Computational Models for Argumentation in MAS

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Outline

- (Very brief) Introduction to Multiagent Systems
- What is argumentation? Fundamentals
- A Case Study: DeLP and its extensions as an argument-based approach to logic programming.
- Argumentation meets agents: argument-based negotiation
- Conclusions

Types of Dialogues

Type	Initial Situation	Main Goal	Participant's aims	Subtypes
Information seeking	Personal ignorance	Spreading knowledge	Gain, pass on, show, or hide knowledge	• Expert consultation • Interview • Interrogation
Persuasion	Conflicting Beliefs	Resolution of conflict by verbal means	Persuade the other(s)	• Dispute
Inquiry	General Ignorance	Growth of knowledge & agreemt'	Find a proof or destroy one	• Scientific Research • Investigation

Types of Dialogues

Type	Initial Situation	Main Goal	Participant's aims	Subtypes
Deliberation	Need for action	Reach a decision	Influence Outcome	• Board meeting • War planning
Negotiation	Conflict of interests & need for cooperation	Making a deal	Get the best for oneself	• Bargaining • Union negotiation • Land dispute

Typology by Walton & Krabbe, 1995

What is negotiation?

Negotiation is a form of interaction in which:

Initial situation
- a group of self-interested agents
- with conflicting interests
- and a desire to cooperate

Goal
- attempt to reach agreement
- on the division of scarce resources

Scarce: competing claims cannot be simultaneously satisfied

Resources: bandwidth, memory, money, processing power, fuel, equipment, …

Negotiation Components

- Mechanism (or Protocol)
  - Rules of the game
  - Who is allowed to say what, and when
- Agent Strategies within the rules of the protocol
  - *e.g.* what offer should I make?
  - *e.g.* what information should I provide?
- Outcomes
  - One of a set of possible deals (i.e. negotiation set), or
  - Conflict

Mechanism + Participant Strategies = Outcome

Approaches to Automated Negotiation

- Game-theoretic Approaches
- Heuristic Approaches
- Argumentation-based Approaches

Game Theory

- Branch of economics
- Study rational decisons (& outcomes) in multi-party strategic decision making
- Agents seen as utility maximizers
- Given a mechanism → analyze strategies & outcomes
- What mechanism to design?

What is Mechanism Design?

- Assuming perfect rationality
- Design rules of the game
- Such that rational agents would have to behave in a certain way
  - *e.g.*, Truth-telling is the dominant strategy
- And hence guarantee certain outcome properties

Problems with Game-Theoretic Approaches

- Assumption of **perfect rationality**:
  - Each agent knows space of possible deals
  - Each agent knows how to evaluate such deals
  - Each agent knows space of possible strategies
  - No time constraints (decisions computed instantly)
  - No computation cost
  - Optimal recursive modelling of opponents
- Game theory says *nothing about how to program the agent*, *e.g.,*
  - How to compute the utility function
  - How to compute the space of possible strategies

Heuristic Approaches

- Agents do not necessarily know each other's preferences
- Like a game of chess / tic-tac-toe
- Protocol does not prescribe an optimal strategy
- How to program strategies?
  - Time-dependent tactics (Fatima, 2001,2004)
  - Fuzzy similarities to generate counteroffer (Faratin, 2001)
  - Fuzzy modelling of market conditions (He et. al.)
  - Bayesian learning of opponents (Zeng & Sycara)
- Study strategy performance empirically

Heuristic Approaches: Limitations

- But...we still have similar problems as before!
  - Each agent knows space of possible deals
  - Each agent knows how to evaluate such deal
- Approximate notions of rationality → subopt-imal outcomes: full space of possible outcomes not examined
- Needs extensive empirical evaluation: very difficult to predict how the system and constitutent agents will behave.

