Argumentation framework for collective decision-making*

Maxime Morge†

†Dipartimento di Informatica
Università di Pisa

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Outline

1. ARGUGRID
2. Argumentation
3. Argumentation-based decision-making
4. Multi-Agent System
5. Argumentation-based collective decision-making
6. Conclusions & Future works
ARGUementation 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.
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
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 logic [Prakken & Sartor 97], i.e.

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

- **Status of arguments**
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

\[
a \leftrightarrow b \quad c \leftrightarrow d
\]
Abstract argumentation framework

- $\emptyset$ 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

\[ a \rightarrow b \quad c \rightarrow d \]

- \( \{b, c, f\} \) 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])

A set \( X \) of arguments is:

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- **ideal** iff \( X \) is admissible and it is contained in every preferred sets.
The statements

- $\mathcal{L}$ a logic language

**Definition ([Prakken & Sartor 97])**

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

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

head$(R) = L_0.$

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

- $\mathcal{I}$ is an incompatibility relation amongst sentences in $\mathcal{L}$
  - $\mathcal{I}(b_1, \neg b_1)$ and $\mathcal{I}(\neg b_1, b_1)$,
  - $\mathcal{I}(b_1, \text{not } b_1)$
Forms of arguments:

- An **abstract entity** with an unspecified logic,
  \[ A = \text{‘Tweety flies because it’s a bird’}; \]

- A **pair** (Premises, Conclusion),
  \[ A = (\{\text{bird(Tweety)}, \text{bird}(X) \rightarrow \text{fly}(X)\}, \text{fly(Tweety)}); \]

- A deduction **sequence** of rules and facts
  \[ A = (f_1(\text{Tweety}), r_1(\text{Tweety})); \]

- An inference **tree** grounded in premises;

```
fly(Tweety)

bird(Tweety) not penguin(Tweety)
```
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.*

```
fly(Tweety)    ¬fly(Tweety)
```
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].

The strength of an argument depends on the quality of information:

- the likelihood of beliefs;
- the preferences between goals;
- the credibility of decisions.
- Defeat relation focus on two arguments not on a dispute, eg
Burden of proof rather than correspondence with reality

(Declarative) Model-theoretic Semantic

Completeness

Soundness

(Procedural) Dialectical Proof Procedure
Dialectical enquiry

**Definition**

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

\[
\{p, r\} \text{ and } \{p, s\} \text{ are preferred}
\]

\[
\begin{align*}
M_1 &= \langle \text{PRO}, p \rangle \\
M_2 &= \langle \text{CON}, q, M_1 \rangle \\
M_3 &= \langle \text{PRO}, r, M_2 \rangle \\
M_4 &= \langle \text{CON}, s, M_3 \rangle \\
M_5 &= \langle \text{PRO}, r, M_4 \rangle
\end{align*}
\]

\[
\begin{align*}
\text{PRO} &\quad \text{CON} & \quad \text{PRO}
\end{align*}
\]

\[
\begin{align*}
\text{CON} &\quad \text{PRO} & \quad \text{CON}
\end{align*}
\]

**Theorem**

*Soundness and completeness of TPI for the credulous 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.
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Which kind of decision maker are you? [Tetlock 06]

Corporate executives say:
- “it is annoying to listen to someone who cannot seem to make up his or her mind”
- “the most common error in decision-making is to abandon good ideas too quickly”

Hedgehogs know one big thing, have intuitions, and never surrender.

