Agent and Multi-Agent Systems: architectures and reasoning

Interaction mechanisms: models and implementation

29.09.2021

CentraleSupélec- SAFRAN AI Training

Before to start !

https://www.wooclap.com/XKIRDK

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Interaction Mechanisms

Interaction Mechanisms

Interaction

- An interaction occurs when two or more agents are brought into a dynamic relationship through a set of reciprocal actions.
- Interactions develop out of a series of actions whose consequences in turns have an influence on the future behavior of agents.

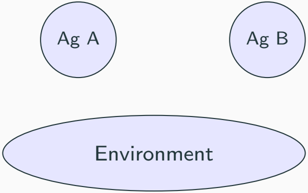
Problems in MAS

- Agents run asynchronously
- Method invocation is synchronous

Asynchronous interactions

PRS Architecture

- Actions modify the environment
- (Asynchronous) perception of the modification



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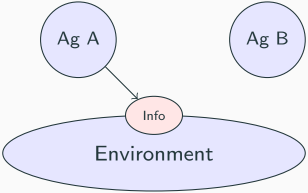

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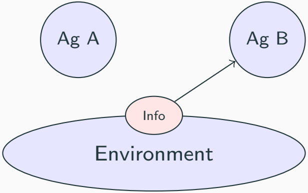

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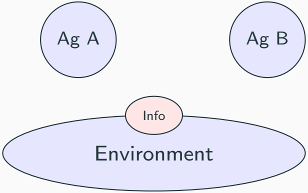


Interaction Mechanisms

Interaction situations

- According to compatibility of goals
    - Agents cooperate when their goals are compatible
    - Agent compete when their goals are incompatible
- According to agent ability to available resources
    - Conflicts arises when resources are insufficient.
- According to agent ability to fulfill tasks
    - Collaboration arises when agent have insufficient ability to solve complex problems

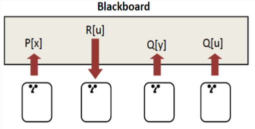
Indirect interactions

Indirect interactions

- No intention to communicate to a specific agent
- Agents interact through an intermediate entity
- This medium supplies specific interaction mechanisms and access rules
- These rules and mechanisms define agent local context and perception

Artifact-mediated interaction: Blackboard systems

- Agents access a shared artifact (stores data) that: they can observe and can modify
- Such artifact is a communication channel characterized by an intrinsically broadcast transmission.
- Specific laws regulating access to this medium
- It represents a part of agents' environment.



- The PLAN component of the Mission Control System for RADARSAT-1: an Earth observation satellite developed by Canada to monitor environmental changes and Earth's natural resources.
- Adobe Acrobat Capture : to decompose and recognize image pages to understand the objects, text, and fonts on the page (Adobe Acrobat as "OCR Text Recognition").
- Blackbord is used routinely in many military C4ISTAR systems for detecting and tracking objects.

Direct interactions

Direct interactions

Principle

- Intention to communicate to a specific agent
  - Messages with sender, recipient and structured content
- Information exchange
  - Communication/Conversation rules ("protocols"): Agent Communication Language (ACL)
  - Message structure (shared ontology): Content Language

Direct interactions

With whom?

With which agent to interact to obtain a service, a resource, . . . ?

Problem: heterogeneity

Communication layers:

- Transport level → environment (network)
- Syntax level → message structure
- Semantic level → knowledge representation
- Pragmatic (communication) level → protocols

⇒ This has to be normalised!

Speech Acts Theory I

Searle, 1969

Communication is an action

Communicate → change interlocutor's mental state

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Communication is an action

Communicate → change interlocutor's mental state

Three aspect of a speech act

- Locutionary: the act of saying (What was said. "Is there any salt?")
- Illocutionary: the intention of the speech (What was done. "Please give me some salt")
- Perlocutionary: the effect of the speech (What happened as a result. "might cause somebody to pass the salt")

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Illocutionary act

Performative Verb (Propositional Content)

Speech Acts Theory I

Examples

Content = 'the door is closed'

- Performative = request
    - speech act= 'please close the door'
- Performative = inform
    - speech act= 'the door is closed'
- Performative = inquire
    - speech act= 'is the door closed?'

