Argumentation-Based Practical Reasoning

New Models and Algorithms

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Practical Reasoning Support as “Good Advices” [Girle et al., 2003]

- The advice should be presented in a form which can be readily understood by decision makers.
- There should be ready access to both information and reasoning underpinning the advice.
- If decision support involves details which are unusual to the decision maker, it is of primary importance that s/he can discuss these details with his advisor.

Practical Reasoning

knowledge Representation

 Dialogue Models

Computation of Outcomes
Rich and interdisciplinary area of research;
for commonsense reasoning;
for conflict resolution in computer science applications.

[Argumentation is] a verbal and social activity of reason aimed at increasing (or decreasing) the acceptability of a controversial standpoint for the listener or reader, by putting forward a constellation of propositions intended to justify (or refute) the standpoint before a rational judge.

[van Eemeren et al., 1996, p. 5]
History of the Research

November 2008
- Practical reasoning study-case concerning critiques on critiques

May 2009
- Study-case for argument and critique schemes in pract. reas.

July 2009
- Proposal of AFRA as a modeling tool for practical reasoning

November 2009
- First proposal of our approach based on arg. and critique schemes

December 2010
- Enriched proposal with emotions and relations with personality models

April 2009
- Study-case for dialogue schemes considering HCI issues

May 2010
- Dialogue schemes considering HCI issues in knowledge sharing

October 2010
- Case study on moral dilemmas and infinite AFRAs

July 2011
- Formal languages for infinite AFRAs representation and computation

September 2011
- Approach extended to Dung's AF

January 2011
- Technical study of AFRA formalism

January 2012
- Ph.D. Thesis
An Approach based on Four Components

- Argument Schemes
- Critique Schemes
- Evaluation Schemes
- Dialogue Schemes
An Approach based on Four Components

- **Argument Schemes**
  - Analysis of existing schemes;
  - New schemes specifically designed for practical reasoning;

- **Critique Schemes**
  - Novel concept giving us a presumption in favour of a critique between argumentation elements;

- **Evaluation Schemes**
  - Analysis of proposed approaches;
  - Novel formalism extending an existing one:
    - a framework for encompassing an unrestricted recursive notion of attack to attack;
    - an approach for describing infinite argumentation frameworks through formal languages;

- **Dialogue Schemes**
  - Preliminary approach considering HCI issues in the design of a dialogue [not covered in this presentation].
Outline of the Presentation

1. Semi-formal Representation:
   - argument schemes and critique schemes;

2. Formal Representation and Computation:
   - a new formalism for allowing recursive attacks and thus being useful for computing the final outcomes of a practical reasoning process;

3. Infinite Argumentation Frameworks:
   - an approach using formal languages for describing infinite argumentation frameworks and for computing the semantics extensions on them.
Semi-formal Representation

Formal Representation and Computation
Infinite Argumentation Frameworks
Conclusions and Future works
Background: Walton et al. approach [Walton, 1996]

**Practical Inference**

**Major Premise:** I have a goal G.

**Minor Premise:** Carrying out this action A is a means to realise G.

**Conclusion:** Therefore, I ought to carry out this action A.

**CQ1:** What other goals that I have that might conflict with G should be considered?

**CQ2:** What alternative actions to my bringing about A that would also bring about G should be considered?

**CQ3:** Among bringing about A and these alternative actions, which is arguably the most efficient?

**CQ4:** What grounds are there for arguing that it is practically possible for me to bring about A?

**CQ5:** What consequences of my bringing about A should also be taken into account?

- Possibility to chain practical arguments;
  - Lack of formalisation;
  - Unclear how and when posing a critical question can give rise to a defeat.
Background: Atkinson et al. approach [Atkinson et al., 2004]

AS1 In the current circumstances R
- We should perform action A
- Which will result in new circumstances S
- Which will realise goal G
- Which will promote some value V

CQ1 Are the believed circumstances true?
CQ2 Assuming the circumstances, does the action have the stated consequences?
CQ3 Assuming the circumstances and that the action has the stated consequences, will the action bring about the desired goal?

…

+ High level of formalisation;
- Arguments cannot be chained together;
- Unclear when critical questions are posed.
Semi-formal Representation Models: New Concepts

- Six new argument schemes for practical reasoning:
  - the base set, comprising the practical argument scheme, and the evidence argument scheme;
  - the additional set, considering the value argument scheme, the preference and auditor argument scheme, and the emotional argument scheme;
  - improvement of the formalisation level still keeping simple formalisation and the possibility to chain arguments together;

- New concept of critique scheme:
  - reasoning pattern giving us a presumption in favour of a critique among argumentation elements (arguments or critiques);
  - solve (part of) questions concerning burden of proof;
  - explicit description of what happen with a critique.
John is a non-governmental organisation volunteer who is about to go to Brazil for awhile;