Argumentation-based Approaches

- In Game-Theoretic and Heuristic approaches → share some limitations
  - E.g. agents exchange *proposals* (potential agreements or deals). Ags are not allowed to exchange any additional information (e.g.: network goods such as fax machines)
  - Agents' *utilities or preferences* are assumed to be *completely characterised prior to the interaction*.
  - Agents' preferences are assumed to be *proper* (ie, they reflect the true benefit the agent gets).
  - Game theoretic and heuristic approaches assume that agents' utilities or preferences are *fixed* (ie, agents cannot influence on other agents' preference models or internal mental attitudes).
- Argumentation-based approaches attempt to overcome these limitations…

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Argumentation

- Argument:
  - Reason/justification for some conclusion (belief, action, value, goal, etc.)
- Argumentation:
  - Reasoning about arguments → decide on conclusion
- Dialectical argumentation
  - Multi-party argumentation through dialogue

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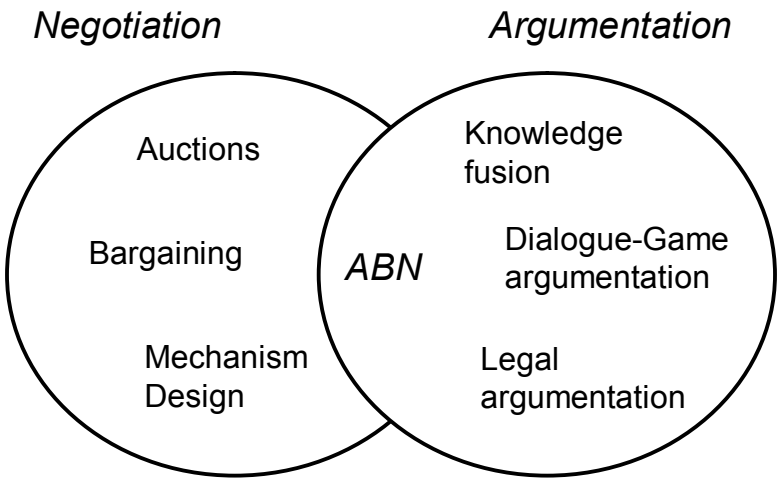
Argumentation-Based Negotiation



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Approaches: summary

	Advantages	Disadvantages
Game-theoretic	Strong analytical results	➡ Assumed fix, correct and complete preferences ➡ Says little about how to program agents
Heuristic-based	Concentrate on programming agents	➡ Assumed fix, correct and complete preferences ➡ Hard to validate strategies
Argumentation-based	Very expressive Preferences can change	➡ Validating strategies still at very early stages

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Elements of ABN Frameworks

- Communication Languages & Domain Language
- Negotiation Protocol
- Information Stores

EXTERNAL FEATURES (*ENVIRONMENT*)

- Argument and Proposal Evaluation
- Argument and Proposal Generation
- Argument Selection

AGENT-BASED FEATURES

Comm.Language & Domain Language

- Communication Language: characterized by locutions, utterances or speech acts (***propose***, ***accept***, ***reject***, etc.)
- Domain language: used for referring to concepts of the environment. E.g. (Sierra et. Al, 1998)

Offer (*a,b,Price*=\$200 $\wedge$ *Item=palm130*, t_1)

Agent a offers agent b a Palm130 for the price of \$200 at time t_1

Reject (*b, a, Price*=\$200 $\wedge$ *Item=palm130*, t_2)

Agent b rejects proposal from agent a at time t_2

Non-ABN vs. ABN Frameworks

	Non-ABN Frameworks	ABN Frameworks
Domain language	Expresses proposals only	Expresses proposals as well as metainformation about the world (beliefs, prefs., etc.)
Communication language	Locutions allow agents to pass call for bids, proposals, acceptance, etc.	In addition, locutions allow agents to pass meta-information

Comm.Language: State of the Art

- Two major proposals for ACL have been advanced: KQML (Knowledge Query and Manipulation Lang., 1996) and FIPA ACL (Foundation for Intell. Physical Agents, 2001).
- FIPA ACL offers 22 locutions, and contents of messages can be in any domain language, *e.g.*, "***inform***(a,b,φ,L)" stands for "Ag.a informs Ag.b about φ in language L".
- But… FIPA ACL fails to capture all utterances needed in a negotiation interaction!
  - There is no locution for expressing desire of enter/leave a negotiation interaction, request an argument for a claim, etc.
  - As a solution, new negotiation-specific locutions have been defined **outside** FIPA ACL (eg. ***threaten***, ***promise***, etc.)

Example of FIPA ACL Limitations

➡ Consider the following locution:

Request(Ag2 , Ag1, Do(Ag1, α), Do(Ag1, α) → Do(Ag2, β))

Agent2 request Agent1 to perform action α, and supports that request with an argument stating that "if Agent1 accepts, Agent2 will perform action β in return".