Judges say:
- “when considering most conflicts, I can usually see how both sides could be right”
- “I prefer interacting with people whose opinions are very different from my own”

Foxes knows many little things, interact, and change their mind.
Interaction-based explanation of the decision

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Argumentation framework for collective decision-making
Influence diagram (Id) for decision analysis [Clemen. 06]
Id for business location [ARGUGRID. 06]
Id for business location [ARGUGRID. 06]

$g_2 \prec g_1$

Recommended location ($g_0$)

$g_5 \prec g_4 \prec g_3 \prec g_4 + g_5$

Regulation ($g_1$)

$g_7 \prec g_6$

Accessible ($g_2$)

Taxes ($g_3$)

$\ a_1 \prec a_2$

Permit ($g_4$)

$a_2 \prec a_1$

Assistance ($g_5$)

$a_2 \prec a_1$

Sewage ($g_6$)

$a_2 \prec a_1$

Transport ($g_7$)

Decision

London($a_1$) or Pisa($a_2$)

Sea? Sea($a_2$)

Road? ¬Road($a_2$) \prec Road($a_2$)
Preferences, uncertainty, and credibility over statements

The theory compiles:

- **goal rules** such as $R_{12}^\alpha : g_0 \leftarrow g_1, g_2$
- **epistemic rules** such as $R_{12}^\beta : b_0 \leftarrow b_1, \neg b_2$
- **recommending rules** such as $R_{1}^\gamma : D(a_1) \leftarrow b_0$
- **decision rules** such as $R_{11}^\delta : g_1 \leftarrow D(a_1), b_0$

Different priorities for different rules:

- the priority over **goal rules** comes from their levels of preference, eg $R_{1}^\alpha : g_0 \leftarrow g_1$ has priority over $R_{2}^\alpha : g_0 \leftarrow g_2$
- the priority over **epistemic rules** comes from their levels of certainty, eg $F_{1}^\beta : \text{Road}(a_2) \leftarrow$ has priority over $F_{2}^\beta : \neg \text{Road}(a_2) \leftarrow$
- the priority over **decision rules** come from their levels of credibility, eg $R_{51}^\delta : g_5 \leftarrow D(a_1)$ has priority over $R_{52}^\delta : g_5 \leftarrow D(a_2)$
A walk through the example

The goal theory

- \( R_{12}^\alpha : g_0 \leftarrow g_1, g_2 \)
- \( R_{345}^\alpha : g_1 \leftarrow g_3, g_4, g_5 \)
- \( R_{67}^\alpha : g_2 \leftarrow g_6, g_7 \)
- \( R_{45}^\alpha : g_1 \leftarrow g_4, g_5 \)
- \( R_1^\alpha : g_0 \leftarrow g_1 \)
- \( R_3^\alpha : g_1 \leftarrow g_3 \)
- \( R_6^\alpha : g_2 \leftarrow g_6 \)
- \( R_2^\alpha : g_0 \leftarrow g_2 \)
- \( R_4^\alpha : g_1 \leftarrow g_4 \)
- \( R_7^\alpha : g_2 \leftarrow g_7 \)
- \( R_5^\alpha : g_1 \leftarrow g_5 \)
A walk through the example

The epistemic theory

\[
\begin{align*}
F_1^\beta & : \text{Road}(a_2) \leftarrow \\
F_2^\beta & : \text{Sea}(a_2) \leftarrow \\
F_3^\beta & : \neg \text{Road}(a_2) \leftarrow \\
\end{align*}
\]
A walk through the example

The decision theory

\[
\begin{align*}
R_{32}^{\delta} &: g_3 \leftarrow D(a_2) \\
R_{41}^{\delta} &: g_4 \leftarrow D(a_1) \\
R_{51}^{\delta} &: g_5 \leftarrow D(a_1) \\
R_{61}^{\delta} &: g_6 \leftarrow D(a_1) \\
R_{62}^{\delta} &: g_6 \leftarrow D(a_2) \\
R_{71}^{\delta}(x) &: g_7 \leftarrow D(x), \text{Road}(x) \\
R_{31}^{\delta} &: g_3 \leftarrow D(a_1) \\
R_{31}^{\delta} &: g_3 \leftarrow D(a_1) \\
R_{42}^{\delta} &: g_4 \leftarrow D(a_2) \\
R_{52}^{\delta} &: g_5 \leftarrow D(a_2) \\
R_{61}^{\delta} &: g_6 \leftarrow D(a_1) \\
R_{72}^{\delta}(x) &: g_7 \leftarrow D(x), \text{Sea}(x)
\end{align*}
\]
Abductive tree argument