Speech Acts Theory II

Different researchers, different theories. . .

Searle 1972

- Assertive /representatives acts: *Facts*(informing, making a claim)
  ⇝ 'it is raining'
- Directive acts: *Actions* + *Questions* (requesting, commanding)
  ⇝ 'please make the tea'
- Promissive /Commisive acts: *Commitments*(promising , refusing)
  ⇝ 'I promise to ...'
- Expressive acts: *Emotions* (expressing mental states
  ⇝ 'thank you!'
- Declarative acts: *Protocols* (effecting change to state of the world)
  ⇝ 'such as declaring war or naming'

Speech Acts Theory II

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Sperber & Wilson

- Say that: assertions and promisses
- Say about: orders
- Ask if: questions

⇒ Need to define the **semantics** of each performative!

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 the de-facto standard)

FIPA: Foundation for Intelligent Physical Agents

KQML: Knowledge Query and Manipulation Language

KIF: Knowledge Interchange Format

Message structure

KQML- KIF

- KQML: Knowledge Query and Manipulation Language
- . . . is an 'outer' language, defines various acceptable 'communicative verbs' performatives
- KIF (Knowledge Interchange Format): a logical language to describe knowledge, content or domain (first order logic).

Examples

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

Message structure

KQML- KIF: message format

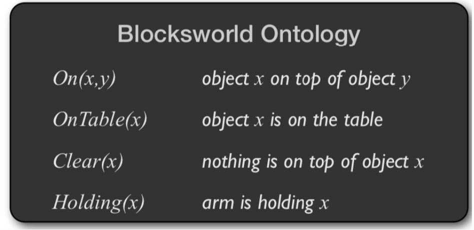
```
(performative
  :sender        <word>    :receiver     <word>
  :in-reply-to   <word>    :reply-with   <word>
  :language    <word>    :ontology     <word>
  :content       <expression>
)
```

Message structure

Remark : KQML and Ontology

- In oder to be able to communicate, agents need to agree on the words (terms) they use to describe the domain.
- A formal specification of a set of terms is known as an ontology
- The role of an ontology is to fix the meaning of the terms used by agents.

BlocksWorld



Blocksworld Ontology

On(x,y)	*object x on top of object y*
OnTable(x)	*object x is on the table*
Clear(x)	*nothing is on top of object x*
Holding(x)	*arm is holding x*

Message structure

KQML/KIF

- KQML/KIF were very successful, but also some problems
- List of performatives (up to 41!) not fixed (interoperability problems)
- No formal semantics, only informal descriptions of meaning
- KQML completely lacks commissives, this is a massive restriction!
- Performative set of KQML rather ad hoc, not theoretically clear or very elegant

⇝These lead to the development of FIPA ACL

FIPA-ACL standard

http://www.fipa.org

Message structure

- Recipient(s) = list of agent IDs
  - *The environment must provide each agent with a unique ID*
- Performative: 1 value in a list of predefined possible acts (20 performative in FIPA)
- Content: expressed in any knowledge representation language
  - *First Order Logics, Lisp syntax, . . .*

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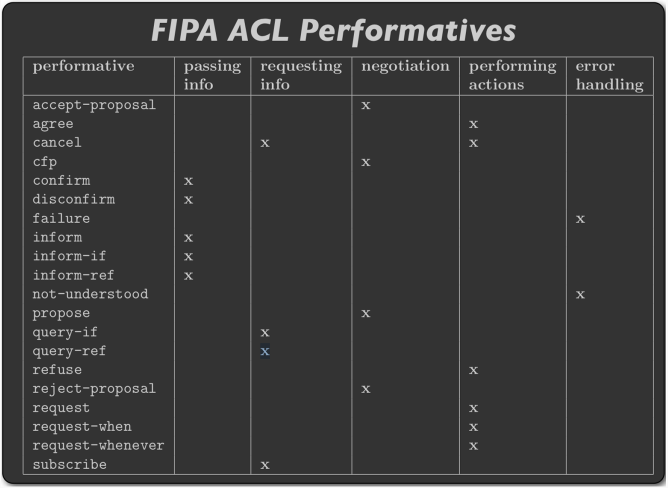
Usual representation: $\langle snd, perf(rcv, content)\rangle$

