Agent and Multi-Agent Systems: architectures and reasoning

Interaction mechanisms : models and implementation

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CentraleSupélec –SAFRAN Training

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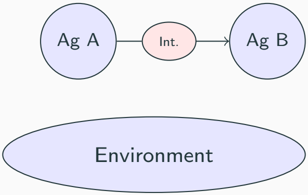
Interaction Mechanisms

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.



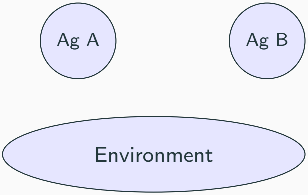
Asynchronous interactions

Problems in MAS

- Agents run asynchronously
- Method invocation is synchronous

PRS Architecture

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



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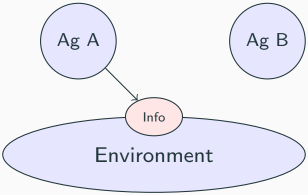

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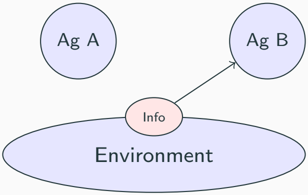

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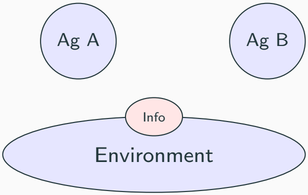

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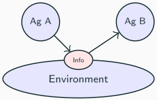


Example from session 1

➜ Alice and Bob manipulate a shared variable.

The action of each agent is triggered by the fact that the other agent modified the variable

Interactions

Two sorts of interactions

- Indirect interactions
  ➜ The agents act on the environment, the interaction is a side-effect of the actions
  See Alice and Bob's example

Interactions

Two sorts of interactions

- Indirect interactions
  ➜ The agents act on the environment, the interaction is a side-effect of the actions
  See Alice and Bob's example

- Direct interactions
  ➜ The agents have explicit communication actions (message sending)
  + *for cognitive agents : communication goals/intentions*

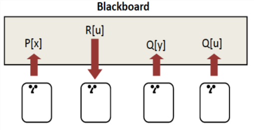
Indirect interactions

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.



For more details
https://en.wikipedia.org/wiki/Blackboard_system

Blackboard systems

Blackboard's limitations

- Centralized mechanism $\rightarrow$ possible failures
- All agents perceive the whole environment!

Blackboard systems

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Local view on the environment

e.g.: Money model or prey-predators

- Agents are spatially situated
  $\rightarrow$ localization variables in relation to the environment, (*e.g.* a grid)
- Each position in the grid is associated to a mini-blackboard

Direct interactions

Direct interactions

Principle

- Intention to communicate to a specific agent
  - Messages with sender & recipient
  - Control over the communication
- Information exchange
  - Structured content → content models and languages
  - Ontologies

Norms

- Agent Communication Language (ACL)
- Communication/Conversation rules ("protocols")

Speech Acts Theory I

Searle, 1969

Communication is an action

Communicate $\rightarrow$ change interlocutor's mental state

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Communication is an action

Communicate $\rightarrow$ 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 behind the speech

  What is expected to be the result: *get the salt*

- Perlocutionary: the effect of the speech

  What happened as a result, what was understood

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  What happened as a result, what was understood

Sucessful communication

$$\text{Illocutionary} = \text{Perlocutionary}$$

Speech Acts Theory II

Searle, 1969

Illocutionary act

Performative Verb (Propositional Content)

Speech Acts Theory II

Searle, 1969

Illocutionary act

Performative Verb (Propositional Content)

Examples

Content = 'the door is closed'

- Performative = request *please close the door*
- Performative = inform *the door is closed*
- Performative = question *is the door closed?*

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Categories of performatives/speech acts

- Assertive (send information)
- Directive (send orders...or ask questions!)
- Commissive, Declarative, Expressive...

Agent Communication Language (ACL)

Agent Communication Language (ACL)

➜ Standard for messages exchanged among agents *e.g.* FIPA-ACL, KQML...

