An Argumentation Framework for Decision Making

Maxime Morge* Paolo Mancarella*

*Dipartimento di Informatica
Università di Pisa

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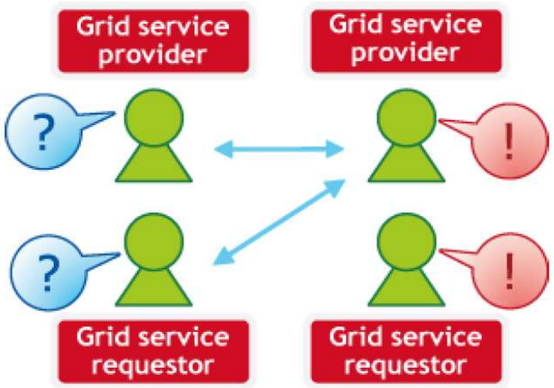
Outline

ARGUmentation as a foundation for the semantic GRID

Project Aims:



- Enact the reasoning and decision making processes and negotiation required for dynamic composition of Grid resources and services into executable workflows, using argumentative agents to support grid service providers and requestors.
- Impact business and business practices by empowering grid-enabled e-business applications where multiple service requestors and providers exist.

ARGUGRID Objectives & Partners

- **Provide a new model for argumentative agents populating and evolving within a trusted grid.**
- Provide a new model for the specification, creation, operation and dissolution of VOs over the grid using argumentation.
- Design an architecture for the semantic grid to support argumentative agents and VOs.
- Develop a grid-based platform to support the implementation of models and architecture and assess the approach.
- Experiment with and evaluate the models, architecture and platform in the context of concrete applications for e-business.

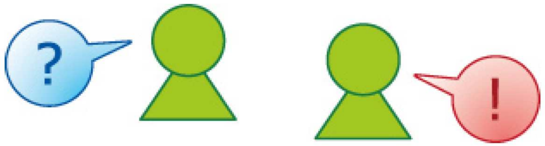
- Department of Computing, **Imperial College London**, UK
- Department of Computer Science, **Royal Holloway University of London**, UK
- School of Engineering and Technology, **Asian Institute of Technology**, Thailand
- **GMV S.A.**, Spain
- Institute of Communication and Computer Systems, **National Technical University of Athens**, Greece
- **InforSense Ltd**, London, UK
- Dipartimento di Informatica, **Universita` di Pisa**, Italy
- **cosmoONE Hellas Market-site S.A.**, Greece

Outline

Overview of argumentation

Argumentation is:

- a conceptualisation of nonmonotonic reasoning;

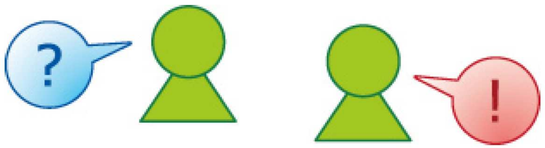


Overview of argumentation

Argumentation is:

- a conceptualisation of nonmonotonic reasoning;
- a process of construction and comparison of arguments for and against certain conclusions formalized by an argumentation framework [Dung 95] , *i.e.*

- Arguments
  - abstract entities
- Attack relation
- Status of arguments



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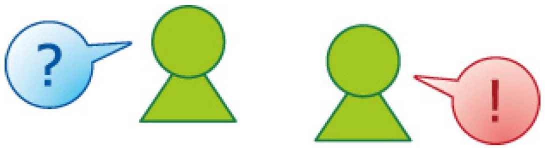
Argumentation is:

- a conceptualisation of nonmonotonic reasoning;
- a process of construction and comparison of arguments for and against certain conclusions formalized by an argumentation logic [Prakken & Sartor 97] , *i.e.*

- Underlying logic
- Arguments
  - abstract entities
  - logical structures
- Attack relation



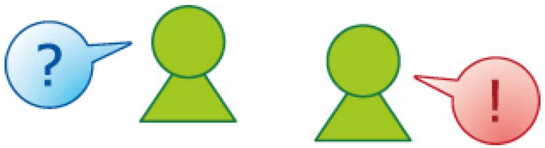
- Status of arguments

Overview of argumentation

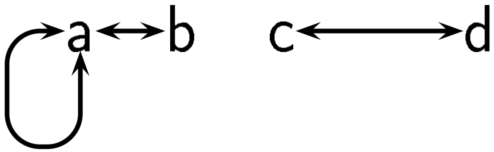
Argumentation is:

- a conceptualisation of nonmonotonic reasoning;
- a process of construction and comparison of arguments for and against certain conclusions formalized by an preference-based argumentation logic [Amgoud & Cayrol 02], *i.e.*

- Underlying logic
- Arguments
  - abstract entities
  - logical structures
- Attack relation
- Priority relation
- Status of arguments



Abstract argumentation framework



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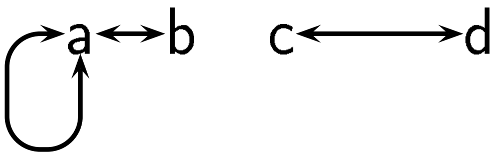


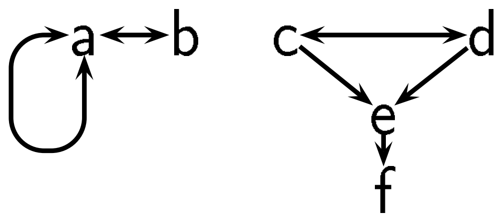
- $\emptyset$ is ground;
- $\{b, c\}$ are $\{b, d\}$ preferred;
- $\{b\}$ is the maximal ideal set.

Definition ([Dung, Kowalski & Toni 06])

A set X of arguments is :

- **admissible** iff X does not attack itself and X attacks every argument Y such that Y attacks X;
- **preferred** iff X is maximally admissible;
- **complete** iff X is admissible and X contains all arguments x such that X attacks all attacks against x;
- **grounded** iff X is minimally complete;
- **ideal** iff X is admissible and it is contained in every preferred sets.

Abstract argumentation framework



- $\{b, c, f\}$ are $\{b, d, f\}$ preferred;
- $\{b\}$ is the maximal ideal set and $\{b\} \subset \{b, f\} \subset \{b, c, f\} \cap \{b, c, f\}$

Definition ([Dung, Kowalski & Toni 06])

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The statements

- $\mathcal{L}$ a logic language

Definition ([Prakken & Sartor 97])

A theory $\mathcal{T}$ is an extended logic program, *i.e* a finite set of rules:

$$R : L_0 \leftarrow L_1, \ldots, L_j, \text{not } L_k, \ldots, \text{not } L_m$$

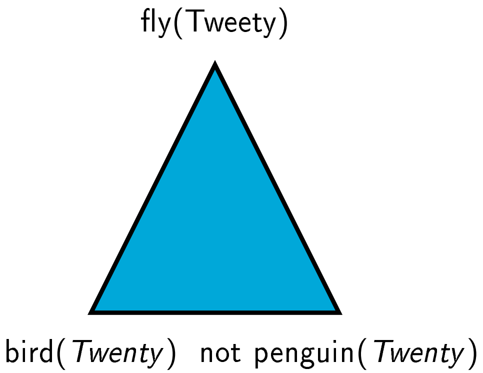
$\text{head}(R) = L_0$.
$\text{body}(R) = \{L_1, ..., \text{not } L_m\}$.

- $\mathcal{I}$ is an incompatibility relation amongst sentences in $\mathcal{L}$
  - $\mathcal{I}(\text{b}_1, \neg\text{b}_1)$ and $\mathcal{I}(\neg\text{b}_1, \text{b}_1)$,
  - $\mathcal{I}(\text{b}_1, \text{not b}_1)$

Argument as 'proof'

Forms of arguments:

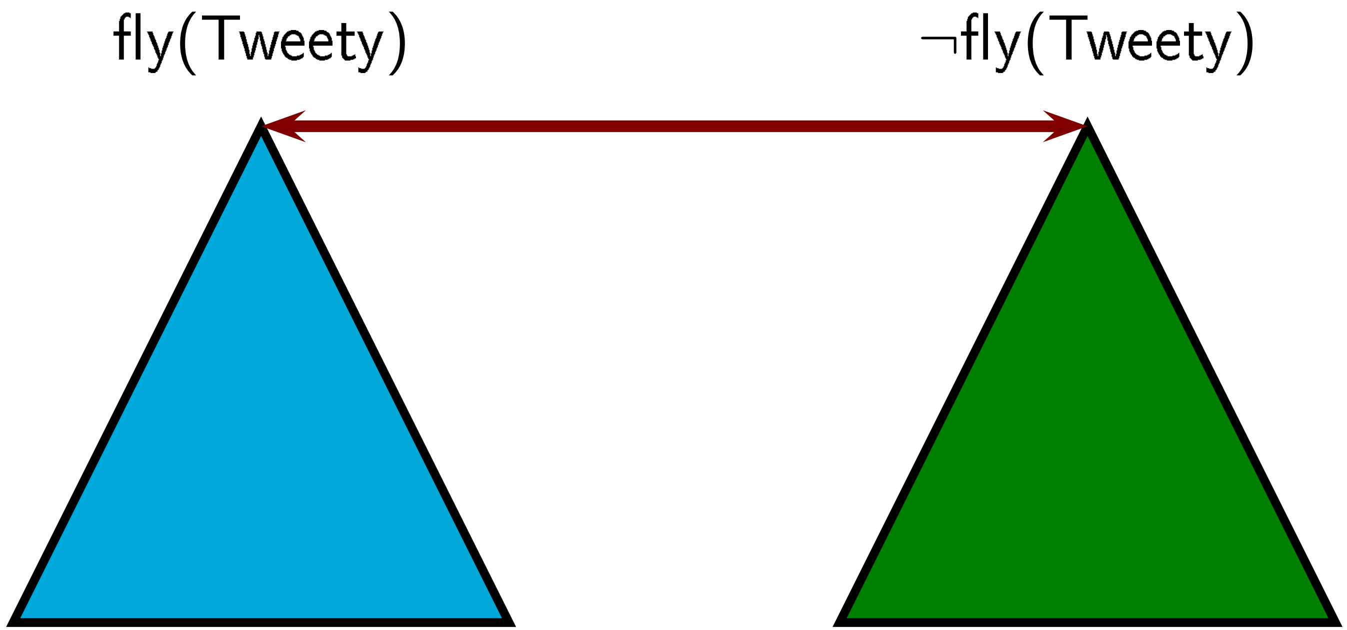
- An **abstract entity** with an unspecified logic,
  $A=$'Tweety flies because it's a bird';
- A **pair** (Premises, Conclusion),
  $A = (\{\text{bird}(\text{Tweety}), \text{bird}(X) \rightarrow \text{fly}(X)\}, \text{fly}(\text{Tweety}))$;
- A deduction **sequence** of rules and facts
  $A = (f_1(\text{Tweety}), r_1(\text{Tweety}))$;
- An inference **tree** grounded in premises;