FIPA-ACL standard

Example

```
(inform
  : sender agent 1
  : receiver agent 5
  : content (price good200 150)
  : language sl
  : ontology hpl-auction
 )
```

FIPA-ACL standard



FIPA ACL Performatives

performative	passing info	requesting info	negotiation	performing actions	error handling
accept-proposal			x		
agree				x	
cancel		x		x	
cfp			x		
confirm	x				
disconfirm	x				
failure					x
inform	x				
inform-if	x				
inform-ref	x				
not-understood					x
propose			x		
query-if		x			
query-ref		x			
refuse				x	
reject-proposal			x		
request				x	
request-when				x	
request-whenever				x	
subscribe		x			

Direct Interactions Implementation

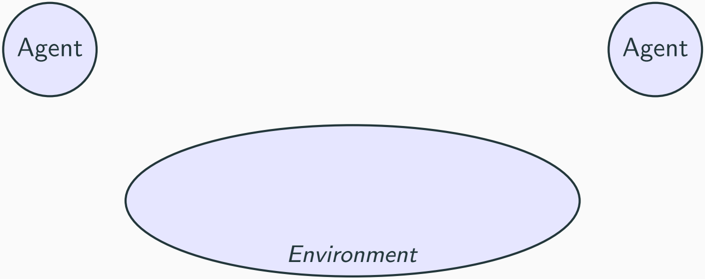
Here is what we cannot do:

```
class Environment:
    ... environment definition ...

class Agent():
    ... agent definition ...
    ... procedural loop ...

    def receive(message):
        ... what to do with the message ...
```

How does this work? Asynchronous message sending



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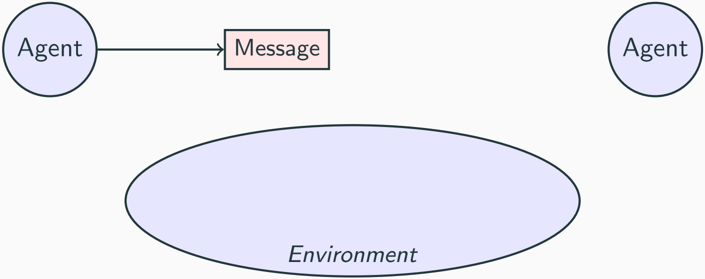

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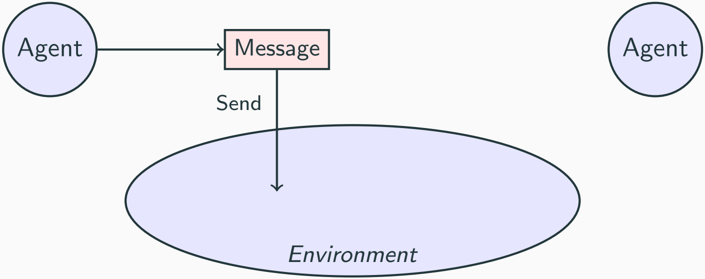

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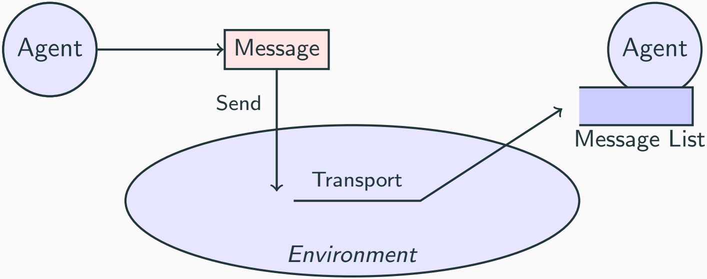

