

Agent Communication

Kostas Stathis
kostas@soi.city.ac.uk
www.soi.city.ac.uk/~kostas



Module outline

- Motivation: What is an agent
- Agent Infrastructure
 - Architectures
 - Mobile Agents
- Components of an agent
 - Planning
 - Learning
- Coordination of agents
 - Agent communication
 - Negotiation
- Applications
 - Information agents
 - Guest lecture

2 Kostas Stathis © 2002 + Laurent Magnin © 2005

Learning outcomes

- Appreciate why communication is important in MAS;
- Learn the basics of *Speech Act Theory*;
- Understand what is an *Agent Communication Language (ACL)*;
- Compare and contrast *KQML* and *FIPA*, with focus on semantics;
- Become aware of agent communication technologies.

3 Kostas Stathis © 2002 + Laurent Magnin © 2005

Overview

- Motivation
- Communication
- Speech Act Theory
- Agent Communication Languages (KQML, FIPA, Interaction Protocols)
- Comparison of KQML and FIPA
- Summary

4 Kostas Stathis © 2002 + Laurent Magnin © 2005

Motivation

(Social) Agents must be able to communicate in order to support:

- user-agent communication and interaction;
- co-operative problem solving;
- action co-ordination;
- inter-operation.

5 Kostas Stathis © 2002 + Laurent Magnin © 2005

Communication

The definition below is due to Russel & Norvig (1995) book on AI:

“ In general, communication is the intentional exchange of information brought about by the production and perception of signs drawn from a shared system of conventional signs.”

6 Kostas Stathis © 2002 + Laurent Magnin © 2005

Human communication

Humans:

- use a limited number of conventional sign (smiling, shaking hands, etc);
- have developed a complex, structured system of signs known as *language*.

7 Kostas Stathis © 2002 + Laurent Magnin © 2005

Types of meaning

The formal study of language provides for:

- how will the communicative actions be structured (syntax);
- what will the symbols of communicative actions denote (semantics);
- how will the communicative action symbols be interpreted (pragmatics).

Can we analyse human communication in order to build communicating agents?

8 Kostas Stathis © 2002 + Laurent Magnin © 2005

Communication as action

Communication is often interpreted as *language action* (or *communicative act*):

- acts are described by *episodes* ;
- each episode assumes a speaker *S* wanting to achieve goal *G* and, as a result, conveys proposition *P* to hearer *H* using communicative act *A*.

Note: we take here an *intentional* stance.

9 Kostas Stathis © 2002 + Laurent Magnin © 2005

Communication as action (cntd)

The speaker engages in the activities of:

- *Intention* - *S* wants that *H* believes (or does) *P*, because *S* believes (or wants) that *P* is (or to be) the case.
- *Generation* - *S* chooses the signs denoting *P*.
- *Synthesis* - *S* utters *A* having *P* as content.

E.g. John, please close the door.

10 Kostas Stathis © 2002 + Laurent Magnin © 2005

Communication as action (cntd)

The activities at the hearer *H* include:

- *Perception* - *H* perceives *A'* (ideally $A = A'$, but misconception is possible).
- *Analysis* - *H* infers that *A'* has possible meanings $P_1..P_n$ (propositions can have several meanings).
- *Disambiguation* - *H* infers that *S* intended to convey P_i (ideally $P_i = P$, but misinterpretation is possible).

11 Kostas Stathis © 2002 + Laurent Magnin © 2005

Communication as action(cntd)

Processes at the hearer *H* include (cntd):

- *Incorporation* - *H* decides to believe P_i (or rejects it if out of line with what *H* believes).

Can we formally generate, analyse, and disambiguate communicative acts?

12 Kostas Stathis © 2002 + Laurent Magnin © 2005

Speech act theory

Based on the work by Austin*:

Speech act theories focus on how language is used by people in their every day activities, to achieve their goals/intentions (also known as *pragmatic theories*).

*Austin (1962), *How to Do Things with Words*.

13 Kostas Stathis © 2002 + Laurent Magnin © 2005

Speech act theory

Consider the act "Shut the door!". We call:

- *the locution* - the physical utterance with context and reference, i.e. who is the speaker and the hearer, which door, etc;
- *the illocution* - the act of conveying intentions, i.e., speaker wants the hearer to close the door;
- *the perlocution* - the action that occur as a result of the illocution, i.e. hearer closes the door.

14 Kostas Stathis © 2002 + Laurent Magnin © 2005

VF...