Rebutting, undermining and undercutting attacks

Rebutting attack conflicting conclusions:

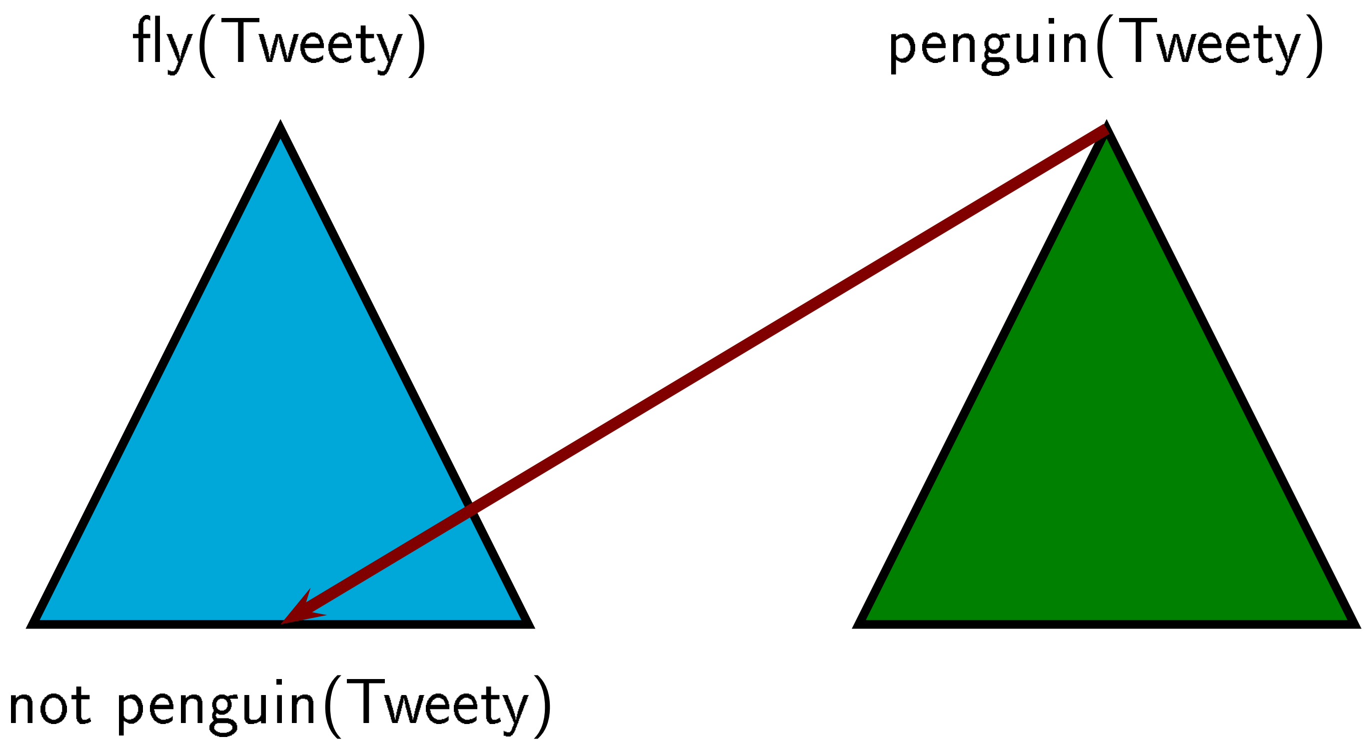
- *Tweety flies because it is a bird;*
- *Tweety doesn't fly because it's a penguin.*



Rebutting, undermining and undercutting attacks

Undermining attack non-provable assumptions:

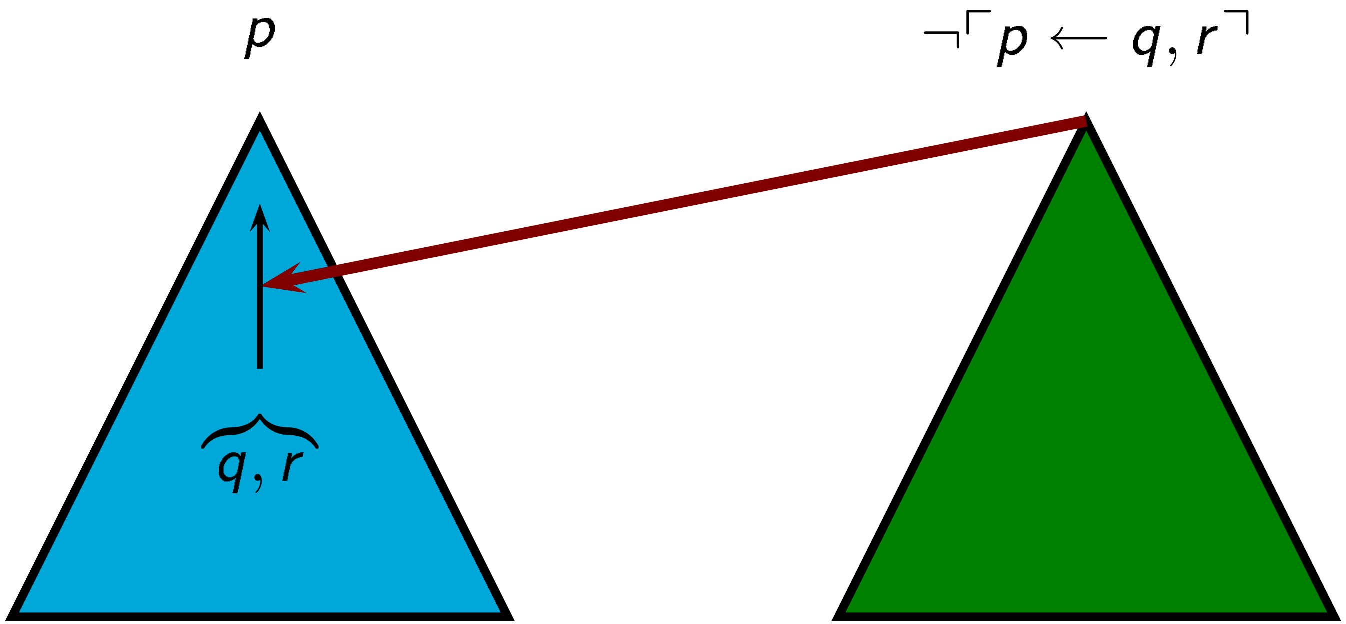
- *Tweety flies because it is a bird and it is not provable that Tweety is a penguin;*
- *Tweety is a penguin.*



Rebutting, undermining and undercutting attacks

Undercutting attack intermediate step:

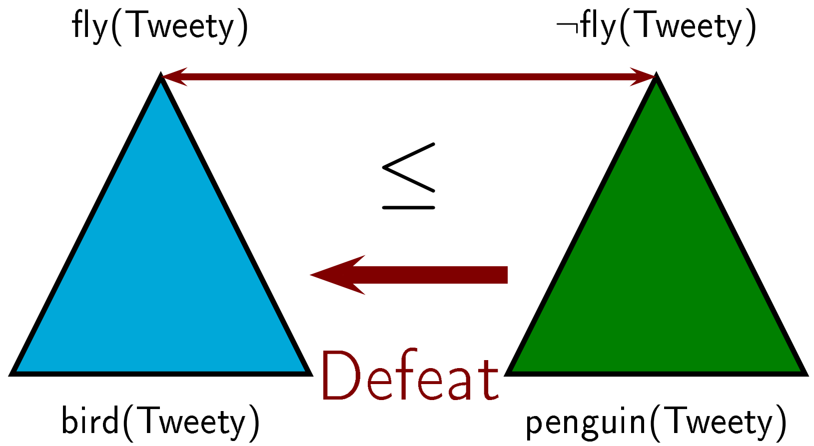
- *Tweety flies because all the birds I've seen fly;*
- *I've seen Tux, it's a bird and it doesn't fly.*



How to evaluate the strengths of arguments?