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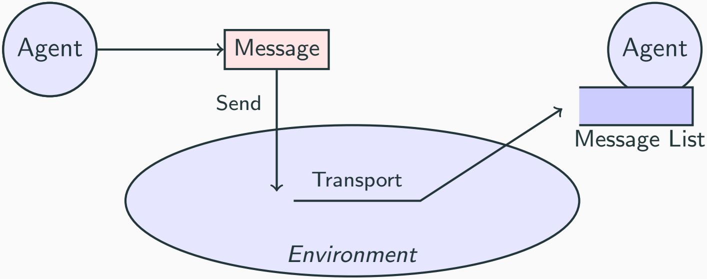
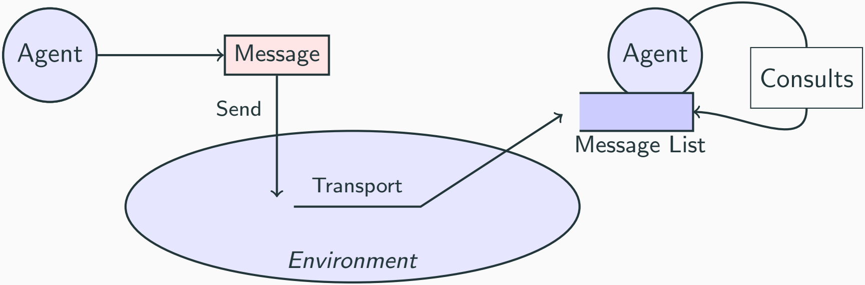


Synchronous method calls

How does this work? Asynchronous message sending



Synchronous method calls | Asynchronous

Interaction protocols

Interaction protocols I

Protocols

Describes how agents can interact in the MAS

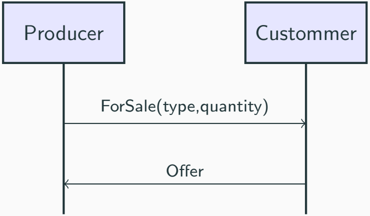
Interaction protocols I

Protocols

Describes how agents can interact in the MAS

AUML (Agent Unified Modeling language) standard

- Inspired from UML sequence diagrams
- Describes message exchange between roles
  - An agent can adopt several roles
  - A role can be fulfilled by several different agents



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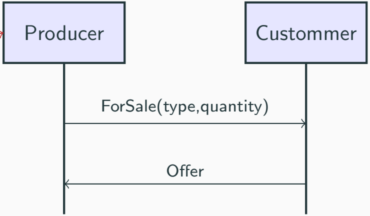

Role

Several agents can have the same role

Interaction protocols I

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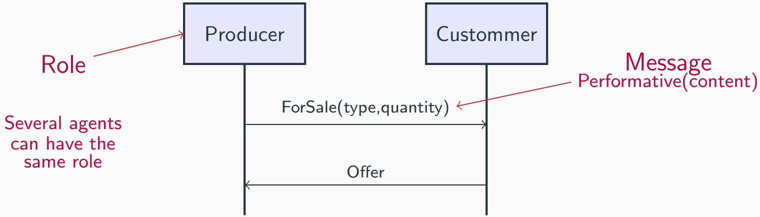

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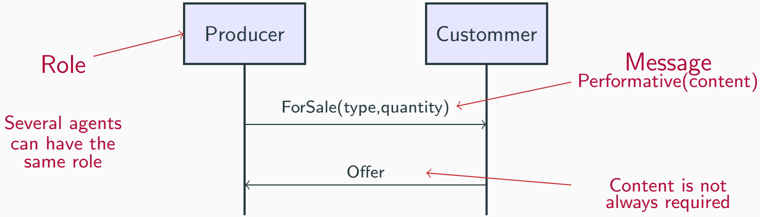
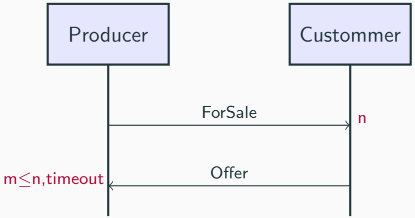