- (<http://www.episteme.u-bordeaux.fr/Dico1/actes.htm>)
- Par la suite, Austin refonde sa typologie en trois catégories d'actes de langage :
 - 1. Les actes *locutionnaires* qui correspondent au fait de dire quelque chose.
 - 2. Les actes *illocutionnaires* accomplis en disant quelque chose.
 - 3. Les actes *perlocutionnaires* accomplis par le fait de dire quelque chose.

15 Kostas Stathis © 2002 + Laurent Magnin © 2005

Speech act classification

Searle* identified different types of speech acts:

- *representatives* - tell others how things are, e.g. "John is English";
- *directives* - try to get others do things, e.g. "Shut the door!";

*Searle (1969), *Speech Acts*, Cambridge University Press.

16 Kostas Stathis © 2002 + Laurent Magnin © 2005

Speech act classification(cntd)

- *commissives* - commit ourselves to future actions, e.g. "I promise to marry you";
- *expressives* - express our feelings and attitudes, e.g. "I am happy";
- *declarations* - bring about changes through our utterances, e.g. "I pronounce you man and wife".

Debatable which classification is appropriate.

17 Kostas Stathis © 2002 + Laurent Magnin © 2005

Speech act components

In general a speech act can be seen to have two main components:

- a *performative* verb
e.g. inquire, inform, ...;
- the *propositional* content
e.g. "shut the door".

18 Kostas Stathis © 2002 + Laurent Magnin © 2005

Speech act examples

- Informing that the door is shut:
 - performative=inform
 - content= "(shut door)" or "shut(door)"
 - speech act= "The door is shut!"
- Inquiring if the door is shut:
 - performative=inquire
 - Content= "(shut door)"
 - speech act= "Is the door shut?"
- Order
 - Performative = "request", content= "(shut door)"

19 Kostas Stathis © 2002 + Laurent Magnin © 2005

Agent Communication

Speech acts form messages in an Agent Communication Language (ACL).

- An ACL is a high-level language whose primitives and structures are expressly tailored to support the exchange of messages amongst multiple artificial agents;
- An ACL exists in a logical layer on top of existing infrastructures such as TCP/IP, HTTP, or IIOP.

20 Kostas Stathis © 2002 + Laurent Magnin © 2005

Agent Communication (cntd)

The two prevalent ACLs are:

- KQML (Knowledge Query and Manipulation Language);
- FIPA ACL (Foundation of Intelligent Physical Agents).

21 Kostas Stathis © 2002 + Laurent Magnin © 2005

KQML

Developed by the (D)ARPA *knowledge sharing initiative*.

- based on the idea that communication requires a common language;
- requires that common language is divided into syntax, semantics and pragmatics, using:
 - KIF - syntax of content;
 - Ontolingua - semantics of content;
 - speech acts - pragmatics of communication;

22 Kostas Stathis © 2002 + Laurent Magnin © 2005

KQML: Syntax

KIF (Knowledge Interchange Format) :

- is based on first-order logic set theory;
- encodes declarative knowledge;
- Lisp like syntax, e.g.:
 - (forall ?x(=>(P ?x)(Q ?x)))
 - (=>(apple ?x)(red ?x))
 - (= (size chip1) 20)
- see <http://logic.stanford.edu/kif/dpans.html> for more details.

23 Kostas Stathis © 2002 + Laurent Magnin © 2005

KQML: Semantics

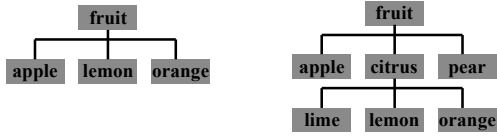
Ontology: a common vocabulary and agreed upon meanings to describe a subject domain.

- Ontolingua is a language for building, publishing, and sharing ontologies
 - ontologies can be automatically translated into other content languages, including KIF, Prolog, etc.
 - the main language included primitives for combining ontologies.
- see www.ksl.stanford.edu/software/ontolingua/ for more details.
- Also protege.stanford.edu : Ontology editor

24 Kostas Stathis © 2002 + Laurent Magnin © 2005

KQML: Semantics (cntd)

Example (by Finin and Lambrou)



25 Kostas Stathis © 2002 + Laurent Magnin © 2005

KQML: Pragmatics

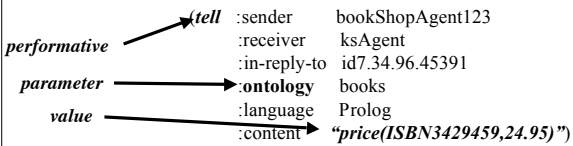
■ The pragmatics define the performative verbs, for example:

- ask-if ('is it true that...');
- perform ('please perform the following action...');
- tell ('it is true that ...');
- reply ('the answer is ...');

More on pragmatics later (see ACL semantics p38).