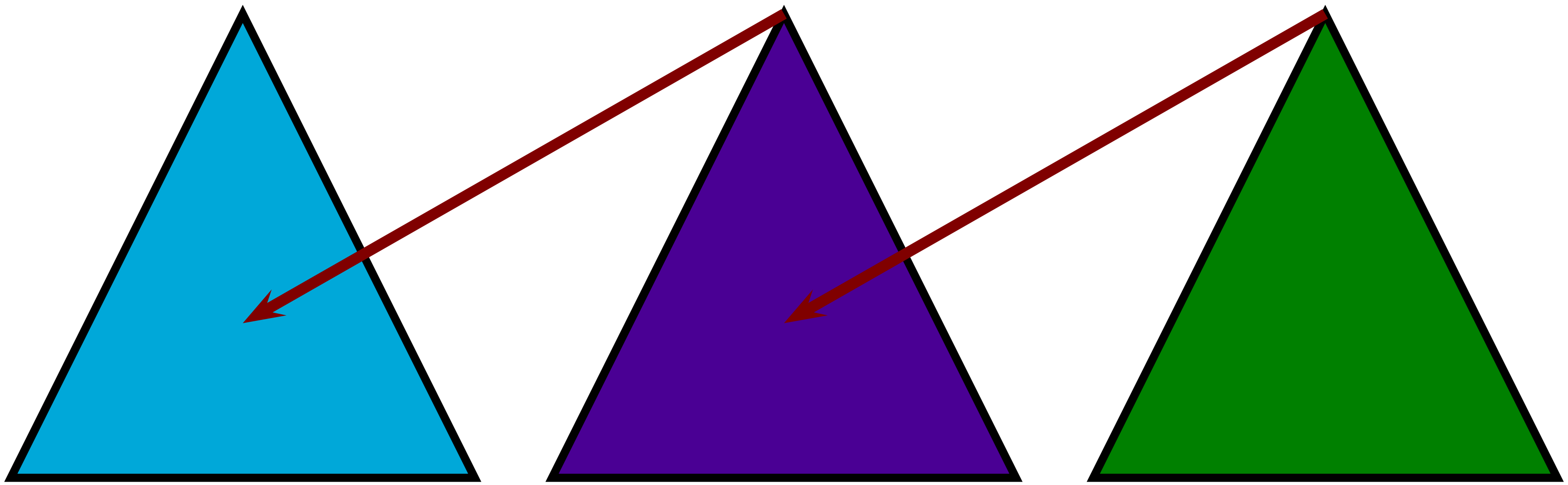
Some domain-independent principles of commonsense reasoning:

- the last link principle [Prakken & Sartor 97];
- the weakest link principle [Amgoud & Cayrol 02];
- the specificity principle [Simari & Loui 92].

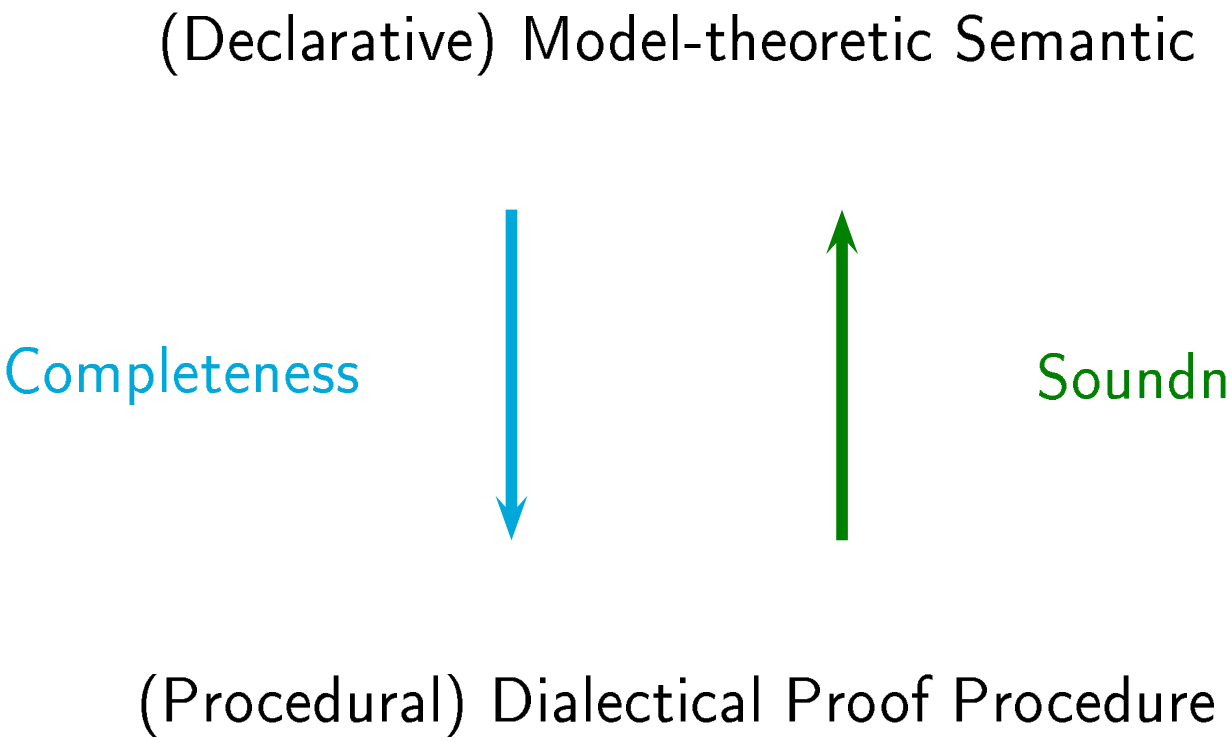


From the defeat relation to the status of arguments

- Defeat relation focus on two arguments not on a dispute, eg



Burden of proof rather than correspondence with reality

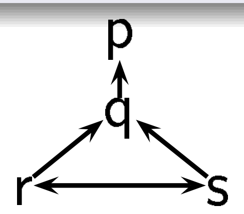


Dialectical enquiry

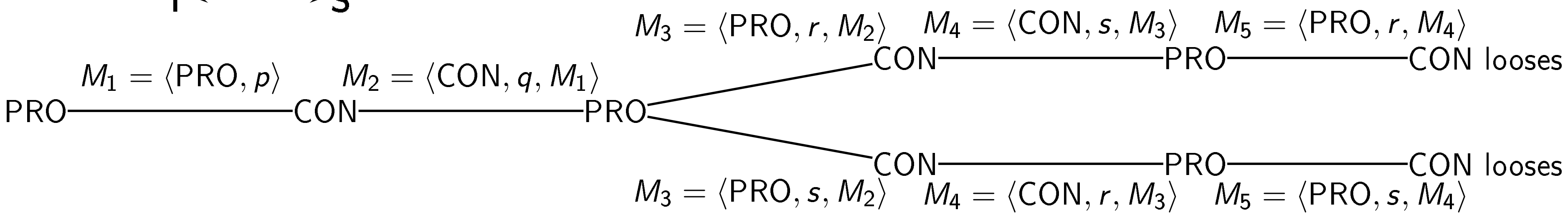
Definition

A Two-Party Immediate Respond Dispute (TPI) is defined s.a.:

- both parties are allowed to repeat PRO;
- PRO is not allowed to repeat CON;
- CON is allowed to repeat CON in a different dispute line.



$\{p, r\}$ and $\{p, s\}$ are preferred



Theorem

Soundness and completeness of TPI for the sceptically preferred semantics.

Take away argumentation technics

Argumentation framework is made of:

- Dialectical proof procedure
- Model-theoretic semantics
- Defeat relation
- Priority/Contradictory relation
- Arguments
- Underlying logic

Argumentation is a promising approach for:

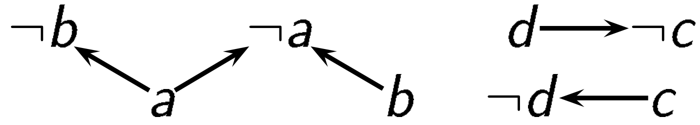
- decision-making, *i.e.* reasoning with inconsistent information;
- dialogue, *i.e.* facilitating rational interaction;
- collective decision making, *i.e.* reach an agreement.

Outline

An abstract argumentation framework [Dung, Kowalski & Toni 06]

- An Assumption-based argumentation framework $ABF = \langle \mathcal{L}, \mathcal{R}, \mathcal{A}, \bar{\ } \rangle$=
  - $(\mathcal{L}, R)$ a deductive system *i.e.*
    - $\mathcal{L}$ a formal language
    - $\mathcal{R}$ set of inference rules, eg $p \leftarrow q, r$
  - $\mathcal{A}$ a set of candidate assumption
  - $\overline{p}$ is the contary of p
- Abstract argument A
  $\Leftrightarrow$ Tight deductions supported by sets of assumptions $A \vdash \alpha$.
- A `attacks` B
  $\Leftrightarrow A \vdash \alpha$, $B \vdash \beta$, and $\alpha = \overline{\delta} \in B$.

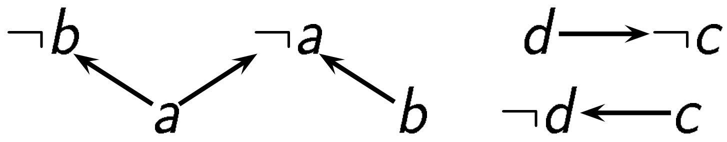
An example of ABF

- $ABF = \langle \mathcal{L}, \mathcal{R}, \mathcal{A}, \bar{\ } \rangle =$
  - $\mathcal{L} = \{a, b, c, d, \neg a, \neg b, \neg c, \neg d\}$
  - $\mathcal{R} = \{$  $\}$

  - $\mathcal{A} = \{a, b, c, d\}$
  - $\overline{a} = \neg a, \overline{b} = \neg b, \overline{c} = \neg c, \overline{d} = \neg d$
- Attack relations:
  - $\{a\}$ attacks itself;
  - $\{a\}$ and $\{b\}$ attack each other.
- Model-theoretic semantics:
  - $\emptyset$ is ground;
  - $\{b, c\}$ are $\{b, d\}$ preferred;
  - $\{b\}$ is the maximal ideal set.

Admissible beliefs derivations example

$ABF = \langle \mathcal{L}, \mathcal{R}, \mathcal{A}, \bar{\ } \rangle =$

- $\mathcal{L} = \{a, b, c, d, \neg a, \neg b, \neg c, \neg d\}$
- $\mathcal{R} = \{$  $\}$

- $\mathcal{A} = \{a, b, c, d\}$
- $\overline{a} = a, \overline{b} = b, \overline{c} = c, \overline{d} = d$

Is $\neg a$ an admissible belief?