Definition

An argument \( A = \langle \text{conc}, \text{premise}, \text{asm} \rangle \) is:

1. **hypothetical**, i.e. built upon an assumption
   \[ \text{sent}(A) = \text{asm}(A) \]
   \[ \text{eg} \ A = \langle D(a_1), \emptyset, [D(a_1)] \rangle \text{ or } A = \langle \text{Sea}(a_1), \emptyset, [\text{Sea}(a_1)] \rangle \]

2. **trivial**, i.e. built upon an unconditional ground statement
   \[ \text{sent}(A) = \text{premise}(A) \]
   \[ \text{eg} \ A = \langle \text{Road}(a_2), [\text{Road}(a_2)], \emptyset \rangle \text{ or } A = \langle \neg \text{Road}(a_2), [\neg \text{Road}(a_2)], \emptyset \rangle \]

3. a minimal and consistent **tree**, i.e. built upon a top rule where all literals in the body are the conclusions of subargument s.a.:
   - \[ \text{sent}(A) = \bigcup_{A_i=\text{subarg}(A)} \text{sent}(A_i) \cup \text{conc}(A) \]
   - \[ \text{conc}(A) \not\subseteq \bigcup_{A_i=\text{subarg}(A)} \text{sent}(A_i) \text{ and } \neg \mathcal{I} (\text{sent}(A)). \]
   \[ \text{eg} \ A = \langle g_0, [g_1, g_2], [D(a_1), \text{Sea}(a_1)] \rangle \text{ or } A = \langle g_2, [g_6], [D(a_2)] \rangle \]
Interactions between concurrent or conflicting explanations

Definition (Attack relation)
attacks \((A, B)\) iff \(\text{sent}(A) \sqsubseteq \text{sent}(B)\).

Definition (Strength relation)
\(\succ^{A}\) is a (partial or total) preorder on arguments s.a. :
1. hypothetical arguments \(\prec^{A}\) 
2. trivial arguments \(\prec^{A}\) 
3. tree arguments 
4. if \(\text{top}(A) \prec \text{top}(B)\), then \(A \prec^{A} B\);

Definition (Defeat relation)
\(A\) defeats \(B\)
1. attacks \((A, B)\)
2. \(\neg(B \succ^{A} A)\).
Take away MARGO (Multicriteria ARGumentation framework for Opinion justification)

A framework for inter-agent dialogue

→ Formalization of a debate

- Influence diagram
  → Abstract representation

- Goal/Decision/Epistemic rules
  → Specific data structures

- Priority over goal/decision/epistemic rules
  → Intuitions about preferences/credibility/uncertainty

- Abductive tree argument
  → Interaction-based explanation of the decision
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Multi-Agent Systems technics for decentralized applications

- Characteristics: multi-(actors, experts, viewpoints, decisions) in an open, distributed and dynamic environment.
- Needs:
  - autonomy at the local level,
  - cooperation (competition, collaboration) at the global level
The vowel approach and the argumentation

**MAS** is

- autonomous and social **Agent**, *i.e.* program exhibiting a behaviour (game theory, BDI logic)
- **Environment**, *i.e.* set of situated objects/resources/agents and the medium of interaction
- **Interaction**, *i.e.* (direct/indirect) mutual influences between agents
- **Organization**, *i.e.* structural (roles) and functional (permissions/obligations) links amongst agents
In order to communicate, agents use an ACL (syntax/semantics/pragmatics). E.g. FIPA-ACL:

- Feasible preconditions:
  \[ B_1 p \land (\neg B_1 (Bif_2 p \lor Uif_2 p)) \]
- Rational effects:
  \[ B_2 p \]
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Multi-Agent formalization of a collective decision-making

