

Knowledge Engineering Semester 2, 2004-05

Michael Rovatsos
mrovatso@inf.ed.ac.uk



Lecture 12 – Agent Interaction & Communication
22th February 2005

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.)

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

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"

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"

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)

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)")
```

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)
```

KQML/KIF

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

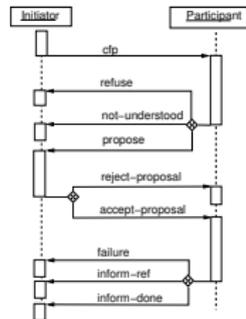
ACL Semantics

- ▶ 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 ϕ
(you don't ask someone to do something unless you think they can do it)
 - ▶ s believes h believe h can do ϕ
(you don't ask someone unless they believe they can do it)
 - ▶ s believes s want ϕ
(you don't ask someone unless you want it!)
 - ▶ Post-conditions (after utterance):
 - ▶ h believes s believe s wants ϕ
(the effect is to make them aware of your desire)

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 agenticify a system"
- ▶ Successfully applied to different domains (e.g. transport logistics)

Contract-Net Protocol

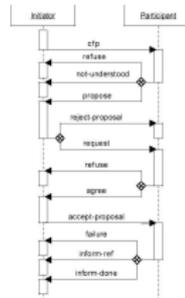


Problem

- ▶ 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**