But we don't have information about if β is desirable for Agent1 or not! (***Request*** locution does not convey this)

If it is, the above situation would represent a **promise** from Agent1 to Agent2. Otherwise, it could be a **threat** !

Domain Language: State of the Art

➡ In negotiation, the domain language must be capable of expressing the object of negotiation, as well as preferences of agents (Sierra, 1998), ***e.g.***

$$(Price = \$200) \wedge (Quality = high) \wedge (Penalty = ?)$$

➡ ABN frameworks may need elements to express plans and resources. E.g. (Sadri, 2002)

$$plan(\underbrace{\langle hit(nail), hang(picture)\rangle}_{\text{Plan (or Intention)}}, \underbrace{\{picture, nail, hammer\}}_{\text{Resources}})$$

Domain Language is important in ABN: the richer the domain language, the richer the arguments that can be exchanged between agents.

Negotiation Protocol

- Given a communication and domain language, we need a *negotiation protocol* (which includes an *interaction protocol*) in order to constrain the use of the language.

Protocol: formal set of conventions governing the interaction among participants.
(Jennings, 2001)

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Negotiation Protocol

- **Interaction protocol**: specifies who is allowed to say what.
- **Negotiation protocol**: involves additional rules
  - Admission Rules: when an agent is allowed to participate in a negotiation? Under what conditions?
  - Rules for Participant Withdrawal: when a participant can withdraw from a negotiation?
  - Termination rules : when an encounter must end?
  - Rules for Proposal Validity : is proposal compliant?
  - Rules for Outcome Determination: what is the outcome?
  - Commitment Rules : which commitments are involved?

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Protocols: State of the Art

- Interaction protocols for ABN agents can be **explicit** or **implicit**.
- Explicitly:
  - by means of *finite state machines* (Sierra et. al.1998). Advantage: handy for a limited number of locutions. Disadv: complex for increased number of locutions.
  - By means of *dialogue games* (Amgoud et al, 2001; McBurney et.al, 2003). Advantage: they have public axiomatic semantics.
- Implicitly:
  - By means of *logical constraints* expressed as "if-then" rules (e.g. Kraus et. al, 1998; Sadri et. al. 2001, 2002). In this case, interaction protocol is "hardwired" in the agents' internal specification.

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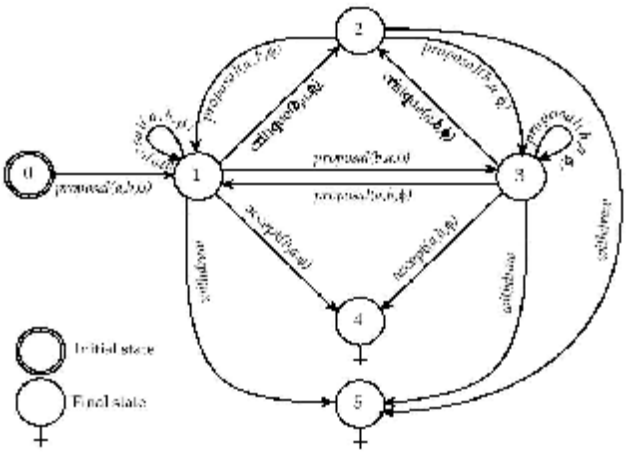
Finite State Machines for Protocols



Negotiation protocol for two agents

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Locutions in Dialogue Games – Example (McBurney et. al, 2003)

Locution: ***willing_to_sell***(**P**$_1$,T,**P**$_2$,V), where **P**$_1$ is either an advisor or seller, T is the set of participants, **P**$_2$ is a seller, V is a set of sales options.

Precond: some participant **P**$_3$ must have previously uttered a locution ***seek_info***(**P**$_3$,S,p), where **P**$_3$∈S (the set of sellers), and the options in V satisfy constraint p

Meaning: Speaker **P**$_1$ indicates audience T that agent **P**$_2$ is willing to supply the finite set V={a_1,a_2,..a_k} of purchase options to any buyer in T. Each option satisfies constraint p in prior ***seek_info(.)*** locution.

Response: None required

Information Store Updates: For each a_i∈V, the 3-tuple (T,**P**$_2$,a) is inserted into IS(**P**$_1$).