Proponent	Opponent	Ass support. P	Culprit choosen in O
$\{\neg a\}$	$\{\ \}$	$\{\ \}$	$\{\ \}$
$\{b\}$	$\{\}$	$\{b\}$	$\{\ \}$
$\{\}$	$\{\{\neg b\}\}$	$\{b\}$	$\{\ \}$
$\{\}$	$\{\{a\}\}$	$\{b\}$	$\{\ \}$
$\{\neg a\}$	$\{\}$	$\{b\}$	$\{a\}$
$\{\}$	$\{\}$	$\{b\}$	$\{a\}$

Credulous and Sceptical Argumentation Prolog Implementation

- Written in Prolog by Dorian Gaertner and Francesca Toni
- Available at `http://www.doc.ic.ac.uk/~dg00/casapi.html`
- The main procedure is `run(derivationtype, outputmode, numberofsolutions)` with:
  - the first argument is the type of dispute derivation, eg ab (for admissible belief);
  - the second argument determines the output mode: (s)ilent or (n)oisy.
  - the third argument indicates whether (1) or (a)ll solutions are required.

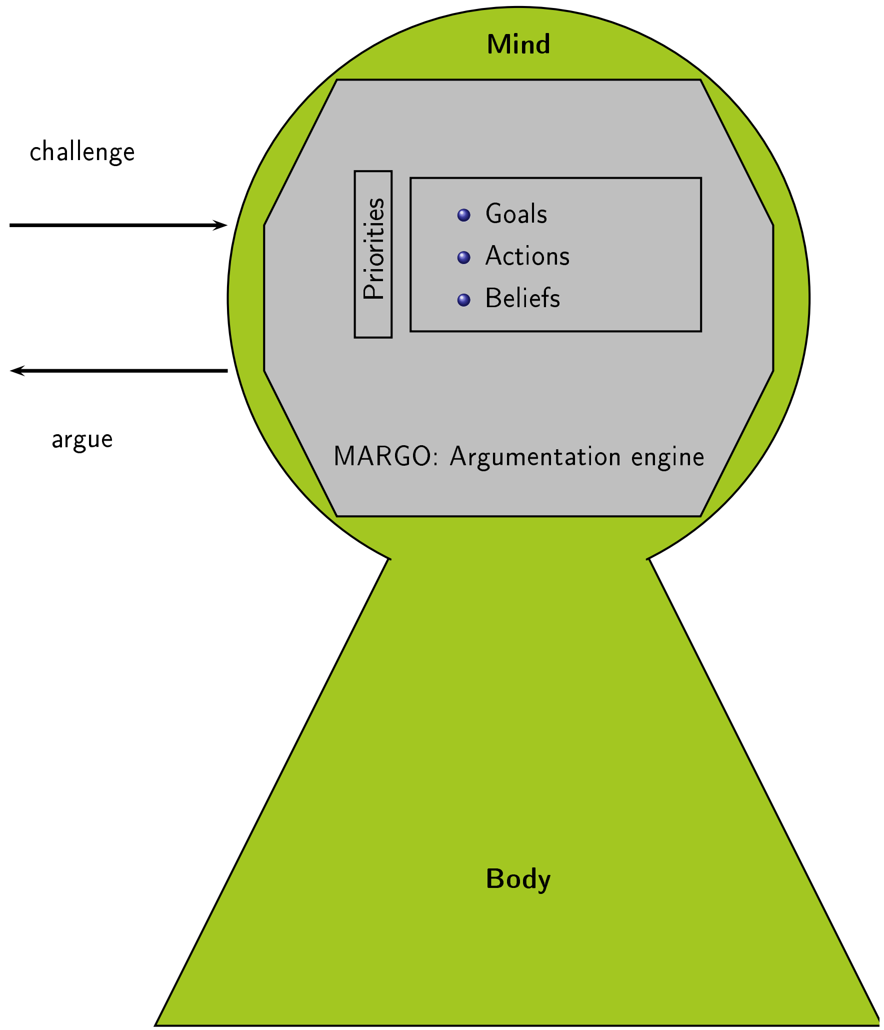
A good example is better than a long explanation

```
:- compile('casapi.pl').

myRule(nb,[a]).
myRule(na,[a]).
myRule(na,[b]).
myRule(nc,[d]).
myRule(nd,[c]).

myAss([a,b,c,d]).

toBeProved([na]).

contrary(na,a).
contrary(nb,b).
contrary(nc,c).
contrary(nd,d).
--------
run(ab,s,a).
FINISHED, one defence set is: [b, b]
```

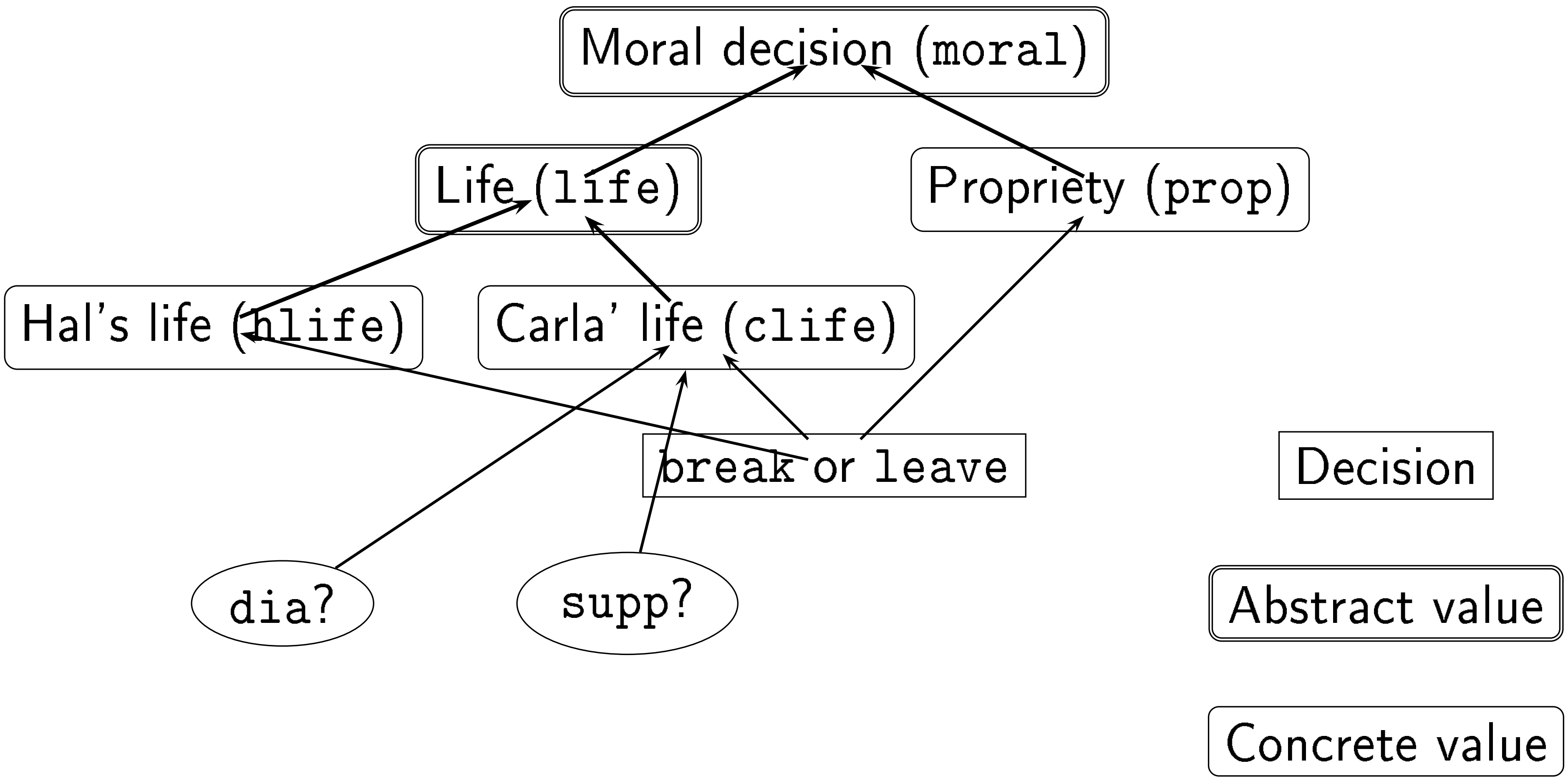
Outline

Outlook: Agents' mind (WP2)

- Design
  - state-of-mind (knowledge, goals, actions)
  - qualitative priorities (probabilities, preferences, utililies)
- Argumentation-based decision-making
- Implementation MARGO: a Prolog prototype



Abstract representation of the problem: influence diagram



Data strutures and priorities: hierarchies of conflicting rules

The theory compiles:

- goal rules such as $R_{012} : g_0 \leftarrow g_1, g_2$
- epistemic rules such as $R_{012} : b_0 \leftarrow b_1, \neg b_2$
- decision rules such as $R_{110} : g_1 \leftarrow D(a_1), b_0$

Different priorities for different rules:

- the priority over goal rules comes from preferences, eg $R_1 : g_0 \leftarrow g_1$ has priority over $R_2 : g_0 \leftarrow g_2$
- the priority over epistemic rules comes from probabilities, eg $F_1 : \texttt{dia} \leftarrow$ has priority over $F_2 : \neg\texttt{dia} \leftarrow$
- the priority over decision rules come from expected utililies, eg $R_{11} : g_1 \leftarrow D(a_1), b_1$ has priority over $R_{12} : g_1 \leftarrow D(a_1), b_2$