Message structure

- Sender of the message (agent ID)
- Receivers (agents IDs)
- Performative (predefined list of possible values)
- Propositional content in some content language (*e.g.* KIF)
- Conversation IDs
- Ontology

FIPA-ACL is the *de-facto* standard `http://www.fipa.org`

- FIPA: Foundation for Intelligent Physical Agents
- KQML: Knowledge Query and Manipulation Language
- KIF: Knowledge Interchange Format

FIPA-ACL standard

Example – KQML-based syntax

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

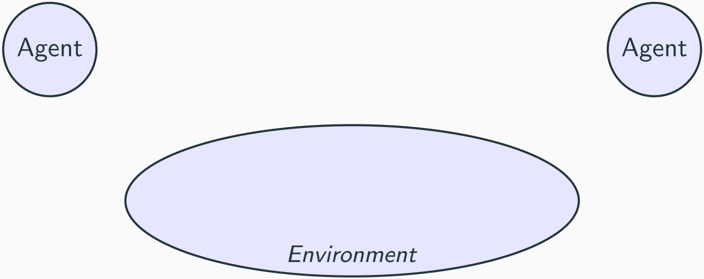
Note that the performative is the leader element!

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			

How does this work? Asynchronous message sending



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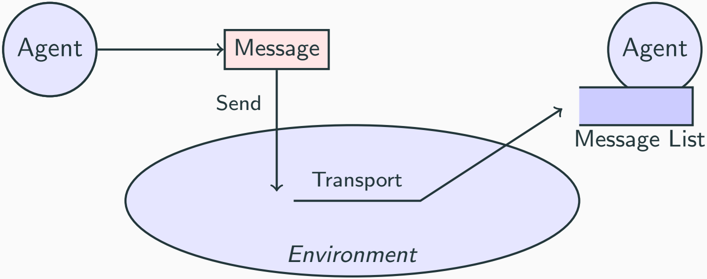
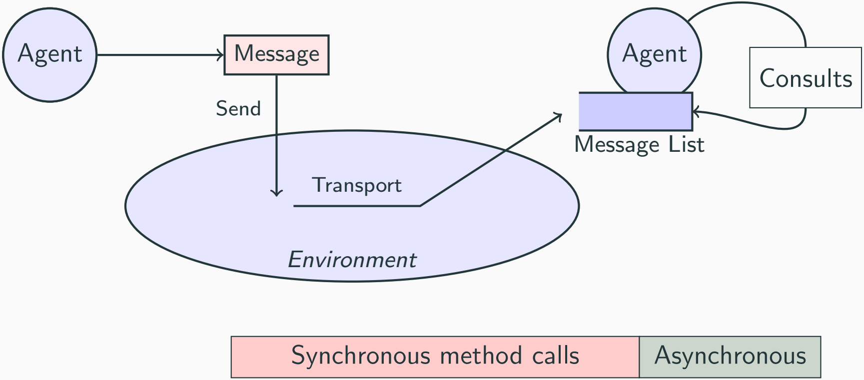


Synchronous method calls

How does this work? Asynchronous message sending



Interaction protocols

Interaction protocols I

Protocols

Describes how agents can interact in the MAS

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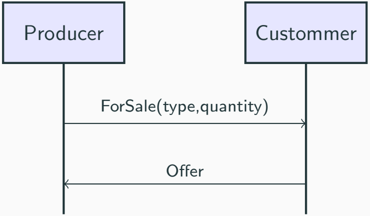
Describes how agents can interact in the MAS

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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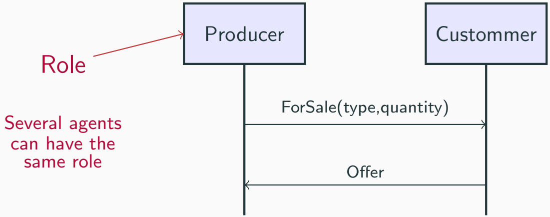

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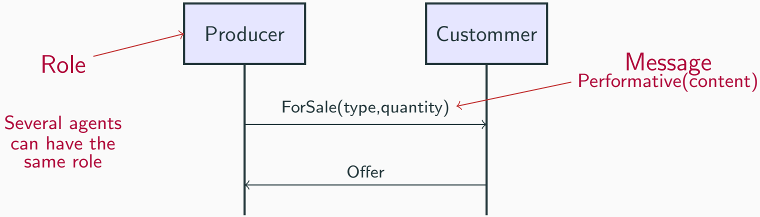