Commitment Store Updates: None

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Preconditions – Example (Sadri et. al, 2002)

Protocol rules are coded as part of the agents' programs (usually abductive logic programs).

$$P(t) \wedge C(t) \rightarrow P'(t+1)$$

"If agent receives performative (locution) P at time t and condition C was satisfied at that time, then the agent must use the performative P' at the next time point."

E.g.: if an agent receives a performative including request of a resource, and it does not have the resource, then it must refuse the request.

Other external elements

- Termination rules can be specified in different ways:
  - E.g. in FSA, they are a set of links to a final state, usually after an agent utters ***withdraw***(·) or ***accept***(·)
  - E.g. in (McBurney et.al, 2003), a rule specifies that the dialolgue ends by the locution ***withdraw_dialogue***(·)
- Outcome determination also varies:
  - Some frameworks determine outcomes based on the logical structure of interacting arguments (i.e., outcome is ***implicit*** in the underlying argumentation logic)
  - In other frameworks, outcomes are reached through uttering a specific locution ***explicitly*** (e.g. ***accept***(·)), usually on the basis of some internal utility evaluation.

Challenges (1)

- Protocols for ABN share challenges faced in design of argumentation protocols in general.
  - Termination: can termination be ensured?
    - ✓ E.g. Protocols proposed by Amgoud & Parsons (2001) do not allow to repeat the same locutions over and over again..
    - ✓ Torroni (2002) studied maximum length dialogues on the basis of properties of abductive logic programs representing agents.
  - Guaranteed success: under which conditions a particular protocol will end up with agreement?
    - ✓ Complexity results (Wooldridge & Parsons, 2000).

Challenges (2)

- Protocols for ABN share challenges faced in design of argumentation protocols in general.
  - Conformance checking: is a particular utterance acceptable given history & context of interaction?
    - ✓ Recently investigated applying model checking techniques (Huget and Wooldridge, 2003).
  - Admission rules: how to govern admission rules?
    - ✓ Relevant work in Electronic Institutions (Rodriguez-Aguilar, 2002)

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Information Stores (IS)

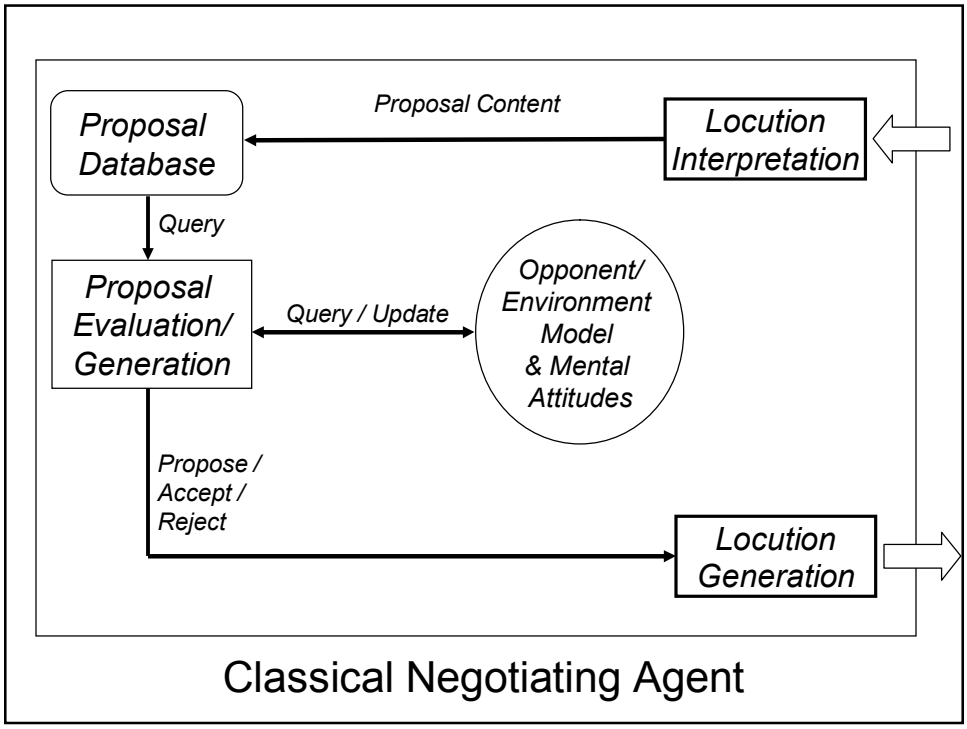
- In some ABN frameworks, there is no centralised IS, and agents keep track of past utterances.
- Commitment Stores (CS): a way of tracking the claims made by participants in dialogue games (Hamblin, 1970).
- CS not to be confused with "interaction history" (only passive storage).
- CS have specific *commitment rules* governing the addition/removal of statements.