26 Kostas Stathis © 2002 + Laurent Magnin © 2005

A KQML Message



Msg above represents a single KQML *speech act* described by a list of *attribute/value pairs* e.g. :content, :language, :from, :in-reply-to.

27 Kostas Stathis © 2002 + Laurent Magnin © 2005

A KQML Dialogue

Consider agents A and B "talking" about the prices of books bk1 and bk2:

- A to B: (ask-if (> (price bk1) (price bk2)))
- B to A: (reply true)
- B to A: (inform (= (price bk1) 25.50))
- B to A: (inform (= (price bk2) 19.99))

For convenience msg format above is simplified and attribute/value pairs for :ontology etc. are omitted.

28 Kostas Stathis © 2002 + Laurent Magnin © 2005

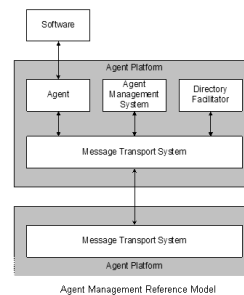
FIPA

FIPA (Foundations of Intelligent Physical Agents)

- its purpose is to promote the success of emerging agent-based applications, services and devices.
- its goal is pursued by making available in a timely manner, internationally agreed specifications for interoperable agent-based applications, services and devices.
- see <http://www.fipa.org/> for more details.

29 Kostas Stathis © 2002 + Laurent Magnin © 2005

Agent Management in FIPA



FIPA provides a reference model for agent:

- creation;
- registration;
- location;
- *communication*;
- migration; and
- retirement.

30 Kostas Stathis © 2002 + Laurent Magnin © 2005

FIPA ACL

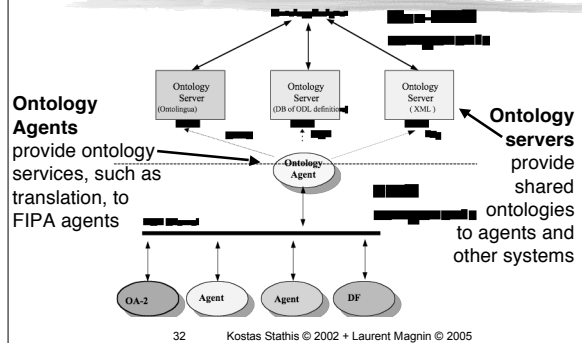
- Like KQML, FIPA ACL is based on idea of Speech Acts (see performatives below).

- agree
- cancel
- cfp
- confirm
- disconfirm
- failure

- inform
- inform-if
- inform-ref
- not-understood
- propose
- query-if
- query-ref
- refuse
- reject-proposal
- request
- request-when
- request-whenEVER
- subscribe

31 Kostas Stathis © 2002 + Laurent Magnin © 2005

Ontologies in FIPA



32 Kostas Stathis © 2002 + Laurent Magnin © 2005

FIPA ACL Example

ACL message

```
(inform
 :sender agent1
 :receiver hpl-auction-server
 :content
 (price (bid good02) 150)
 :in-reply-to round-4
 :reply-with bid04
 :language sl
 :ontology hpl-auction
)
```

Note: FIPA uses a different content language from KQML called SL (see later), which is based on modal logic.

33 Kostas Stathis © 2002 + Laurent Magnin © 2005

FIPA Interaction Protocols

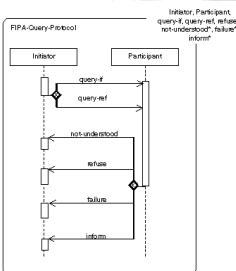
Ongoing conversation between agents often fall in typical patterns:

- typical patterns of message exchange are called *interaction protocols* ;
- FIPA pre-specifies a number of protocols.

Advantage: ease of implementation (an agent can engage in meaningful interactions simply by following an interaction protocol).

34 Kostas Stathis © 2002 + Laurent Magnin © 2005

Example: Query-Protocol

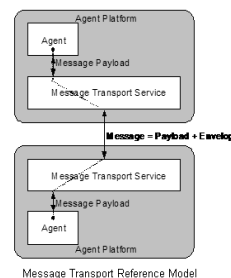


The protocol states that:

- IF an agent asks another agent if a proposition holds or not
- THEN the participant must reply with answer informing the initiator, or may refuse to answer, or fail to understand the question.

35 Kostas Stathis © 2002 + Laurent Magnin © 2005

FIPA Transport management



- a platform provides to each agent a *channel*;
- a transfer *protocol* is used to transfer messages between channels;
- the transport *service* delivers messages within a platform or between platforms;
- ACL is the *payload* of the transport service and protocol.
- the *envelope* contains transport information.