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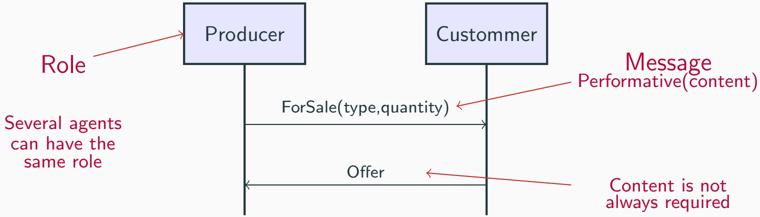
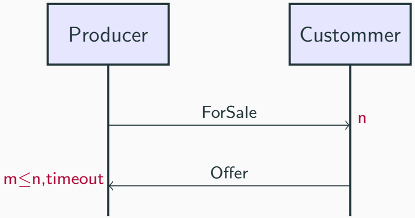


Interaction protocols II

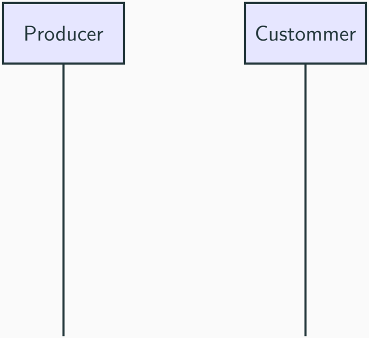
Conditions

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



Interaction protocols III

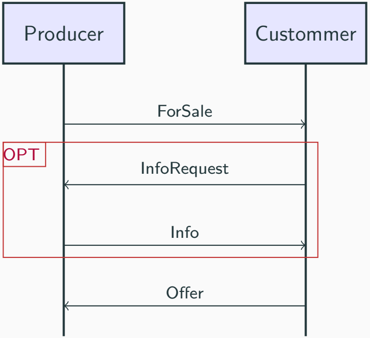
Operators



Interaction protocols III

Operators

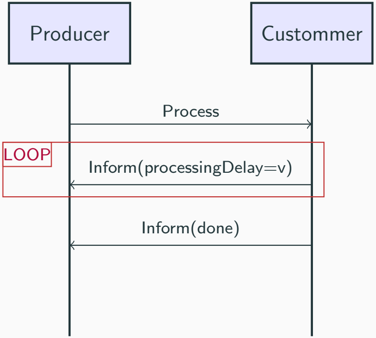
- OPT $\rightarrow$ some parts can be optional



Interaction protocols III

Operators

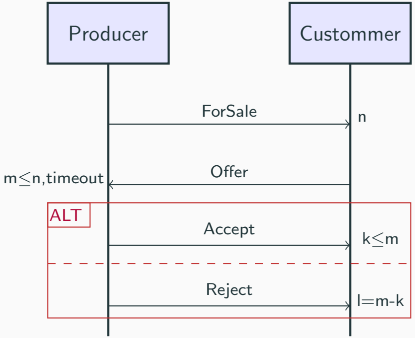
- OPT → some parts can be optional
- LOOP → some parts can be repeated randoml



Interaction protocols III

Operators

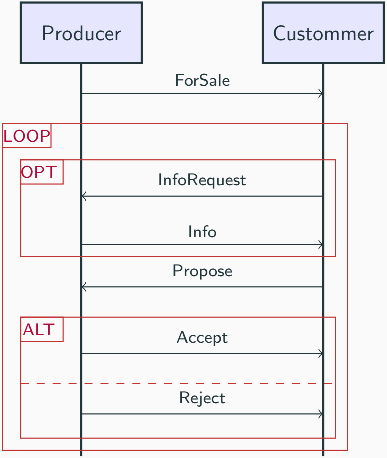
- OPT → some parts can be optional
- LOOP → some parts can be repeated randoml
- ALT → one or the other



Interaction protocols IV

Operators

- Operators can be combined



Interaction protocols

Contract-Net Protocol (CNP)

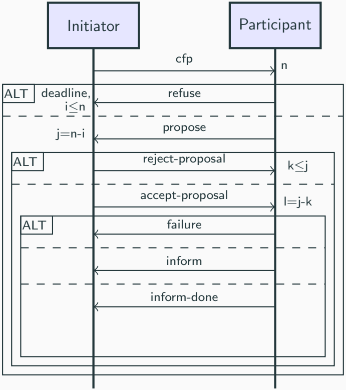
- One of the oldest, most widely used agent interaction protocols
- A manager agent announces one or several tasks, agents place bids for performing them
- Task is assigned by manager according to evaluation function applied to agents' bids (e.g., choose cheapest agent)
- Idea of exploiting local cost 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)

Interaction protocols V

Contract-Net Protocol (CNP)

Standard for agents to agree on a transaction.