A walk through the example

$$\uparrow \begin{array}{l} \hline F_1 : \texttt{dia} \leftarrow \\ \hline F_3 : \neg\texttt{dia} \leftarrow \end{array}$$

$$\uparrow \begin{array}{l} \hline R_{22} : \texttt{prop} \leftarrow D(\texttt{leave}) \\ R_{31} : \texttt{hlife} \leftarrow D(\texttt{break}) \\ R_{41} : \texttt{clife} \leftarrow D(\texttt{leave}) \\ R_{42} : \texttt{clife} \leftarrow D(\texttt{break}), \texttt{supp}, \texttt{dia} \\ \hline R_{21} : \texttt{prop} \leftarrow D(\texttt{break}) \\ R_{32} : \texttt{hlife} \leftarrow D(\texttt{leave}) \\ R_{43} : \texttt{clife} \leftarrow D(\texttt{break}), \texttt{dia} \end{array}$$

$$\uparrow \begin{array}{l} \hline R_{012} : \texttt{moral} \leftarrow \texttt{life}, \texttt{prop} \\ R_{134} : \texttt{life} \leftarrow \texttt{hlife}, \texttt{clife} \\ \hline R_{01} : \texttt{moral} \leftarrow \texttt{life} \\ R_{13} : \texttt{life} \leftarrow \texttt{hlife} \\ \hline R_{02} : \texttt{moral} \leftarrow \texttt{prop} \\ R_{14} : \texttt{life} \leftarrow \texttt{clife} \end{array}$$

Struture of arguments: abductive tree

Definition

An argument $A = \langle \mathtt{conc}, \mathtt{premise}, \mathtt{hyp} \rangle$ is:

1. **hypothetical**, *i.e.* built upon an hypothesis
   $\mathtt{sent}(A) = \mathtt{hyp}(A)$
   $A = \langle D(\mathtt{break}), \emptyset, [D(\mathtt{break})] \rangle$ or $A = \langle \mathtt{supp}, \emptyset, [\mathtt{supp}] \rangle$
2. **trivial**, *i.e.* built upon an unconditional ground statement
   $\mathtt{sent}(A) = \mathtt{premise}(A)$
   $A = \langle \mathtt{dia}, [\mathtt{dia}], \emptyset \rangle$ or $A = \langle \neg\mathtt{dia}, [\neg\mathtt{dia}], \emptyset \rangle$
3. **tree**, *i.e.* built upon a top rule where all literals in the body are the conclusions of subargument s.a:
   - $\mathtt{sent}(A) = \cup_{A_i = \mathtt{subarg}(A)} \mathtt{sent}(A_i) \cup \mathrm{body}(R)$
   - $\neg\, \mathcal{I}\ (\cup_i \mathtt{sent}(A_i))$ and $\neg(\mathtt{conc}(A)\ \mathcal{I}\ \mathtt{sent}(A_i))$.

   $B_1^4 = \langle \mathtt{clife}, (D(\mathtt{leave})), ((D(\mathtt{leave})) \rangle$
   $A_2^4 = \langle \mathtt{clife}, (D(\mathtt{break}), \mathtt{supp}, \mathtt{dia}), (D(\mathtt{break}), \mathtt{supp}) \rangle$
   $A_3^4 = \langle \mathtt{clife}, (D(\mathtt{break}), \mathtt{dia}), (D(\mathtt{break})) \rangle$.

Interaction: choice between different explanations

Definition (Attack relation)

$\texttt{attacks}\ (A, B)$ iff $\texttt{conc}(A)\ \mathcal{I}\ \texttt{sent}(B)$

$\Rightarrow$ build homogeneous explanations:

- $B_1^4 = \langle \texttt{clife}, (D(\texttt{leave})), ((D(\texttt{leave}))\rangle$;
- $A_2^4 = \langle \texttt{clife}, (D(\texttt{break}), \texttt{supp}, \texttt{dia}), (D(\texttt{break}), \texttt{supp})\rangle$;
- $A_3^4 = \langle \texttt{clife}, (D(\texttt{break}), \texttt{dia}), (D(\texttt{break}))\rangle$.

Interaction: choice between different explanations (cont.)

Definition (Hypothesis size)

1. if A is a hypothetical argument, then $\texttt{hypsize}(A) = 1$;
2. if A is a trivial argument, then $\texttt{hypsize}(A) = 0$
3. if A is a tree argument then $\texttt{hypsize}(A) = \Sigma_{A' \in \texttt{subarg}(A)} \texttt{hypsize}(A')$.

Definition (Strength relation)

A_1 a hypothetical argument, and A_2, A_3 two built arguments:

1. $A_2 \succ^{\mathcal{A}} A_1$;
2. If $(\texttt{top}(A_2) \prec \texttt{top}(A_3)) \wedge \neg(\texttt{top}(A_3) \prec \texttt{top}(A_2))$, then $A_3 \succ^{\mathcal{A}} A_2$;
3. If $(\texttt{top}(A_2) \sim \texttt{top}(A_3)) \wedge (\texttt{hypsize}(A_2) \leq \texttt{hypsize}(A_3))$, then $A_2 \succ^{\mathcal{A}} A_3$;

Interaction: choice between different explanations (cont.)

Definition (Defeat relation)

A **defeats** B

1. $\mathtt{attacks}(A, B)$
2. $\neg(B \succ^{\mathcal{A}} A)$.

- $B_1^4 = \langle \mathtt{clife}, (D(\mathtt{leave})), ((D(\mathtt{leave}))\rangle$;
- $A_2^4 = \langle \mathtt{clife}, (D(\mathtt{break}), \mathtt{supp}, \mathtt{dia}), (D(\mathtt{break}), \mathtt{supp})\rangle$;
- $A_3^4 = \langle \mathtt{clife}, (D(\mathtt{break}), \mathtt{dia}), (D(\mathtt{break}))\rangle$.

Since

- $\mathtt{top}(A_3^4) \prec (\mathtt{top}(B_1^4) \sim \mathtt{top}(A_2^4))$,
- $\mathtt{hypsize}(B_1^4) = \mathtt{hypsize}(A_3^4) = 1$ and $\mathtt{hypsize}(A_2^4) = 2$,

B_1^4 defeats A_2^4/A_3^4 and $A_2^4 \succ^{\mathcal{A}} A_3^4$.

Semantics: status of arguments/alternatives

Definition (Acceptability)

A set X of arguments is :

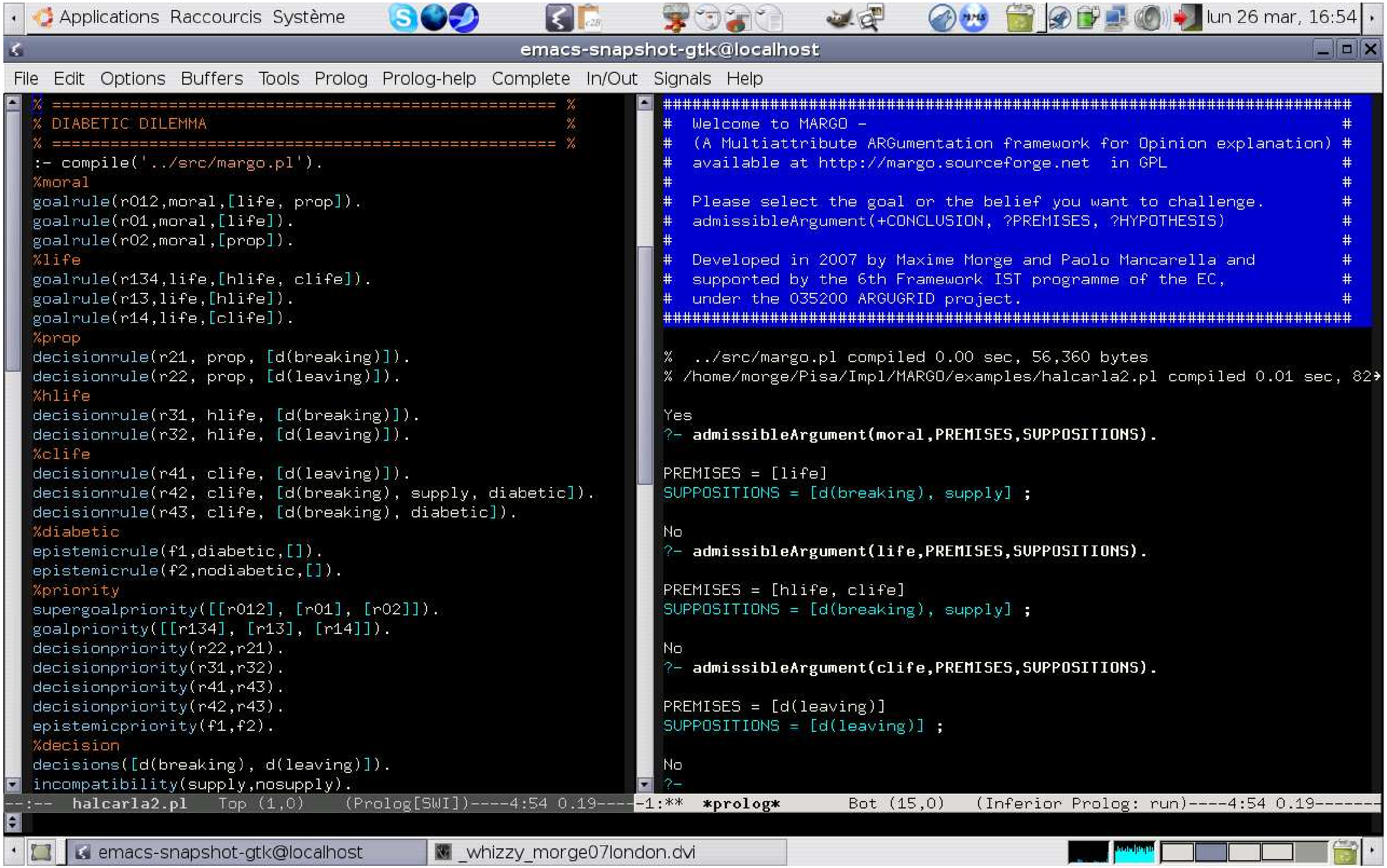
- **admissible** iff X does not attack itself and X attacks every argument Y such that Y attacks X;
- **preferred** iff X is maximally admissible;
- **ideal** iff X is admissible and it is contained in every preferred sets.

- The semantics is:
  - either *credulous*, eg admissible;
  - or *sceptical*, eg ideal, or sceptically preferred semantics.