Interaction protocols II

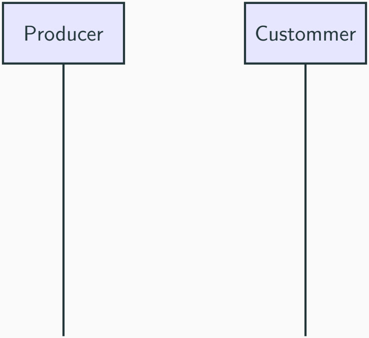
Conditions

- Number of messages sent (arrow end)
- Timeouts
  - Messages received after timeout are considered out of the protocol



Interaction protocols III

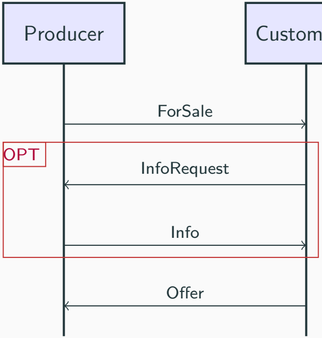
Operators



Interaction protocols III

Operators

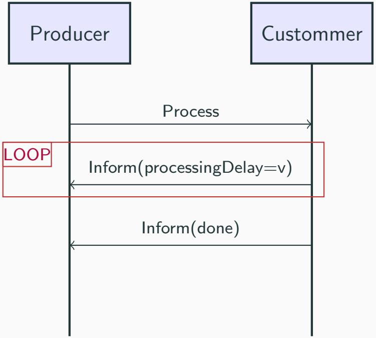
- OPT → some parts can be optional



Interaction protocols III

Operators

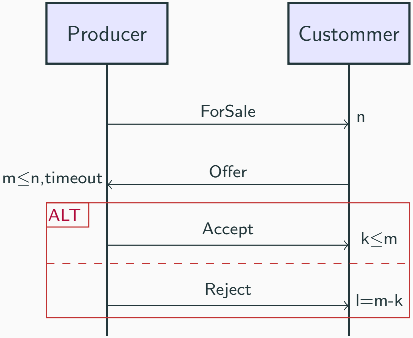
- OPT → some parts can be optional
- LOOP → some parts can be repeated randoml



Interaction protocols III

Operators

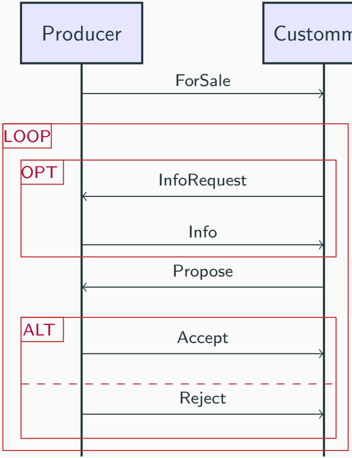
- OPT → some parts can be optional
- LOOP → some parts can be repeated randoml
- ALT → one or the other



Interaction protocols IV

Operators

- Operators can be combined

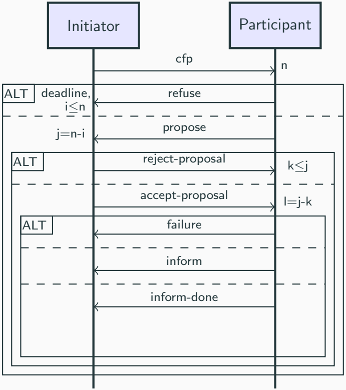


Interaction protocols V

Contract-Net Protocol (CNP)

Standard for agents to agree on a transaction.

- FIPA standard
- The “must-know” protocol



Interaction protocols

Contract-Net Protocol (CNP)

- 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, decentralization can improve global performance
- Successfully applied to different domains (e.g. transport logistics)

Using of messaging communication in Mesa

open and explore mesa.zip

Create two communicating agents named Alice and Bob. Create a third agent named Charles whose role is hold a variable v and process messages from Alice and Bob:

- On their turn, Alice and Bob ask Charles for the value of v, using a message;
- If the value is different from their preferred value, they send a message to Charles to change the value of v;
- On its turn, Charles reads its mailbox and processes all messages:
  - Messages that request information about v produce an anwer;
  - Messages that request a change to v are applied.

Implement the Alice-Bob-Charles example.