- FIPA standard
- The “must-know” protocol



Communication in Mesa

Using of messaging communication in Mesa

open and explore mesa.zip

with the help of the file PW3_ExploringMesa.pdf

(correction provided, but you need to understand the mechanism)

Using of messaging communication in Mesa

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.

Dialogue Games: Negotiation

- Considerable efforts have been expended on the design of artificial languages for agent communication (KQML, FIPA ACL).
- However, agents participating in conversations have too many choices of what to utter at each turn $\rightsquigarrow$ agent dialogues may endure a state-space explosion.
- Appearance of Dialogue games: rule-governed interactions between two or more players (or agents), where each player's move consists in making utterances, according to defined set of rules.

A dialogue

Example

Buyer :	Can't you give me this 806 a bit cheaper?
Seller :	Sorry that's the best I can do. Why don't you go for a Polo instead?
Buyer :	I have a big family and I need a big car (B1)
Seller :	Modern Polo are becoming very spacious and would easily fit in a big family. (S1)
Buyer :	I didn't know that, let's also look at Polo then

Dialogue types [Walton and Krabbe, 1995]

A categorization based on 1) the information the participants have at the begining of a dialogue, 2) their individual goals for the dialogue and 3) the goals they share.

Types of dialogue	Initial situation	Participant's goal	Goal of dialogue
Persuasion	Conflicts of opinions	Persuade other party	Resolve or clarify issue
Negotiation	Conflicts of interests	Get what you most want	Reasonable settlement
Information seeking	One party lacks information	Acquire or give information	Exchange Information
Deliberation	Dilemma or practical choice	Coordinate goals or actions	Decide best course of action
...			

What is Negotiation?

In MAS and according to [Rahwan et al., 2004]

"Negotiation is a form of interaction in which a group of agents, with conflicting interests and a desire to cooperate, try to come a mutually acceptable agreement on the division of scarce resources".

Coordination?

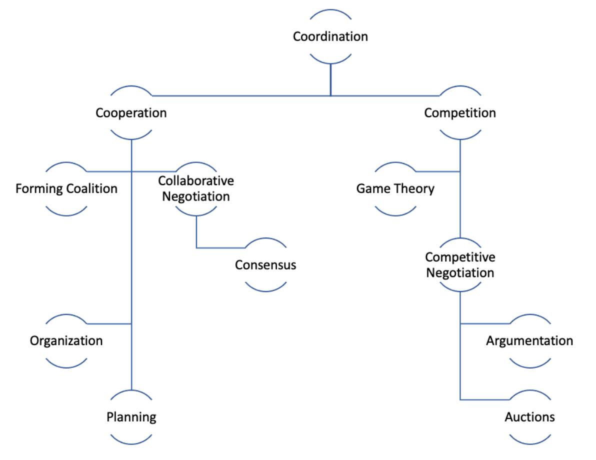
Coordination - Definition 1 [Malon,1988]

"The set of supplementary activities which need to be carried out in a multi-agent environment, and which a single agent pursuing the same goals would not accomplish."

Coordination - Definition 2 [Ferber, 1995]

"The coordination of action can be defined as the articulation of the individual actions accomplished by each agents in such a way that the whole ends up being a coherent and high performance operation. It is a matter of arranging the behaviors of the agents in time and space in such a way that the group action is improved, either through better performance or through a reduction in conflict. So the coordination of actions is one of the main methods of ensuring cooperation between autonomous agents."

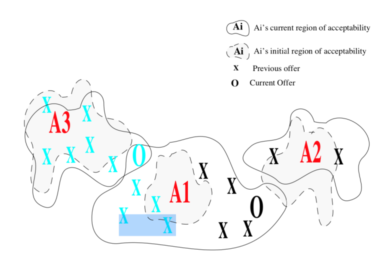
Coordination?



Source: borrowed from Aurélie Beynier's course

Automated Negotiation Mechanisms

- **The negotiation agreement space**: a "distributed search through a space of potential agreements" (Jennings et al., 2001)
  - a set of deals $\Psi = \{\Omega_1, \ldots, \Omega_n\}$, with n the size of the search space,
  - a deal is defined in terms of a set of attributes $A_1, \ldots, A_n$, where $A_i = (a_i^1, \ldots, a_i^m)$ (search space is a multidimensional Euclidean space).