Information Stores (IS)

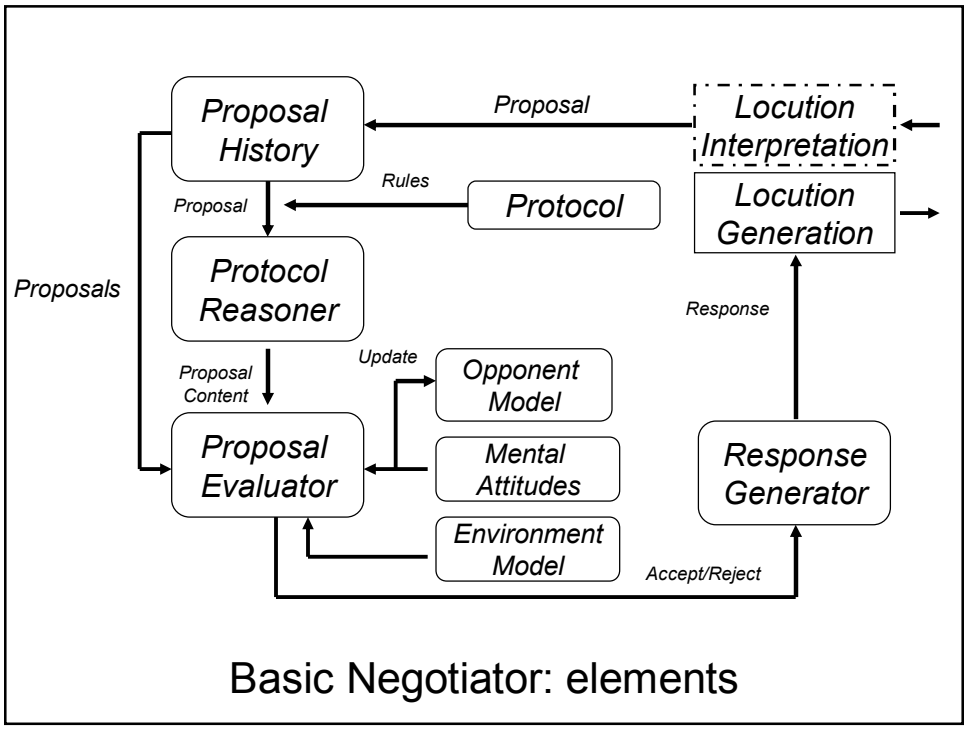
- Information store manipulation rules have a direct effect on the types of utterances agent can make given
  i. previous utterances;
  ii. properties of the dialogue;
  iii. the final outcome.
- Commitment to providing/requesting/exchanging resources may require different treatment from commitment in other types of dialogue (e.g., persuasion).

Elements of ABN Agents

- What constitutes a basic non-ABN negotiating agent? We can distinguish a number of components…
  - *Locution interpretation*: parses incoming messages
  - *Proposal Database*: stores proposals for future reference
  - *Proposal Evaluation/Generation*: ultimately makes a decision about whether to accept, reject, terminate negotiation, etc.
  - *Locution generation*: sends the response to the relevant party or parties.