Definition (Suggestion)

The decision $D(a_1)$ is **suggested** iff $D(a_1)$ is a hypothesis of one argument in an admissible set.

Procedure and its implementation: relax goals requirement and make hypotheses



Take away MARGO (Multicriteria ARGumentation framework for Opinion justification)

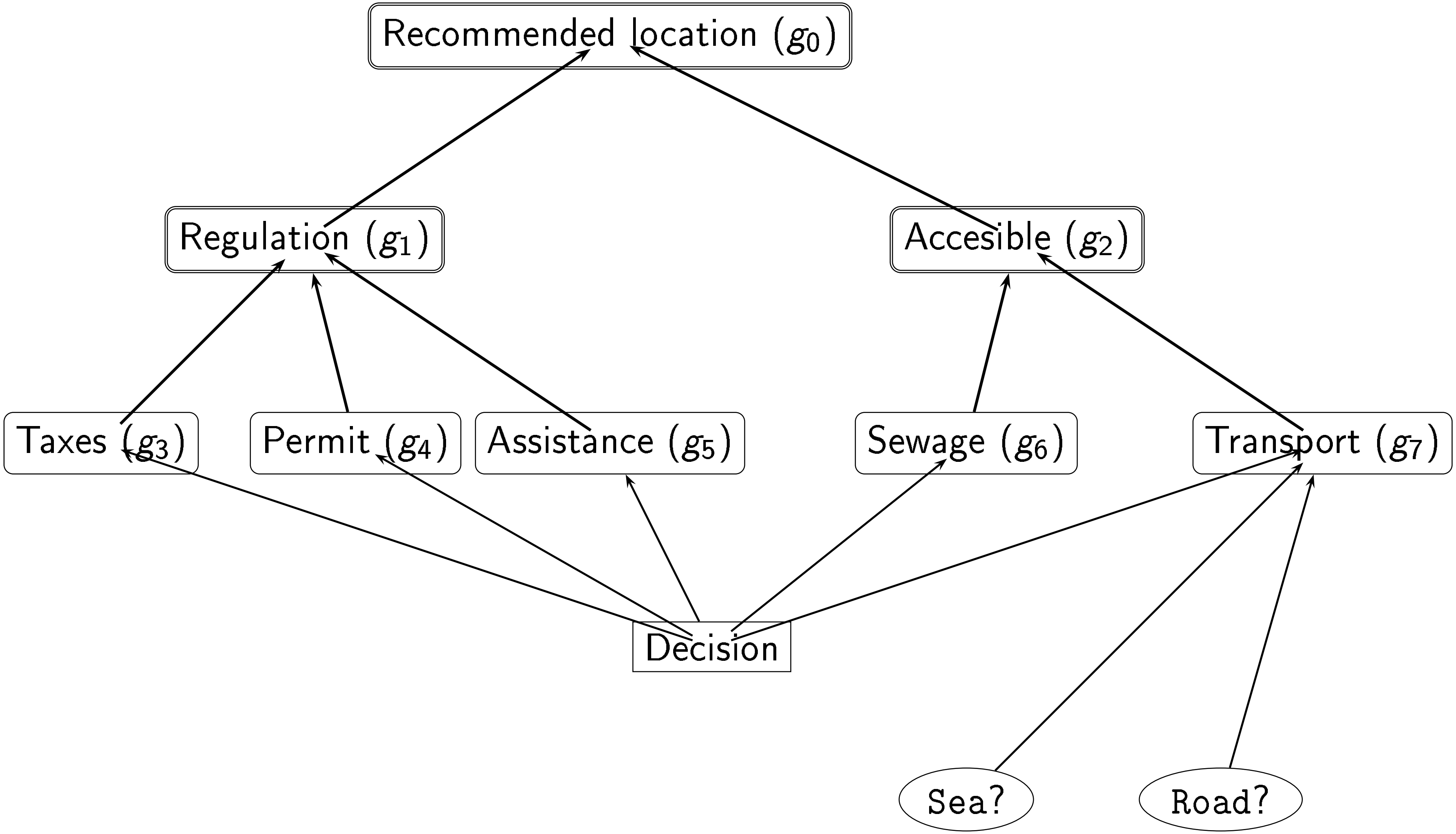
A argumentation framework for practical reasoning

↪ *Formalization of a decision making*

- Influence diagram
  ↪ *Abstract representation*
- Goal/Decision/Epistemic rules
  ↪ *Specific data structures*
- Priority over epistemic/goal/decision rules
  ↪ *Intuitions about probability/preferences/expected utilities*
- Abductive tree argument
  ↪ *Interaction-based explanation of the decision*

Outline

Influence diagram



Epistemic/Goal/Decision theory

$\prec$	R	$c(R)$
$\uparrow$	$R_{012} : g_0 \leftarrow g_1, g_2$	$c(R_{012}) = 1$
	$R_{01} : g_0 \leftarrow g_1$	$c(R_{01}) = 6/10$
	$R_{02} : g_0 \leftarrow g_2$	$c(R_{02}) = 4/10$
$\uparrow$	$R_{1345} : g_1 \leftarrow g_3, g_4, g_5$	$c(R_{1345}) = 1$
	$R_{135} : g_1 \leftarrow g_3, g_5$	$c(R_{135}) = 8/10$
	$R_{134} : g_1 \leftarrow g_3, g_4$	$c(R_{134}) = 8/10$
	$R_{13} : g_1 \leftarrow g_3$	$c(R_{13}) = 6/10$
	$R_{145} : g_1 \leftarrow g_4, g_5$	$c(R_{145}) = 4/10$
	$R_{14} : g_1 \leftarrow g_4$	$c(R_{14}) = 2/10$
	$R_{15} : g_1 \leftarrow g_5$	$c(R_{15}) = 2/10$
$\uparrow$	$R_{267} : g_2 \leftarrow g_6, g_7$	$c(R_{267}) = 1$
	$R_{27} : g_2 \leftarrow g_7$	$c(R_{26}) = 1/2$
	$R_{26} : g_2 \leftarrow g_6$	$c(R_{27}) = 1/2$

$\prec$	R	$c(R)$
$\uparrow$	$R_{31} : g_3 \leftarrow D(\texttt{london})$	$c(R_{31}) = 6/10$
	$R_{32} : g_3 \leftarrow D(\texttt{pisa})$	$c(R_{32}) = 4/10$
$\uparrow$	$R_{42} : g_4 \leftarrow D(\texttt{pisa})$	$c(R_{42}) = 7/10$
	$R_{41} : g_4 \leftarrow D(\texttt{london})$	$c(R_{41}) = 3/10$
$\uparrow$	$R_{52} : g_5 \leftarrow D(\texttt{pisa})$	$c(R_{52}) = 5/10$
	$R_{51} : g_5 \leftarrow D(\texttt{london})$	$c(R_{52}) = 5/10$
$\uparrow$	$R_{61} : g_6 \leftarrow D(\texttt{london})$	$c(R_{61}) = 5/10$
	$R_{62} : g_6 \leftarrow D(\texttt{pisa})$	$c(R_{62}) = 5/10$
$\uparrow$	$R_{71}(x) : g_7 \leftarrow D(x), \texttt{Sea}(x)$	$c(R_{71}(x)) = 6/1$
	$R_{72}(x) : g_7 \leftarrow D(x), \texttt{Road}(x)$	$c(R_{72}(x)) = 4/1$

$\prec$	R	$c(R)$
$\uparrow$	$F_1 : \text{Road}(\textit{pisa}) \leftarrow$	$c(F_1) = 8/10$
	$F_2 : \neg\text{Road}(\textit{pisa}) \leftarrow$	$c(F_1) = 2/10$
$\uparrow$	$F_3 : \text{Sea}(\textit{pisa}) \leftarrow$	$c(F_3) = 7/10$
	$F_4 : \neg\text{Sea}(\textit{pisa}) \leftarrow$	$c(F_4) = 3/10$

Interaction: choice between different explanations (cont.)

Definition (Weight)

1. if A is a hypothetical argument, then $\texttt{wei}(A) = 1$;
2. if A is trivial and built upon $F \in \mathcal{T}$, then $\texttt{wei}(A) = c(F)$
3. if A is a tree built upon $R \in \mathcal{T}$, then:
   1. either R is an epistemic rules of the form $R : B_0 \leftarrow B_1, \ldots, B_n$ with $n \geq 0$, then
      $$\texttt{wei}(A) = c(R) \times \Pi_{i=1}^{n} \texttt{wei}(A_i);$$
   2. or R is a decision rules of the form $R : g \leftarrow D, B_2, \ldots, B_n$ with $n \geq 0$, then
      $$\texttt{wei}(A) = c(R) \times \Pi_{i=1}^{n} \texttt{wei}(A_i);$$
   3. otherwise R is a goal rule of the form $R : g_0 \leftarrow g_1, \ldots, g_n$ with $n > 0$, then
      $$\texttt{wei}(A) = c(R) \times \Sigma_{i=1}^{n} c(R_{0i}) \times \texttt{wei}(A_i).$$

Interaction: choice between different explanations (cont.)

Definition (Strength relation)

A_1 be an hypothetical argument and A_2, A_3 two built arguments.

1. A_2 is stronger than A_1 (denoted $A_2 \succ^{\mathcal{A}} A_1$);
2. If $(\mathtt{top}(A_2) \sim \mathtt{top}(A_3))$ and $(\mathtt{hypsize}(A_2) \leq \mathtt{hypsize}(A_3))$, then $A_2 \succ^{\mathcal{A}} A_3$;
3. Else if $(\mathtt{wei}(A_2) \geq \mathtt{wei}(A_3))$, then $A_2 \succ^{\mathcal{A}} A_3$;

Arguments

Some of the arguments supporting the transport accesibility:

- $B_7^1 = \langle g_7, (D(\mathtt{pisa}), \mathtt{Sea}(\mathtt{pisa})), (D(\mathtt{pisa})\rangle$;
- $B_7^2 = \langle g_7, (D(\mathtt{pisa}), \mathtt{Road}(\mathtt{pisa})), (D(\mathtt{pisa})\rangle$;
- $A_7^1 = \langle g_7, (D(\mathtt{london}), \mathtt{Sea}(\mathtt{london})), (D(\mathtt{london}), \mathtt{Sea}(\mathtt{london}))\rangle$;
- $A_7^2 = \langle g_7, (D(\mathtt{london}), \mathtt{Road}(\mathtt{london})), (D(\mathtt{london}), \mathtt{Road}(\mathtt{london}))\rangle$.