Source: A space of negotiation agreement (Jennings et al. 2000)

Automated negotiation

- **Evaluating deals**: to evaluate a deal (outcome) at the agent level, we need to capture agent preference over Ψ
    - preferences of agent i can be captured using a preference relation $\succsim_i$ over Ψ
    - the preference relation of agent i is often described in termes of a *utility function* that captures the level of satisfaction of an agent with a particular outcome
    - At the global evaluation we may use notions such as dominance and Pareto optimality

Automated negotiation

- **Negotiation mechanisms**. Given a set of agents, a set of resources (decision, actions,...):
  - the aim is to find an allocation that is better in some sense, if such allocation exists.
  - a mechanism specifies a set of rules, such as: what agents are allowed to say and when[1], how allocations are calculated, whether calculations are done using a centralized algorithm or in a distributed fashion, and so on.

[1] see Communication protocol in course Interaction Mechanisms

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  - a mechanism specifies a set of rules, such as: what agents are allowed to say and when[1], how allocations are calculated, whether calculations are done using a centralized algorithm or in a distributed fashion, and so on.
- **A collection of strategies**: one for each agent, which determine what proposals the agent will make. Usually, the strategy that an agent plays is private.

[1] see Communication protocol in course Interaction Mechanisms

Automated negotiation–Efficient mechanisms

- Simplicity: less computational processing and communication overhead
- Efficiency: producing good outcome. What is meant by 'good,' however, may differ from one domain to another.
- Distribution: does not involve a central decision-maker.
- Symmetry: should not be biased for or against some agent based on inappropriate criteria. Again, what constitutes an 'inappropriate' criterion depends on the domain.
- Stability: if no agent has incentive to deviate from some agreed-upon strategy or set of strategies (e.g. to bid truthfully in an auction).
- Flexibility: should lead to agreement even if agents did not have complete and correct private information in relation to their own decisions and preferences.

Approaches to automated negotiation

Game-theoretic analysis (Rosenschein & Zlotkin, 1994; Kraus, 2001; Sandholm, 2002);

- Game theory is a branch of economics that studies interactions between self-interested agents.
- The preferences of the agents over the possible agreement are modeled by using von Newmann and Morgenstern[2] utility function.
- Aim: to determine the optimal strategy by analyzing the interaction as a game between identical participants and seeking its equilibrium.
- the negotiation process involves basically an iterative exchange of offers and counter-offers.

[2] A rational agent behaves in such a way as to maximise his gain in a risky choice situation.

Example: Le dilemme du Prisonnier!

		Prisonnier 1	
		Dénonce	Dénonce pas
Prisonnier 2	Dénonce	(3 ; 3)	(5 ; 0)
	Dénonce pas	(0 ; 5)	(0,5 ; 0,5)

Game-theoretic analysis

- ✓ Outcomes are optimal
- ✓ Computing agent's equilibrium with complete information is polynomial.

- ✗ assumes that agent have unbounded computational resources and that the space of outcomes is completely known.
- ✗ Agent's utilities or preferences are usually assumed to be completely characterized prior to interaction ($\rightsquigarrow$incomplete information?), and fixed (no possibility to influence another agent's preference model or internal mental attitudes: beliefs, desires goals, etc.)

Approaches to automated negotiation

Heuristic-based approaches (Faratin, 2000; Kowalczyk & Bui, 2001; Fatima et al., 2002):

- Aim: use heuristics rules that produce good enough, rather than optimal, outcomes/decisions.
- it also involves an iterative exchange of offers and counter-offers.

Heuristic-based approaches

- ✓ the models are based on realistic assumptions; hence they provide a more suitable basis for automation and they can, therefore, be used in a wider variety of application domains;
- ✓ the designers of agents, who are not wedded to game theory, can use alternative, and less constrained, models of rationality to develop different agent architectures.

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- ✓ the designers of agents, who are not wedded to game theory, can use alternative, and less constrained, models of rationality to develop different agent architectures.

- ✗ Outcomes are sub-optimal (do not examine the full space of possible outcomes)
- ✗ It is difficult to predict precisely how the system and the constituent agents will behave, thus the models need extensive evaluation through simulation and empirical analysis.
- ✗ Agent's utilities or preferences are usually assumed to be completely characterized prior to interaction ($\rightsquigarrow$incomplete information?), and fixed (no possibility to influence another agent's preference model or internal mental attitudes: beliefs, desires goals, etc.)

