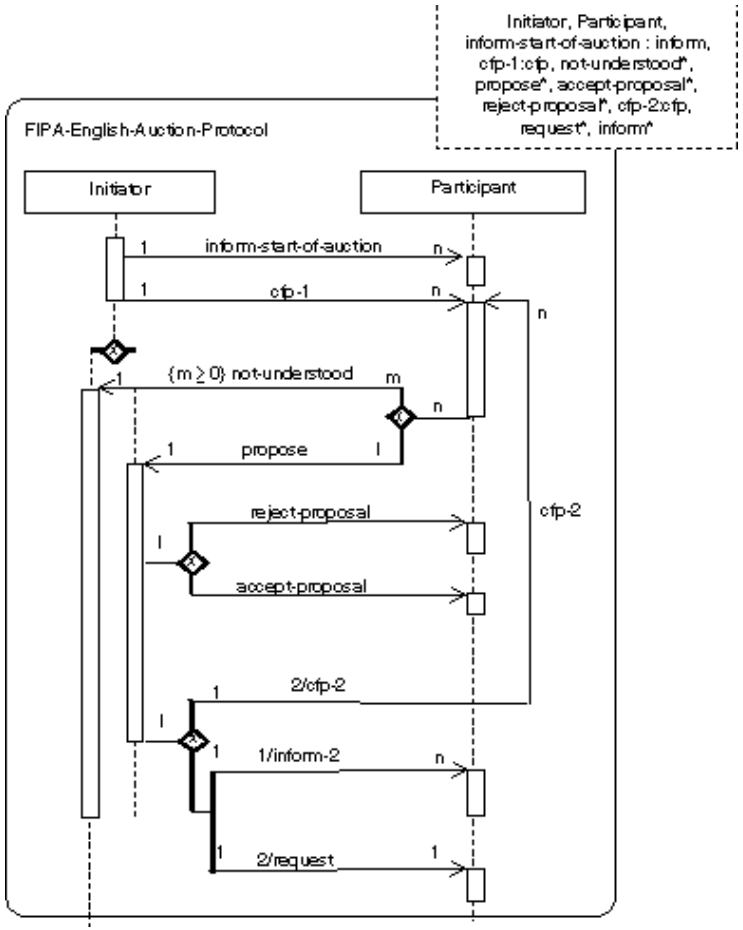
- Impossible for the speaker to enforce those beliefs on the hearer!
- More generally: No way to verify mental state of agent on the grounds of its (communicative) behaviour
- Alternative approaches use notion of **social commitments**
  - "A debtor *a* is indebted to a creditor *b* to perform action *c* (before *d*)"
  - Often public commitment stores are used to track status of generated commitments
  - At least (non)fulfillment of commitments can be verified
- This is a fundamental problem of all mentalistic approaches to communication semantics!

# Interaction Protocols

- ACLs define the syntax and semantics of individual utterances
- But they don't specify what agent *conversations* look like
- This is done by **interaction protocols** for different types of agent dialogues
- Interaction protocols govern the exchange of a series of messages among agents
- Restrict the range and ordering of possible messages (effectively define patterns of admissible sequences of messages)
- Often formalised using finite-state diagrams or "interaction diagrams" in FIPA-AgentUML
  - Define agent roles, message patterns, semantic constrains

# Example

Interaction protocol for the English ("first-price open-cry") auction in FIPA-AgentUML