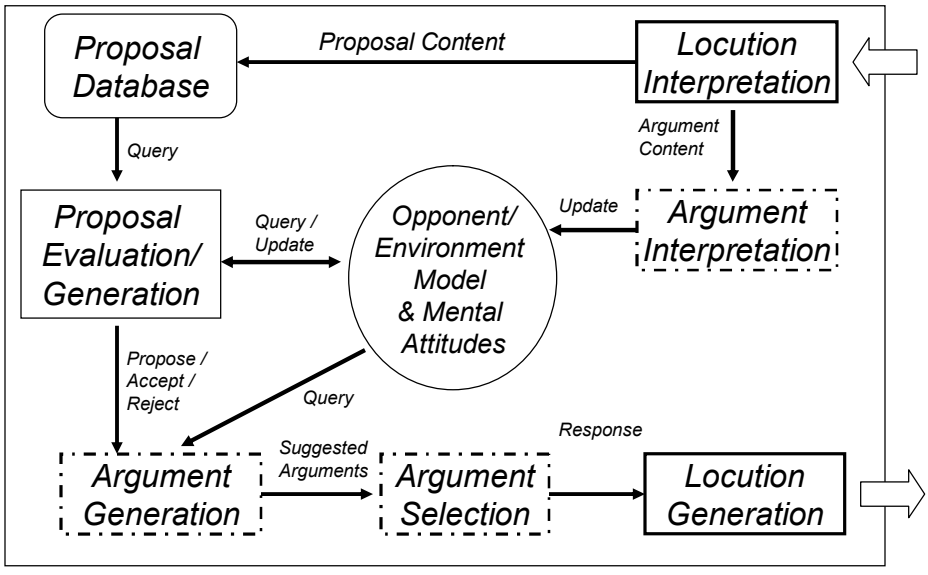
Classical Negotiating Agent



Basic Negotiator: elements

Elements of ABN Agents (2)

- In addition to evaluating and generating proposals, an agent capable of participating in ABN must be equipped with mechanisms for
  - ***Evaluating* arguments** (updating mental states accordingly)
  - ***Generating and Selecting* arguments**
  - ***Evaluating and interpretating* arguments**



ABN Agent

Argument and Proposal Evaluation

- An ABN agent needs to evaluate potential agreements proposed by its counterparts.
- *Proposals* may be evaluated through comparison with some subjective preference criteria.
- *Argument* evaluation → less trivial…
  - **Objective considerations**: assessing "quality" of argument as a tentative proof (e.g. Specificity (Poole, 1984), acceptability classes (Dung, 1995), etc.).
  - **Subjective Considerations**: an agent may choose to consider its own preferences and motivations in making a judgement.

Different Types of Dialogues…

- ***Theoretical Reasoning***: reasoning about what is true in the world should be rational and without biases of the participants.
- ***Practical Reasoning***: a dialogue for deciding a course of action, or division of scarce resources. Agents not concerned in truth *per se,* but rather with the satisfaction of their needs.
- In negotiation dialogues agents are required to perform argument evaluation based on **objective** and **subjective** criteria.

Proposal & Argument Evaluation

- ***"Benevolence" approach*:** assume agents are benevolent, using the following rule: ***If I do not need a resource, I should give it away when asked*** (e.g. Parsons et. al, 1998; Amgoud et. al, 2000; Sadri et al, 2001).
- **Agents present arguments defending their intentions.** Two kinds of conflict may appear:
  - Agents have conflicting intentions (rebutting arguments)
  - An agent rejects one of the elements of the argument supporting the intention of another agent B (undercutting arguments).

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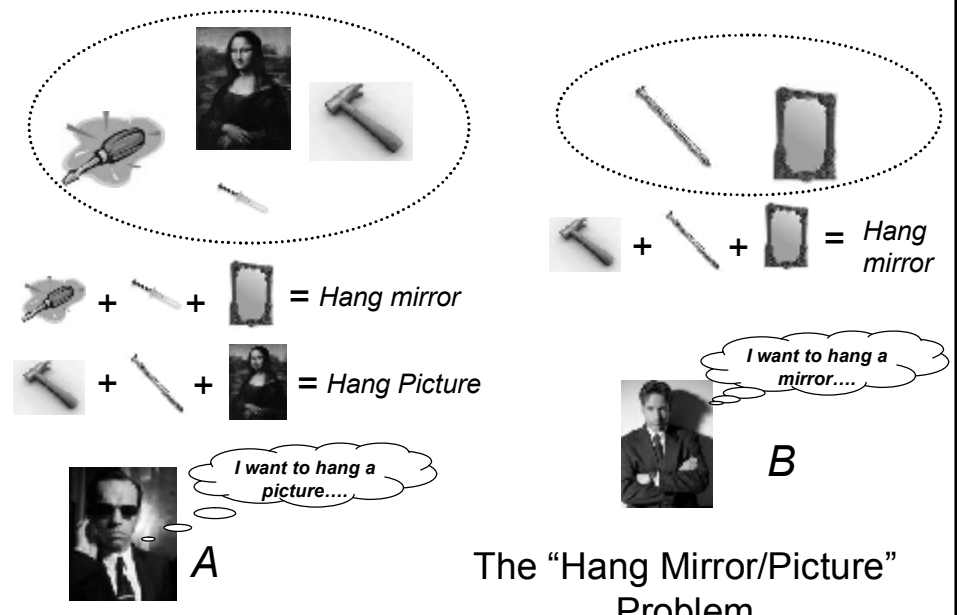