Since

- $\mathtt{wei}(B_7^1) = 42/100$, $\mathtt{wei}(B_7^2) = 32/100$, $\mathtt{wei}(A_7^1) = 60/100$, and $\mathtt{wei}(A_7^2) = 40/100$,
- $\mathtt{hypsize}(B_7^1) = \mathtt{hypsize}(B_7^2) = 1$ and $\mathtt{hypsize}(A_7^1) = \mathtt{hypsize}(A_7^2) = 2$.

B_7^1/B_7^2 defeat A_7^1/A_7^2 and B_7^1 (resp. A_7^1) is stronger than B_7^2 (resp. A_7^2)

$\Rightarrow$ Pisa must be selected as the best alternative to achieve g_7 and the best explanation is based upon the availability of sea transports.

Semantics

The admissible arguments are:

- $A^1_0 = \langle g_0, (g_1, g_2), (D(\mathtt{london}), \mathtt{Sea}(london))\rangle$;
- $B^1_2 = \langle g_2, (g_6, g_7), (D(\mathtt{pisa}))\rangle$.

Definition (Full admissibility)

- A is fully acceptable with respect to S in $\mathcal{T}$ (denoted $A \in \underline{\mathcal{S}}^S_{\mathcal{A}}(\mathcal{T})$) iff A is acceptable with respect to S in $\mathcal{T}$ and all its subarguments A' are acceptable with respect to the set of arguments and subarguments of S in $\mathcal{T}_{\mathtt{conc}(A')}$;
- S is fully admissible in $\mathcal{T}$ iff S is conflict-free and $\forall A \in S,\ A \in \underline{\mathcal{S}}^S_{\mathcal{A}(\mathcal{T})}$;

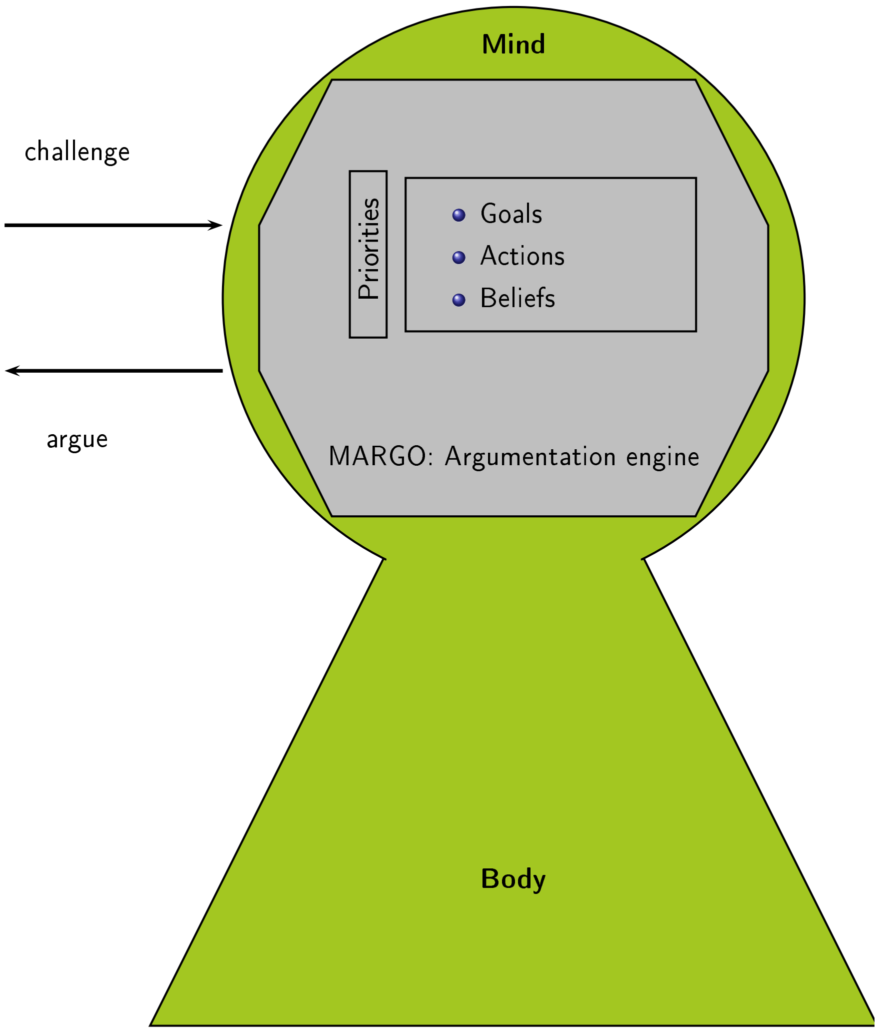
The fully admissible arguments are:

- $A^2_0 = \langle g_0, (g_1), (D(\mathtt{london}), \mathtt{Sea}(london))\rangle$;
- $B^1_2 = \langle g_2, (g_6, g_7), (D(\mathtt{pisa}))\rangle$.

Outline

Outlook: Agents' mind (WP2)

- Design
  - state-of-mind (knowledge, goals, actions, plans)
  - qualitative/quantitative priorities
  - workflow in state-of-mind
- Implementation
  MARGO: a Prolog prototype
- Application
  procurement/migration/EO scenarios



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Brief overview

- Written in Prolog
- Available in GPL at `http://margo.sourceforge.net`
- Built upon CaSAPI (Credulous and Sceptical Argumentation Prolog Implementation) written by Dorian Gaertner and Francesca Toni
  `http://www.doc.ic.ac.uk/~dg00/casapi.html`
- The main procedure is
  `admissibleArgument(+CONC, -PREMISES, -SUPPOSITIONS)`
  with:
  - the first argument is the goal/belief of the admissible arguments ie the conclusions;
  - the second argument stands for the premises;
  - the third argument stands for the suppositions.

A good example is better than a long explanation

```
:- compile('../src/margo.pl').
decisionrule(r71a, g7, [d(london), sea(london)]).
decisionrule(r71b, g7, [d(pisa), sea(pisa)]).
epistemicrule(f11,road(london),[]).
epistemicrule(f12,road(pisa),[]).
epistemicpriority(f12,f11).
supposition(a11,road(london)).
supposition(a12,road(pisa)).
supposition(a21,sea(london)).
supposition(a22,sea(pisa)).
decisions([d(london), d(pisa)]).
```

`admissibleArgument(g7,PREMISES,SUPPOSITION)` **returns**

```
PREMISES = [d(london), sea(london)]
SUPPOSITIONS = [d(london), sea(london)] ;
PREMISES = [d(pisa), sea(pisa)]
SUPPOSITIONS = [d(pisa), sea(pisa)] ;
```

(1) MARGO in the shell: translation in CaSAPI

```
%%%Define CaSAPI rules with priorities/rules
myRule(FACT,[not(del(NAME))]):-supposition(NAME,FACT).
myRule(HEAD,[not(del(NAME))|BODY]):-decisionrule(NAME,HEAD,BODY).
myRule(HEAD,[not(del(NAME))|BODY]):-goalrule(NAME,HEAD,BODY).
myRule(HEAD,[not(del(NAME))|BODY]):-epistemicrule(NAME,HEAD,BODY).
myRule(del(R1),[not(del(R2))]):-epistemicpriority(R2,R1).
myRule(del(R1),[not(del(R2))]):-decisionpriority(R2,R1).

%%%Define set of assumptions with decision/epistemic rules
myAss(Ass):-findall(D, isDecision(D), DS),
decisionrules(DR), append(DS,DR,SUBA),
epistemicrules(ER), append(ER,SUBA,A),
incompatibilities(I), append(I,A,Ass).

%%%Define CaSAPI's contrary with decisions/incompatibilities
contrary(d(X),d(Y)):- decisions(D), member(d(X),D), member(d(Y),D), \+ X=Y.
contrary(not(del(X)), del(X)):-!.
contrary(del(X), not(del(X))).
contrary(X,Y):-incompatibility(X,Y).
contrary(X,Y):-incompatibility(Y,X).
contrary(X,Y):-asincompatibility(Y,X).
```

(2) MARGO in the shell: CaSAPI meta-interpreter

```
Data: A problem description, a conclusion
Result: SENTENCES of an admissible argument
myAss(ASSUMPTIONS) ; // set the assumptions
run(ab,s,a,[CONC],ASSUMPTIONS,SENTENCES) ; // run CaSAPI
if no argument is found then
    while strongestrules() do
        nextstrongestrule(TOPRULE) ; // find one of the
        strongest rule
        usefulSuppositions(BODY,USL) ; // find minimal non-empty
        useful hypotheses
        append(USL,ASSUMPTIONS,NEWASSUMPTIONS);
        run(ab,s,a,[CONC],NEWASSUMPTIONS,SENTENCES) ;
        // run CaSAPI with these new assumptions
    end
end
```