# Protocol Design

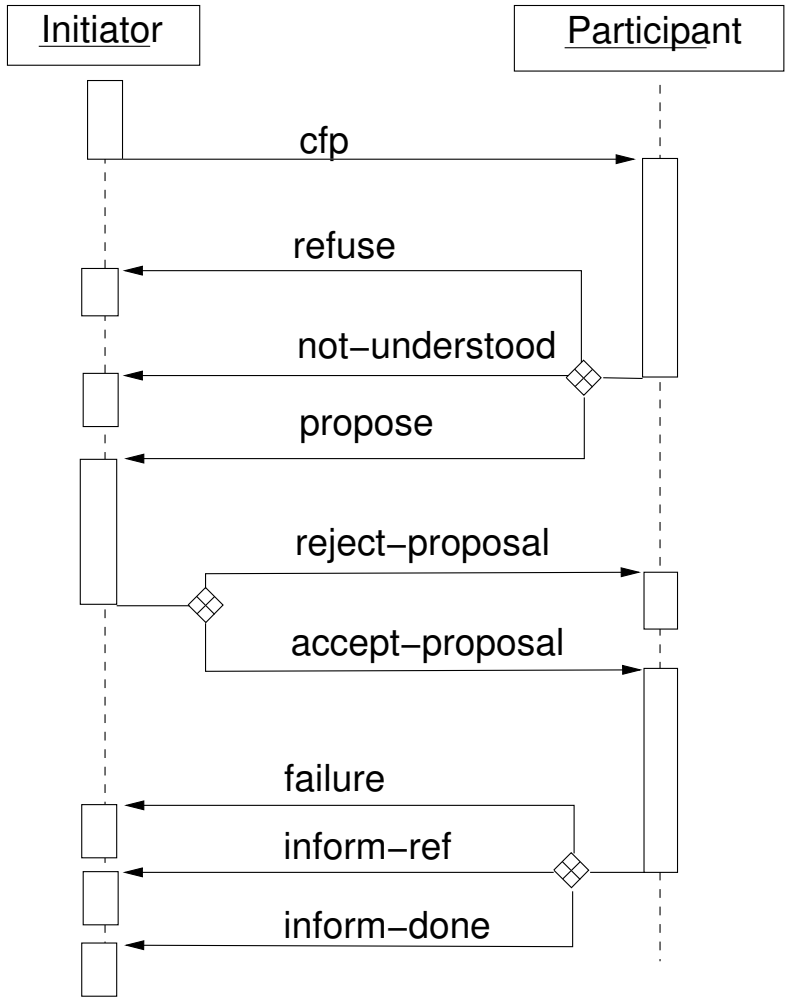
Described as a six-step process (Koning, Francois & Demazeau 1999):

1. Describe the interaction capabilities of the agents in use
2. Clarify the types of messages involved
3. Describe the agents' behaviours
4. Explain the possible message sequences between agents
5. Clarify the various internal agent states
6. Establish the diagram of the protocol (if AgentUML is used)

# Contract-Net Protocol

- One of the oldest, most widely used agent interaction protocols
- A manager agent announces one or several tasks, agents place bids for performing them
- Task is assigned by manager according to evaluation function applied to agents' bids (e.g. choose cheapest agent)
- Idea of exploiting local cost function (agents' private knowledge) for distributed optimal task allocation
- Even in purely cooperative settings, decentralisation can improve global performance
- A typical example of "how it can make sense to agentify a system"
- Successfully applied to different domains (e.g. transport logistics)

# Contract-Net Protocol

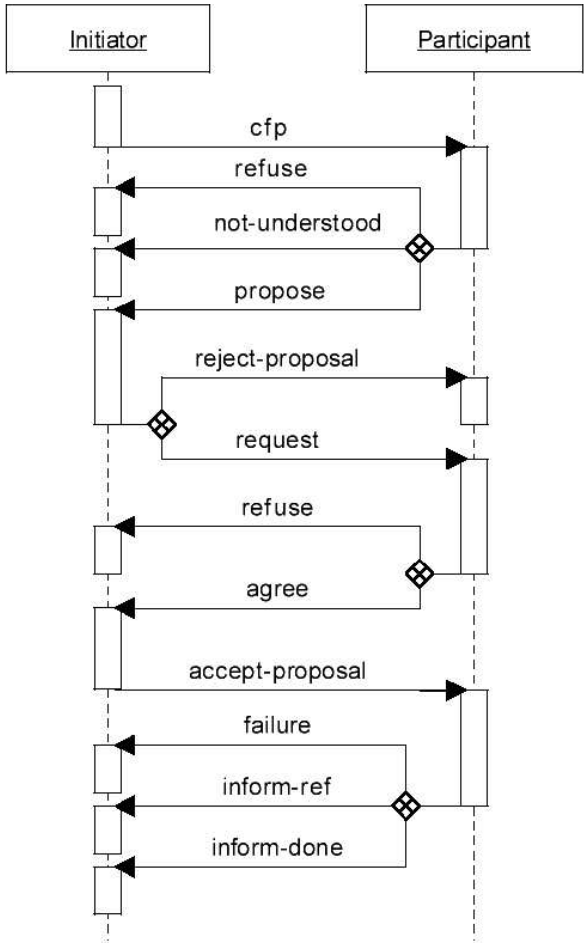


# Problem

- Many protocol definitions do not include a specification of participants' mental states during execution
- Trade-off between being agent design task and protocol design task
  - Ensure global objectives are met
  - Don't be too prescriptive about internal design of agents!
- Example: The "Eager Bidder Problem"
  - Assume several manager agents at a time
  - Individual agents might over-commit despite lack of resources
  - Deadlines won't solve the problem!

# Contract-Net with Confirmation Protocol

A possible solution to the eager bidder problem:



# Summary

- Different kinds of interaction and communication
- Focus on agent-to-agent communication
- Speech act theory – theoretical foundation for ACLs
- Agent communication languages & their semantics
- Interaction protocols
- But how about agent strategies in interaction and their global effects?
- Next time: **Distributed Rational Decision-Making**