Approaches to automated negotiation

Agents might:

- lack some information relevant to making a comparison between two potential outcomes,
- have limited resources preventing them from acquiring such information
- have the information, but lack the time needed to process it in order to make the comparison or the choice,
- have incoherent preferences,
- ...

$\rightsquigarrow$ process of acquiring information, resolving uncertainties, revising preferences, etc often take places as part of the negotiation itself.

Approaches to automated negotiation

Argumentation-based approaches (Kraus et al., 1998; Parsons et al., 1998; Sierra et al., 1998)

- Aim: allow to exchange different kinds of information, to "argue" about their beliefs and other mental attitudes during the negotiation process.
- an argument can be viewed as a piece of information to i) *justify* its negotiation stance, or ii) *influence* another agent's negotiation stance
- the process involves an iterative exchange of offers, counter-offers, threats, promises, persuasive arguments, etc.

Argumentation-based approaches

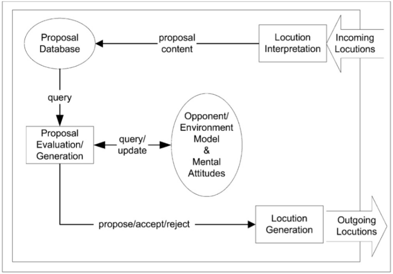
✓ allows to explain *explicitly* the opinion of the agent making the argument.
$\rightsquigarrow$ identifying an entire area of the negotiation space as being not worth exploring by the other agent

Argumentation-based approaches

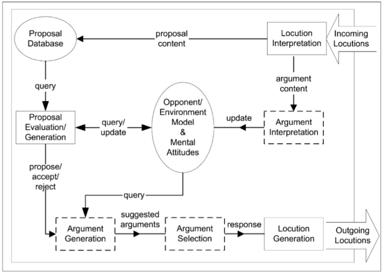
✓ allows to explain *explicitly* the opinion of the agent making the argument.
$\rightsquigarrow$ identifying an entire area of the negotiation space as being not worth exploring by the other agent

✗ add considerable overheads to the negotiation process, not least in the construction and evaluation of arguments

Argument-based negotiating agent



Conceptual elements of a classical negotiating agent



Conceptual elements of an argumentation-based negotiating agent
(the dashed lined boxes represent the additional components)

Argument-based negotiating agent

To design and build an agent capable of effective argumentation-based negotiation

- Mechanisms for passing proposals and their supporting arguments in a way that other agents understand.
- Techniques for generating proposals (counter-proposals or critiques) and for providing the supporting arguments;
- Techniques for assessing proposals (counter-proposals or critiques) and their associated supporting arguments;
- Techniques for responding to proposals (counter-proposals or critiques) and their associated supporting arguments;

Conclusion

Pour résumer

- Les SMA sont à l'intersection de plusieurs domaines scientifiques : informatique répartie et génie logiciel, intelligence artificielle, vie artificielle...
- Ils s'inspirent également d'études issues d'autres disciplines connexes notamment la sociologie, la psychologie sociale, les sciences cognitives et bien d'autres.
- C'est ainsi qu'on les trouve parfois à la base des : systèmes distribués; interface hommes-machines ; protocoles de communication et réseaux de télécommunications, robotique cognitive et coopération entre robots, applications distribuées comme le web, l'Internet, le contrôle de trafic routier, le contrôle aérien, les réseaux d'énergie, etc;

Pour résumer

Un SMA est généralement caractérisé par :

1. chaque agent a des informations ou des capacités de résolution de problèmes limitées, ainsi chaque agent a un point de vue partiel;
2. il n'y a aucun contrôle global du système multi-agent;
3. les donnés sont décentralisées;
4. le calcul est asynchrone.

Pour résumer, Les SMA

- possèdent les avantages traditionnels de la résolution distribuée et concurrente de problèmes comme la *modularité*, la *vitesse* (avec le parallélisme), et la *fiabilité* (due à la redondance).
- héritent des bénéfices envisageable de l'IA comme le *traitement symbolique* (au niveau des connaissances), la facilité de *maintenance*, la réutilisation et la portabilité mais surtout, ils ont l'avantage de faire intervenir des schémas d'interaction sophistiqués.

The end !

Merci pour votre attention.