Relax of user's needs in CaSAPI

```
%goal rules
myRule(g1,[g4, g5, not(del(r145))]).
myRule(g1,[g4, not(del(r14))]).
myRule(g1,[g5, not(del(r15))]).
%decision rules
myRule(g4,[d(london), not(del(r41))]).
myRule(g4,[d(pisa), not(del(r42))]).
myRule(g5,[d(london), not(del(r51))]).
myRule(g5,[d(pisa), not(del(r52))]).
% decision priorities
myRule(del(r42),[not(del(r41))]).
myRule(del(r51),[not(del(r52))]).

contrary(d(london),d(pisa)).
contrary(d(pisa),d(london)).
contrary(not(del(X)),del(X)) :- !.
contrary(del(X),not(del(X))).
```

```
run(ab,s,a,[g1],[d(pisa), d(london),
not(del(r145)),
not(del(r51)), not(del(r52)),
not(del(r41)), not(del(r42))],X).
says No.

run(ab,s,a,[g1],[d(pisa), d(london),
not(del(r14)),
not(del(r51)), not(del(r52)),
not(del(r41)), not(del(r42))],X).
says
X = [not(del(r14)), d(london),
     not(del(r41))]

run(ab,s,a,[g1],[d(pisa), d(london),
not(del(r15)),
not(del(r51)), not(del(r52)),
not(del(r41)), not(del(r42))],X).
says
X = [not(del(r15)), d(pisa),
     not(del(r52))] ;
```

Natural relax of user's needs in MARGO

```
%goal rules
goalrule(r145, g1, [g4, g5]).
goalrule(r14, g1, [g4]).
goalrule(r15, g1, [g5]).
%decision rules
decisionrule(r41, g4, [d(london)]).
decisionrule(r42, g4, [d(pisa)]).
decisionrule(r51, g5, [d(london)]).
decisionrule(r52, g5, [d(pisa)]).

%goal priority
goalpriority([[r145],[r14],[r15]]).

%decisio priority
decisionpriority(r41,r42).
decisionpriority(r52,r51).

decisions([d(london), d(pisa)]).
```

```
Then argument(g1,PREMISES,SUPPOSTIONS).
PREMISES = [g4]
SUPPOSTIONS = [d(pisa)].
```

Hypotheses over knowledge in CaSAPI

```
myRule(g7,[d(london),sea(london),
       not(del(r71a))]).
myRule(g7,[d(pisa),sea(pisa),
       not(del(r71b))]).

myRule(sea(pisa),[not(del(supp1))]).
myRule(sea(pisa),[not(del(supp2))]).

contrary(d(london),d(pisa)).
contrary(d(pisa),d(london)).
contrary(not(del(X)),del(X)) :- !.
contrary(del(X),not(del(X))).
```

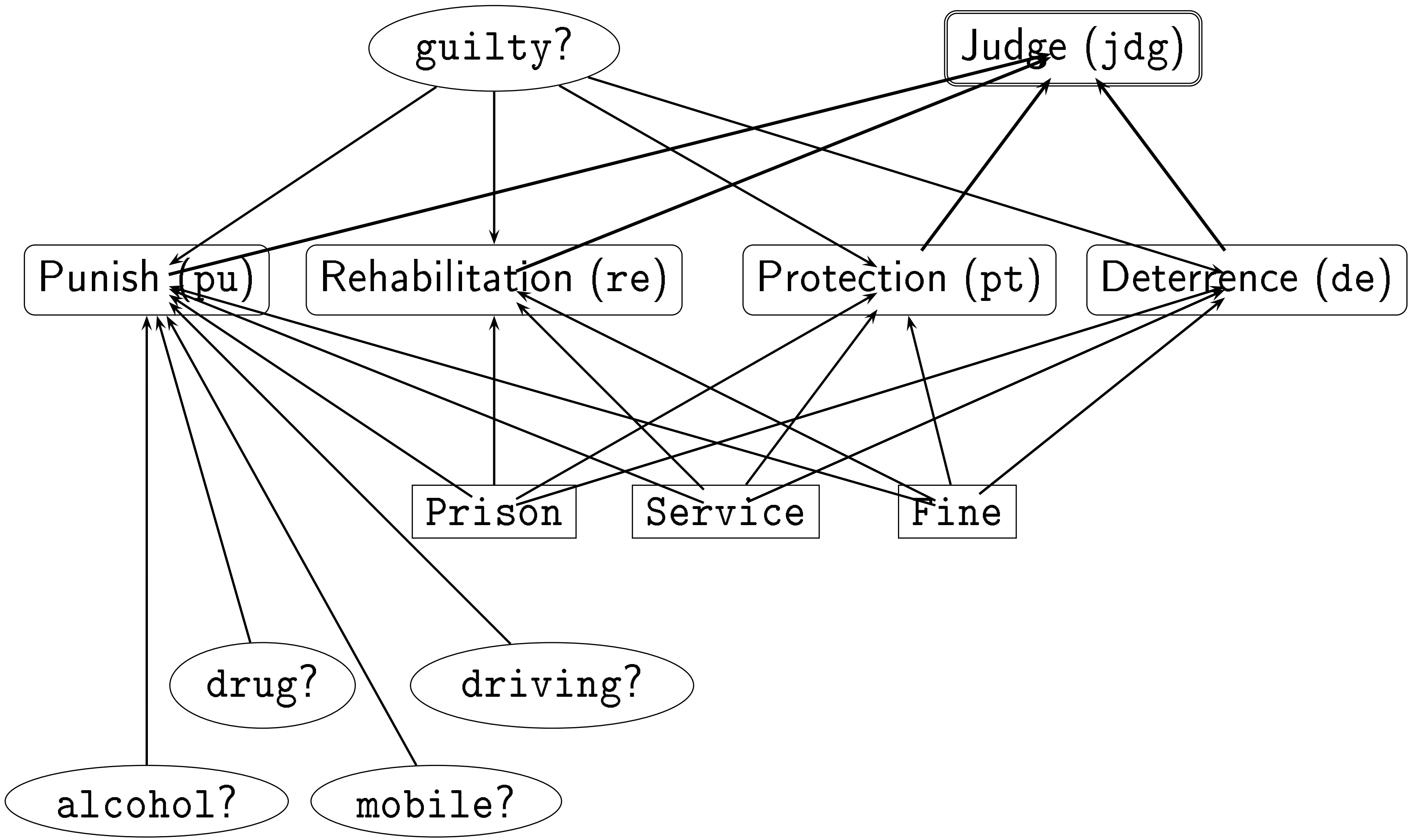
```
run(ab,s,a,[g7],[d(pisa), d(london),
    not(del(r71a)), not(del(r71b))],X).
says No

run(ab,s,a,[g7],[d(pisa), d(london),
    not(del(r71a)), not(del(r71b)),
    not(del(supp1)),not(del(supp2))],X).
says
X = [d(pisa), not(del(r71b)),
     not(del(supp1))] ;
X = [d(pisa), not(del(r71b)),
     not(del(supp2))] ;
```

Natural hypotheses over knowledge in MARGO

```
decisionrule(r71a, g7,
             [d(london), sea(london)]).
decisionrule(r71b, g7,
             [d(pisa), sea(pisa)]).

supposition(a11,road(london)).
supposition(a12,road(pisa)).
supposition(a21,sea(london)).
supposition(a22,sea(pisa)).

decisions([d(london), d(pisa)]).
```

```
argument(g7,PREMISES,SUPPOSITIONS) says

PREMISES = [d(london), sea(london)]
SUPPOSITIONS = [d(london), sea(london)]

PREMISES = [d(pisa), sea(pisa)]
SUPPOSITIONS = [d(pisa), sea(pisa)]
```

Influence diagram



Epistemic/Goal/Decision theory

R_{01} : jdg ← pu, re, pt, ¬de
R_{02} : jdg ← pu, re, ¬de
R_{03} : jdg ← pu, ¬re, pt, de
R_{04} : jdg ← pu, re, de

F_0 : driving ←
F_1 : guilty ←
F_2 : drug ←
F'_2 : ¬drug ←
F_3 : alcohol ←
F'_0 : ¬driving ←

R_{11} : pu ← Prison(yes), drug, driving, guilty
R'_{11} : pu ← Prison(yes), alcohol, driving, guilty
R''_{11} : pu ← Prison(yes), mobile, driving, guilty
R_{12} : pu ← Service(yes), guilty
R_{13} : pu ← Fine(yes), not guilty
R_{212} : re ← Prison(yes), Service(yes), guilty
R'_{212} : ¬re ← Prison(yes), Service(no), guilty
R_{422} : de ← Prison(yes), Service(yes), guilty
R'_{422} : de ← Prison(no), Service(yes), guilty
R_{21} : ¬re ← Prison(yes), guilty
R'_{21} : ¬re ← Prison(yes), not guilty
R_{22} : re ← Service(yes), guilty
R'_{22} : ¬re ← Service(yes), not guilty
R'_{23} : re ← Fine(yes), not guilty
R_{31} : pt ← Prison(yes), guilty
R_{33} : ¬pt ← Fine(yes), guilty
R'_{33} : pt ← Fine(yes), not guilty
R_{41} : de ← Prison(yes), guilty
R'_{41} : de ← Prison(yes), not guilty
R_{42} : ¬de ← Service(yes), guilty
R'_{42} : de ← Service(yes), not guilty
R_{43} : ¬de ← Fine(yes), guilty
R'_{43} : de ← Fine(yes), not guilty

Arguments

Some of the arguments concluding pu are the following:

- $A = \langle \mathtt{re}, (\mathtt{Prison}(\mathtt{yes}), \mathtt{Service}(\mathtt{yes}), \mathtt{guilty}), (\mathtt{Prison}(\mathtt{yes}), \mathtt{Service}(\mathtt{yes}))\rangle$;
- $B = \langle \neg\mathtt{re}, (\mathtt{Prison}(\mathtt{yes}), \mathtt{guilty}), (\mathtt{Prison}(\mathtt{yes}))\rangle$;
- $C = \langle \mathtt{re}, (\mathtt{Service}(\mathtt{yes}), \mathtt{guilty}), (\mathtt{Service}(\mathtt{yes}))\rangle$;

Since

- $(\mathtt{top}(B) \sim \mathtt{top}(C)) \prec \mathtt{top}(A)$,
- $\mathtt{hypsize}(A) = 2$ and $\mathtt{hypsize}(B) = \mathtt{hypsize}(C) = 1$,

$A \succ^{\mathcal{A}} B/C$.

$\Rightarrow$ Prison and community service must be selected to promote rehabilitation.