Message Transport Reference Model

36 Kostas Stathis © 2002 + Laurent Magnin © 2005

Using FIPA ACL (Java-based)

```
ACLMessage incoming;
ServiceAgent me;
...
%suppose that agent me has received an incoming request about whether
% the price of bk1 is £25, and wants to reply that this is true. Here is an
% example of how to formulate reply using a FIPA like platform.

ACLMessage reply = new ACLMessage("inform");
reply.setDest(msg.getSource());
reply.setSource(me.getName());
reply.setContent("true");
reply.setReplyTo(msg.getReplyWith());
reply.setProtocol("fipa-request");
reply.setOntology(Constants.ONTOLOGY);
reply.setLanguage(Constants.LANGUAGE);
me.send(reply);
...
```

37 Kostas Stathis © 2002 + Laurent Magnin © 2005

Comparing ACLs

In developing agent communication one needs to know: Which ACL is better?

- FIPA?
- KQML?
- Some other?

Comparison involves, amongst other things, asking how meaning is assigned to an ACL's speech acts.

38 Kostas Stathis © 2002 + Laurent Magnin © 2005

ACL Semantics

We will examine the semantics of:

- KQML;
- FIPA;
- KQML vs FIPA;

Semantics: Not about what does the content of an act denotes, but how should the act be interpreted by an agent.

39 Kostas Stathis © 2002 + Laurent Magnin © 2005

KQML Semantics: Objectives

- to capture intuitions expressed about KQML;
- to avoid commitments to specific system designs and architectures, agent theories, problem-solving strategies, etc.
- to offer a formalism that might be understood by people that are not logicians;
- to (loosely) model performatives as speech acts.

40 Kostas Stathis © 2002

KQML semantics: Assumption

Describing the state of an agent before sending a message and after receiving it is a useful basis for ascribing meaning to the communicative acts (Lambrou 1996, PhD Thesis).

↓

A two-step process:

- Which agents' states?
- Having a language to describe agents' states.

41 Kostas Stathis © 2002

KQML semantics: which agent states?

- *Preconditions* - indicate the necessary state for an agent in order to send a performative and for the receiver to accept it and successfully process it.
- *Postconditions* - describe the states of both participants after the successful utterance of a performative (by the sender) and after the receipt and processing (but before a counter utterance) of a message (by the receiver).

42 Kostas Stathis © 2002 + Laurent Magnin © 2005

KQML Example: TELL(A,B,P)

A tells B that A believes P to be true (for A).

- Pre(A): $\text{bel}(A,P) \wedge \text{know}(A, \text{want}(B, \text{know}(B,S)))$
and $S = \text{bel}(B,P) \text{ or } \neg \text{bel}(B,P)$
- Pre(B): $\text{intend}(B, \text{know}(B, S))$
- Post(A): $\text{know}(A, \text{know}(B, \text{bel}(A,P)))$
- Post(B): $\text{know}(B, \text{bel}(A,P))$
- Completion: $\text{know}(B, \text{bel}(A,P))$
- The completion and post conditions hold unless a SORRY or ERROR suggests B's inability to properly acknowledge the TELL.

43 Kostas Stathis © 2002

FIPA ACL Semantics

Define semantics of performatives in terms of:

- *Feasibility Preconditions* - define the conditions that ought to be true before an agent may plan to execute a communicative act;
- *Rational Effects* - the effects that an agent hopes to bring about by performing an action (but with no guarantee that they will be achieved).

FPs and REs involve agents state descriptions in SL.

44 Kostas Stathis © 2002 + Laurent Magnin © 2005

Semantic Language (SL)

- SL is the formal language used to define the semantics of FIPA ACL;
 - logical propositions are expressed in a logic of mental attitudes and actions;
 - the logical framework is a first order modal language with identity (similar to Cohen & Levesque);
 - SL provides formalizations for three primitive mental attitudes: Belief, Uncertainty and Choice (or Goal);
- SL can express propositions, objects and actions.

45 Kostas Stathis © 2002 + Laurent Magnin © 2005

BUC

(<http://www.fipa.org/specs/fipa00008/SC000081.html>)

- (B <agent> <expression>)Belief. It is true that agent believes that expression is true.
- (U <agent> <expression>)Uncertainty. It is true that agent is uncertain of the truth of expression. Agent neither believes expression nor its negation, but believes that expression is more likely to be true than its negation.
- (I <agent> <expression>)Intention. It is true that agent intends that expression becomes true and will plan to bring it about.