Collective decision=
- multi-actors process
- complex reasoning of actors
- collaborative process
- outcome of individual actions
Multi-Agent formalization of a collective decision-making

Collective decision=

- multi-actors process
  ⇒ autonomous agent
- complex reasoning of actors
  ⇒ cognitive agent
- collaborative process
  ⇒ social agent
- outcome of individual actions
  ⇒ framework for interaction
From the speech act theory to the dialectics

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<th>Goals</th>
<th>Speech act theory</th>
<th>Dialectics</th>
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<tr>
<td>Manage conflicts</td>
<td>✗BDI model</td>
<td>✓Argumentation</td>
</tr>
<tr>
<td>Reason together</td>
<td>✗Private and subjective semantics</td>
<td>✓Commitment stores</td>
</tr>
<tr>
<td>Warrant to reach an agreement</td>
<td>✗Rigid protocol</td>
<td>✓Dialogue-game</td>
</tr>
</tbody>
</table>

- **Argumentation**, *i.e.* a process of construction and comparison of arguments for and against certain conclusions.
- **Commitment stores**, *i.e.* data types to record commitments during the dialogue.
- **Dialogue-game**, *i.e.* flexible and refined process managing the sequence of moves from an initial situation to reach the goal.
Argumentation to manage conflicts

1. **Audience #1**

   - \( T \)
     - \( R^0_{71}(x) : g_7 \leftarrow D(x), \text{Road}(x) \)
     - \( R^0_{72}(x) : g_7 \leftarrow D(x), \text{Sea}(x) \)
     - \( F_1 : \text{Road}(a_2) \)
     - \( F_2 : \text{Sea}(a_2) \)
     - \( F_3 : \neg \text{Road}(a_2) \)

2. **Audience #2**

   - \( T \)
     - \( R^0_{71}(x) : g_7 \leftarrow D(x), \text{Road}(x) \)
     - \( R^0_{72}(x) : g_7 \leftarrow D(x), \text{Sea}(x) \)
     - \( F_3 : \neg \text{Road}(a_2) \)
     - \( F_1 : \text{Road}(a_2) \)
     - \( F_2 : \text{Sea}(a_2) \)

---

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Argumentation framework for collective decision-making
Model of agents to reason together

Agent #1

\[ R_{71}^\delta(x) : g_7 \leftarrow D(x), \text{Road}(x) \]
\[ R_{72}^\delta(x) : g_7 \leftarrow D(x), \text{Sea}(x) \]
\[ F_1 : \text{Road}(a_2) \]
\[ F_2 : \text{Sea}(a_2) \]
\[ CS_2^1 = \{ F_3 : \neg \text{Road}(a_2) \} \]
Speech act semantics to reason together

= argumentative/social semantics

1. assert(h)

- Rational condition of utterance: 
  $ag_1$ has an argument for $h$

- Updating rules of commitment stores: 
  $ag_2$ and $ag_3$ record that $ag_1$ commits himself on $h$
Speech act semantics to reason together

= argumentative/social semantics

1. Concede(h)

Rational condition of utterance:
\(ag_1\) has a personal and non-trivial argument for \(h\)

Updating rules of commitment stores:
\(ag_2\) and \(ag_3\) record that \(ag_1\) commits himself on \(h\)
Utterances to reason together

<table>
<thead>
<tr>
<th>$\ll_1$</th>
<th>Agent #1</th>
<th>$\mathcal{I}^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mathcal{R}^\delta_1(x): g_7 \leftarrow D(x), \text{Road}(x)$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mathcal{R}^\delta_2(x): g_7 \leftarrow D(x), \text{Sea}(x)$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F_1: \text{Road}(a_2)$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F_2: \text{Sea}(a_2)$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$CS^1_{2} = {F_3: \neg \text{Road}(a_2)}$</td>
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</tbody>
</table>

- Agent #2 asserts $\neg \text{Road}(a_2)$
- Agent #1 can assert $D(a_2)$ but cannot assert/concede $D(a_1)$
Dialectical multi-agent system to reach an agreement

A dialogical move =
- a message;
- the id of the move to which it responds;
- a protocol.