The "Hang Mirror/Picture" Problem

(Credits to F.Dignum for original slide)

Proposal & Argument Evaluation

- (Parsons et.al. 1998): agent A intends to hang a picture.
  - After executing its planning procedure, produces intentions to acquire a nail, a hammer and a picture.
  - A asks B to give him a nail, so he can hang the picture.
  - Agent B does not want to give A the nail, because he needs it for his plan.
  - Agent A says: I don't want the nail, but just to hang the picture. If I give you screw and screwdriver (I do not need them), you can have a plan for hanging the mirror, as you want.
  - Agent B says: ok, let's proceed that way. I give you the nail, and both of us are happy!

Other Approaches

- ***"Count on you" approach*** (Sadri et. al, 2001): not argue about beliefs *e.g.*:
  - Agent A receives a request from Agent B for a resource that he needs it for achieving goal G_A with a plan P.
  - Agent A rejects the request, unless an alternative acceptable plan P' for G_A can be produced by B, with a promise to provide A with every needed resource for plan P'.
- **Agents are assumed to have some ordering in their plans.**

*In both approaches, we are relying on the (rather naive) assumption that agents accept **any request on resources that they do not currently need.** What if agents are purely self-interested, and want "something in return" ?*

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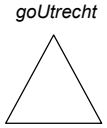
Utility in Proposal & Argument Evaluation

- **Idea**: the agent can calculate ***expected utility*** for cases of accepting/rejecting proposals. Comparing expected utilities, a decision is made.
- In (Kraus,1998) ***combined factors*** are used to calculate utilities (collision_flag, convincing_factor, acceptability_value)
- (Ramchurn et.al, 2003) take into account ***trust*** in the counterpart to calculate expected values.
- (Sierra et.al., 1998) introduce ***authority*** as a criterion for evaluating arguments (authority graph). *e.g.*: introduction of conciliatory agent to solve appeal-to-authority arguments.

Challenges

- In most models, agents do not *voluntarily modify* their position, but rather *forcedly concede* as a result from pressure from counterparts. *Can* ***objective evaluation of arguments*** *be combined with* ***subjective evaluation of its consequences***?
- Unifying argumentation frameworks and facilitate negotiation dialogues about goals, beliefs, plans, etc.
- (Rahwan et.al, 2003) argue that *argumentation systems designed for arguing about beliefs are not readily suitable for allowing argumentation over goals.*

Example: Travel to Utrecht



$Justify(conferenceInUtrecht,\ goUtrecht)$
$Achieve(\{buyTicket,\ arrangeAccom\},\ goUtrecht)$
$Instrum(goUtrecht,\ presentPaper)$

$\langle(\ \{presentPaper\},\ \{conferenceInUtrecht\},\ \{buyTicket,\ arrangeAccom\}\ ):\ goUtrecht\rangle$

Some ways of attacking argument $\langle\ A,\ goUtrecht\ \rangle$

1) Present statement: $\neg achieve(\{buyTicket,\ arrangeAccom\},goUtrecht)$

Counterpart attacks the relation between subgoals and the goal, arguing that buying a ticket and arranging accomodation are not enough for going to Utrecht. **Effect:** $\neg achieve(\{buyTicket,\ arrangeAccom\},\ goUtrecht)$ is removed from the KB of the agent. If no alternative plan is found, goal is deemed unachivable.

2) Present statement: $Instrum(goRotterdam,\ presentPaper)$

Counterpart presents an alternative (go to Rotterdam, there is a similar conference there). **Effect:** $Instrum(goRotterdam,\ presentPaper)$ is added to the agent's KB. Plans are compared and outcome is determined.