46 Kostas Stathis © 2002 + Laurent Magnin © 2005

FIPA ACL Semantics: Inform

i informs j about ϕ being true.

- $\langle i, \text{inform}(j, \phi) \rangle$
FP: $B_i\phi \wedge \neg B_i(B_j\phi \vee U_j\phi)$
RE: $B_j\phi$
- The sender:
 - believes that proposition ϕ is true;
 - intends that receiver j also comes to believe that ϕ is true;
 - does not already believe receiver has any knowledge about ϕ .
- It's up to receiver to adopt the belief.

47 Kostas Stathis © 2002 + Laurent Magnin © 2005

KQML vs FIPA: differences?

- Different semantics; mapping performatives between FIPA and KQML is a fruitless exercise.
- Different treatment of the "administration primitives"; in FIPA ACL register, unregister, etc., are treated as requests with reserved meaning;
- FIPA ACL has no *facilitation primitives*, e.g., broker, recommend, recruit, etc.;
- KQML does not commit to a content language while FIPA does.

48 Kostas Stathis © 2002 + Laurent Magnin © 2005

KQML vs FIPA: which one?

Finin and Lambrou argue that:

- programmers do not care about semantics, especially when applications do not require modalities (belief, intention, etc.);
- similar syntax helps that a developer will not have to alter the code about messages.
- the code that processes the primitives should change depending on whether the code follows the proper semantics.

49 Kostas Stathis © 2002 + Laurent Magnin © 2005

KQML vs FIPA: which one?(cntd)

- FIPA ACL is more powerful with composing new primitives (power due to SL language as a content language to describe agents' states).
- KQML's weakness is its non-commitment to a content language.
- Both have shortcomings; see references at the end of the lecture.

50 Kostas Stathis © 2002 + Laurent Magnin © 2005

Alternative approaches

- CORBA;
- Java (RMI, EJB, Jini);
- OLE/COM/DCOM/ActiveX (Microsoft);
- SOAP (XML-based);
- Service-based platforms (e.g. JXTA);
- Services-based languages (e.g. e-Speak).

51 Kostas Stathis © 2002 + Laurent Magnin © 2005

Summary

- Communication
- Speech act theory
- Agent communication languages
 - KQML
 - FIPA
- Comparison of KQML and FIPA
- Alternative approaches

52 Kostas Stathis © 2002 + Laurent Magnin © 2005

Websites

KQML	http://www.cs.umbc.edu/kqml/
KIF	http://logic.stanford.edu/kif/
Ontolingua	http://www-ksl-svc.stanford.edu:5915/&service=frame-editor
FIPA	http://www.fipa.org/
DAML	http://www.daml.org/

53 Kostas Stathis © 2002 + Laurent Magnin © 2005

Further reading

- [1] M. Wooldrige. Reasoning about Rational Agents. The MIT Press, 2000, Chapter 7
- [2] M. Huhns, L. Stephens. Multiagent systems and societies of agents. In Multiagent Systems - A Modern Approach to Distributed Artificial Intelligence, G. Weiss (Ed.), The MIT Press, 2001, p.79-120.
- [3] F. Dignum and M. Greaves. Issues in Agent Communication: An Introduction. In F. Dignum and M. Greaves(eds.) Issues in Agent Communication (LNCS-1916), Springer-Verlag, 2000, pages 1-16. <http://www.cs.uu.nl/~dignum/papers/papers.html>
- [4] Y. Labrou, T. Finin and Y. Peng. The current landscape of AgentCommunication Languages. Intelligent Systems, volume 14, number 2, March/April 1999, IEEE Computer Society. <http://umbc.edu/~finin/papers/>
- [5] M. P. Singh. Agent Communication Languages: Rethinking the Principles. <http://www.csc.ncsu.edu/faculty/mpsingh/papers/index.html>

54 Kostas Stathis © 2002 + Laurent Magnin © 2005

Further reading (cntd)

- [6] Jeremy Pitt, Abe Mamdani: Some Remarks on the Semantics of FIPA?s Agent Communication Language. *Autonomous Agents and Multi-Agent Systems* 2(4): 333-356 (1999)
- [7] Jeremy Pitt, Abe Mamdani: Designing Agent Communication Languages for Multi-agent Systems. *MAAMAW* 1999: 102-114
- [8] Cohen, P. R. and Levesque, H. J. (1990b). Rational interaction as the basis for communication. In Cohen, P. R., Morgan, J., and Pollack, M. E., editors, *Intentions in Communication*, pages 221-256. The MIT Press: Cambridge, MA.