A dialectical system on a topic =
- an initiator and a partner, i.e.
  two argumentative agents who play;
- a witness, i.e.
  an argumentative agent who arbitrates;
- a turn-taking function;
- a convention determining the moves which are allowed.
A protocol to reach an agreement

• Protocol of persuasion:
  • Initial situation: conflict
  • Main goal: verbally resolve the conflict

<table>
<thead>
<tr>
<th>Sequence rules</th>
<th>Acts</th>
<th>Resists</th>
<th>Surrenders</th>
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</thead>
<tbody>
<tr>
<td>sr Q/A</td>
<td>question(h)</td>
<td>assert(h)</td>
<td>unknown(h)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>assert(¬h)</td>
<td></td>
</tr>
<tr>
<td>sr A/R</td>
<td>assert(H)</td>
<td>challenge(h), h ∈ H</td>
<td>concede(H)</td>
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<td>challenge(h)</td>
<td>assert(H), H ⊨∪ h</td>
<td>withdraw(h)</td>
</tr>
<tr>
<td>sr T</td>
<td>unknow(H)</td>
<td>∅</td>
<td>∅</td>
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<tr>
<td></td>
<td>concede(H)</td>
<td>∅</td>
<td>∅</td>
</tr>
<tr>
<td></td>
<td>withdraw(H)</td>
<td>∅</td>
<td>∅</td>
</tr>
</tbody>
</table>

• a set of histories, i.e. sequences of moves
• dialogue i.e. terminal history
• an utility function determining if a player is a winner

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A dialogue-game to reach an agreement

Witness

Partner

\[ T^* \]

\[ R^0_1(x) : g_1 \leftarrow D(x), \text{Road}(x) \]

\[ R^0_2(x) : g_1 \leftarrow D(x), \text{Sea}(x) \]

\[ \text{CS}_{\text{init}}^{\text{wit}} = \{ \} \]

\[ \text{CS}_{\text{init}}^{\text{wit}} = \{ \} \]

\[ \text{CS}_{\text{part}} = \{ \} \]

\[ \text{CS}_{\text{part}} = \{ \} \]

\[ \text{part} \]

\[ T^* \]

\[ R^0_1(x) : g_1 \leftarrow D(x), \text{Road}(x) \]

\[ R^0_2(x) : g_1 \leftarrow D(x), \text{Sea}(x) \]

\[ F_1 : \text{Road}(a_2) \]

\[ F_2 : \text{Sea}(a_2) \]

\[ \text{CS}_{\text{init}}^{\text{part}} = \{ \} \]

\[ \text{CS}_{\text{init}}^{\text{part}} = \{ \} \]

\[ \text{init} \]
A dialogue-game to reach an agreement

Witness

Partner

\( \leq^* \text{wit} \)

\( T^* \)

\( R^0_{I1}(x) : g_7 \leftarrow D(x), \text{Road}(x) \)

\( R^0_{I2}(x) : g_7 \leftarrow D(x), \text{Sea}(x) \)

\( \text{CS}_{\text{wit}}^{\text{init}} = \{ \} \)

\( \text{CS}_{\text{wit}}^{\text{part}} = \{ \} \)

\( \leq^* \text{part} \)

\( R^0_{I1}(x) : g_7 \leftarrow D(x), \text{Road}(x) \)

\( R^0_{I2}(x) : g_7 \leftarrow D(x), \text{Sea}(x) \)

\( F_1 : \text{Road}(a_2) \)

\( F_2 : \text{Sea}(a_2) \)

\( \text{CS}_{\text{part}}^{\text{init}} = \{ \} \)

Partner

\( \leq^* \text{init} \)

\( R^0_{I1}(x) : g_7 \leftarrow D(x), \text{Road}(x) \)