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Argument and Proposal Generation

- Problem: generating ***candidate arguments*** to present to a dialogue counterpart.
- Such arguments are sent to "entice" the counterpart to accept some proposed agreement.
- Some approaches:
  - (Sierra et.al, 1998) assume agents have a means of generating proposals that increase (or maximise) utilities.
  - (Kraus, Parsons, Sadri) assume that an underlying planner generates a set of actions or resources needed to achieve some intention.
- Proposals may be accompanied by arguments generated by explicit rules (e.g. Kraus et. Al, 1998)

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Generating Candidate Arguments

IF

A request has been sent to agent B to perform action α &
Agent B rejected this request &
Agent B has goals $\mathbf{G_1}$ and $\mathbf{G_2}$ &
Agent B prefers $\mathbf{G_2}$ to $\mathbf{G_1}$ &
Agent B doing α achieves $\neg \mathbf{G_1}$ and doing β achieves $\neg \mathbf{G_2}$
Agent A believes doing β is credible and appropriate

THEN

Agent A request B to do action α with the following threat:
"*if you don't do* α, *I will do* β"

Agent A may generate other candidate arguments (e.g., promises or appeals) using other rules.

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Argument and Proposal Generation

- Other frameworks take a **planning approach** to proposal generation:
  - agents justify requests by simply stating the truth about needs, plans, underlying assumptions, etc.
  - Note difference wrt utility-based approaches, where agents "create" arguments by exploiting their abilities to influence outcomes (e.g. threats, rewards).
- Authority can also be used in argument generation
  - (Sierra et. al, 1998) propose a simple "authoritarian" agent which always exploits its social power by threatening whenever possible.

***Challenge**: formal characterization of the "space" of possible arguments, and understand influence among factors (authority, expected utility, trust, honor, etc.)*

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Argument Selection

- **Given a number of candidate arguments, which is the most suitable one?**
- Argument selection may take part in conjunction with argument generation.
- (Kraus et. al, 1998) propose the following scale for argument strength:
  - Appeal to prevailing practice
  - A counter-example
  - An appeal to past promise
  - An appeal to self-interest
  - A promise of future reward
  - A threat

Weakest arguments

Strongest arguments

Argument Selection

- In (Ramchurn et. al, 2003), agents evaluate trust and utility to decide which candidate argument to send with a request

If trust is ***low*** *and utility of the proposal is* ***high***
(ie, I need to do X and I don't trust you)
then send a strong argument
} *Rule 1*

If trust is ***high*** *and utility of the proposal is* ***low***
(ie, I don't need to do X so much but I trust you)
then send a weak argument
} *Rule 2*

Low *and* ***High*** *are linguistic variables manipulated using fuzzy operators*

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Argument Selection: Challenges

- Argument Selection as a problem can be considered to be the essence of **strategy** in ABN dialogues.
- There is little existing work on strategies in MAS dialogues.
  - There has been research in persuasion dialogues (e.g. Amgoud & Maudet, 2002) and inquiry and information seeking dialogues (Parsons et. al, 2002, 2003).
  - (Rahwan et. al, 2003a) provide a first attempt at characterising strategic factors in negotiation dialogues.
- Information about negotation counterpart should be taken into account → **learning** techniques required to find patterns.

Outline

- (Very brief) Introduction to Multiagent Systems
- What is argumentation? Fundamentals
- A Case Study: DeLP and its extensions as an argument-based approach to logic programming.
- Argumentation meets agents: argument-based negotiation
- Conclusions

Open issues and future directions

- Argumentation: state of the art.
- Multiagent systems (MAS): state of the art.
- Integration of argumentation and MAS
- Open issues and future directions:
  - Argumentation & communicative rationality in MAS
  - Argumentation & trust in MAS
  - Complexity of argument-based approaches in a MAS context
  - Argument-based programming languages for agents

Summary of This Tutorial

- Multiagent Systems: a brief overview
- Foundations of Argumentation Systems
  - Argument. Defeat. Status of Argument. Warrant.
- DeLP, O-DeLP, P-DeLP: argument-based approaches to logic programming
  - Main definitions. Using DeLP in Reasoning Modules in Agents. DeLP, P-DeLP and O-DeLP in real-world applications.
- Argumentation meets agents
  - Important emerging field: argument-based negotiation.
- Conclusions

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