\( R^0_{I2}(x) : g_7 \leftarrow D(x), \text{Sea}(x) \)

\( F_3 : \neg \text{Road}(a_2) \)

\( \text{CS}_{\text{part}}^{\text{init}} = \{ \} \)

question "\( g_7 \)"
A dialogue-game to reach an agreement

**Witness**

\[ T^* \]

- \( R_{\theta_1}^0 (x) : g_7 \leftarrow D(x), \text{Road}(x) \)
- \( R_{\theta_2}^0 (x) : g_7 \leftarrow D(x), \text{Sea}(x) \)

\( \text{CS}^{\text{wit}}_{\text{init}} = \{ \} \)

\( \text{CS}^{\text{wit}}_{\text{part}} = \{ \neg g_7 \} \)

**Partner**

\[ T^* \]

- \( R_{\theta_1}^0 (x) : g_7 \leftarrow D(x), \text{Road}(x) \)
- \( R_{\theta_2}^0 (x) : g_7 \leftarrow D(x), \text{Sea}(x) \)
- \( F_1 : \text{Road}(a_2) \)
- \( F_2 : \text{Sea}(a_2) \)

\( \text{CS}^{\text{init}}_{\text{part}} = \{ \neg g_7 \} \)

**Question** "\( g_7 \)"

**Assert** "\( \neg g_7 \)"

Dr. Maxime MORGÉ

Argumentation framework for collective decision-making
A dialogue-game to reach an agreement

\[
\begin{align*}
&\text{Witness} \\
&\text{Partner} \\
&\text{Partner}
\end{align*}
\]

**Question**: "\(g_7\)"

**Assert**: "\(\neg g_7\)"

**Assert**: "\(g_7\)"
A dialogue-game to reach an agreement

<table>
<thead>
<tr>
<th>Witness</th>
<th>Partner</th>
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</tr>
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<tbody>
<tr>
<td>$T^*$</td>
<td>$R^0_{71}(x) : g_7 \leftarrow D(x), \text{Road}(x)$</td>
<td>$R^0_{72}(x) : g_7 \leftarrow D(x), \text{Sea}(x)$</td>
</tr>
<tr>
<td>$CS^{init}_{wit} = {g_7}$</td>
<td>$CS^{init}_{part} = {\neg g_7}$</td>
<td>$CS^{init}_{part} = {g_7}$</td>
</tr>
<tr>
<td>$CS^{wit}_{part} = {\neg g_7}$</td>
<td>$\neg g_7$</td>
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question "$g_7$"
assert "$\neg g_7$"
assert "$g_7$"
challenge "$g_7$"
A dialogue-game to reach an agreement

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<td>( T^* )</td>
<td>( R_7^1(x): g_7 \leftarrow D(x), \text{Road}(x) )</td>
</tr>
<tr>
<td>( R_7^2(x): g_7 \leftarrow D(x), \text{Sea}(x) )</td>
<td></td>
</tr>
<tr>
<td>( \text{CS}_{\text{init}}^{\text{wit}} = { g_7, D(a_2), F_1 : \text{Road}(a_2), } )</td>
<td></td>
</tr>
<tr>
<td>( \text{CS}_{\text{part}}^{\text{wit}} = { \neg g_7 } )</td>
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<td></td>
</tr>
<tr>
<td>( F_3 : \neg \text{Road}(a_2) )</td>
<td></td>
</tr>
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question "\( g_7 \)"
assert "\( \neg g_7 \)"

assert "\( g_7 \)"
challenge "\( g_7 \)"

assert "\( D(a_2), \text{Road}(a_2) \)"
A dialogue-game to reach an agreement

**Witness**

**Partner**

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<td>( R_{71}^0 (x) : g_7 \leftarrow D(x), \text{Road}(x) )</td>
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</tr>
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<td>( \text{CS}_{\text{part}}^{\text{wit}} = {\neg g_7, F_3 : \neg \text{Road}(a_2)} )</td>
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**Partner**

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- Question "\( g_7 \)"
- Assert "\( \neg g_7 \)"
- Assert "\( g_7 \)"
- Challenge "\( g_7 \)"
- Assert "\( D(a_2), \text{Road}(a_2) \)"
- Reject "\( \text{Road}(a_2) \)"

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A dialogue-game to reach an agreement

![Diagram](image)

**Witness**

**Partner**

**Question "g_7"**

**Assert "¬g_7"**

**Assert "g_7"**

**Challenge "g_7"**

**Assert "D(a_2), Road(a_2)"**

**Reject "Road(a_2)"**

**Assert "D(a_2), Sea(a_2)"**

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Properties to reach an agreement

Definition (Omniscient agent)

\[ \mathcal{T}_{\text{omn}} = \mathcal{T}_{\text{init}} \cup \mathcal{T}_{\text{part}} \text{ and } \ll_{\text{omn}} \equiv \ll_{\text{wit}} \]

Definition (A dialogue)

- **sound** iff the witness is convinced by the topic or its negation.
- **complete** iff witness’ decision = omniscient agent’s decision.

Theorem

the dialogue is (i) finite, (ii) sound, (iii) not necessarily complete.

Proof.

i. \( \exists ! \) move / competent players/ finite KBaSe /No redundancy;

ii. complete order on reputations;

iii. the witness has an argument which none player has.
Take away DIAL (DIAL is an Argumentative Labour)

A framework for inter-agent dialogue

→ **Formalization** of a debate

- Argumentation framework
  → **Goal 1:** manage conflicts

- Model of agents
  → **Goal 2:** reason together

- Dialectical multi-agent system
  → **Goal 3:** warrant to reach an agreement
# Outline

1. ARGUGRID
2. Argumentation
3. Argumentation-based decision-making
4. Multi-Agent System
5. Argumentation-based collective decision-making
6. Conclusions & Future works
Summary

- **Argumentation** is a process of construction/comparison of arguments for/again conclusions.

- **Multi-agent system** is a set of autonomous and social agents situated in an environment and interacting within an organization.

- **Argumentation** is a promising approach for:
  - decision-making, *i.e.*
    - MARGO is an argumentation framework for multicriteria decision-making explaining decision
  - dialogue, *i.e.*
    - DIAL is a dialectical multi-agent system facilitating rational interaction
  - collective decision making, *i.e.*
    - DIAL + MARGO dialectical multi-agent system debating over a collective decision making
Outlook: Agents’ mind

- **Design**
  - Representation of state-of-mind (goals, plans, actions, beliefs, preferences)
  - communications acts
  - contracts in state-of-mind
  - workflow in state-of-mind
  - Argumentation-based decision

- **Implementation**
  - a Prolog prototype

- **Application**
  - procurement/migration/EO scenarios
Outlook (cont.): Debating over heterogeneous ontologies

Dialogue amongst customer and a service provider:

1. customer: Do you know a free software to view my PDF?
2. provider: acrobat is a free software.
3. customer: Why is it a free software?
4. provider: acrobat is free because this is a freeware.
5. customer: IMHO, acrobat is not a free software.
6. provider: Why is it not a free software?
7. customer: Since it is a freeware, this is not a free software.
8. provider: OK, however xpdf is a free software.
9. customer: Why is it a free software?
10. provider: xpdf is a free software because it is opensource.
11. customer: Why is it opensource?
12. provider: xpdf is opensource because it is copyleft.
13. customer: OK, I will consider xpdf?
Philip E. Tetlock
Expert Political Judgment: How Good is It? How Can We Know?

R. T. Clemen.
Making Hard Decisions.

T. Stournaras.
Concrete scenarios identification & simple use cases.
Delivrable, ARGUGRID, 2006.

P. M. Dung.
On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games.
Artificial Intelligence, 77(2) 201-257, 1995.
References (cont.)