John suffers from disc herniation;

There are three possible actions for treating this disease:

1. take analgesics (and thus be free to go to Brazil);
2. have a surgery;
3. have a long non-invasive treatment with drugs.
JA2: goal: reducing disc herniation,
action: have discectomy surgery,
state: disc cut,
condition: {John suffers from pain due to spinal disc hernia},
exception: {anaesthesia allergy and no alternative anaesthesia}. 
Critiques Between Practical Arguments

\[ I_A^J = \{ \langle \text{take analgesics, have discectomy surgery} \rangle, \langle \text{have discectomy surgery, take analgesics} \rangle, \langle \text{take analgesics, have long non-invasive treatment} \rangle, \ldots \} \]

**JPCS1a:**
- **source:** JA1 instance of PAS,
- **target:** JA2 instance of PAS,
- **condition:** \( \langle \text{source.action, target.action} \rangle \in I_A^J \).
- John has a history of anaesthesia allergy;
- A physician, after some tests, informs John that there is a new kind of anaesthesia to which he is not allergic.
JA4: evidence: anaesthesia allergy and no alternative anaesthesia.


JEvCS1: source: JA5 instance of EvAS, target: JA4 instance of EvAS, condition: ⟨source.evidence, target.evidence⟩ ∈ I_{Ev}
Example (3)

- The action “take analgesics” lets John to be free to go to Brazil, thus promoting the value of charity;
- Both the actions “have a discectomy surgery” and “have a long non-invasive treatment with drugs” promote the value of safety.

- A value justifies a goal (e.g. the value of “safety” justifies the goal of “reducing disc herniation”), which is similar to goals which justify actions (e.g. the goal “reducing disc herniation” justifies the action “have discectomy surgery”);
- Values and practical arguments are strongly related, and this gives rise to a defence provided by the values in favour of the related practical arguments.
**JV1:** value: charity,  
goal: being free to go to Brazil,  
condition: {},  
exception: {}.

**JV2:** value: safety,  
goal: reducing disc herniation,  
condition: {},  
exception: {}.
Critiques Concerning Value Arguments

**JVDef1.2:**
- **source:** JV2 instance of VAS,
- **target:** JPCS1a instance of PCS,
- **defended:** target.target instance of PAS,
- **condition:** target.target ∈ V-chain-P(source) and target.source ∈ V-chain-P(x), x instance of VAS and x ≠ JV2.

**JVDef2.3:**
- **source:** JV2 instance of VAS,
- **target:** JVDef1.1 instance of VDef1,
- **defended:** target.target.source instance of PAS,
- **condition:** target.source ≠ source and target.target.source ∈ V-chain-P(source).

**JEvVCS1:**
- **source:** JA4 instance of EvAS,
- **target:** JVDef1.2 instance of VDef1 or VDef2,
- **condition:** target.defended.exception ∈ Ev-sat-Ex(source.evidence) and source ∈ P-chain-V(target.defended).

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Between a long non-invasive treatment and a discectomy surgery, John prefers the surgery because it is quicker;

Moreover, since the evidence informing that there is a new kind of anaesthesia to which John is not allergic results from a clinical test, this evidence is preferable over the other informing that John has a history of anaesthesia allergy;

In this situation, John can counterbalance the preferences between the two values, in order to analyse different what-if situations.
Preference (and Auditor) Arguments

JP\textsuperscript{e1}: preferred: anaesthesia allergy and no alternative anaesthesia, not preferred: anaesthesia allergy and alternative anaesthesia, condition: \{test result\}, exception: {}.

JP\textsuperscript{a1}: preferred: having discectomy surgery, not preferred: having long non-invasive treatment, condition: \{surgery is quicker\}, exception: {}.

JM\textsuperscript{1}: preferred: safety, not preferred: charity, condition: {}, exception: {}.
Critiques Concerning Preference (and Auditor) Arguments

**JPrCaS1:**
- source: JPa1 instance of PraAS,
- target: JPCS3b instance of PCS,
- condition: source.preferred = target.target.action and source.notpreferred = target.source.action.

**JMCs1:**
- source: JM1 instance of MAS,
- target: JVDef2.1 instance of VDef2,
- condition: source.notpreferred = target.source.value and source.preferred = target.target.source.value.

**JPrRebCS1:**
- source: JM1 instance of PraAS or PreAS or PrvAS,
- target: JM2 instance of PraAS or PreAS or PrvAS,
- condition: JM1.preferred = JM2.notpreferred and JM1.notpreferred = JM2.preferred.
Unfortunately, John is frightened by surgeries...

JEmCS1: source: JE1 instance of EmAS, target: JA2 instance of PAS, condition: source.object = target.action and source.feeling = unfavourable.
Semi-formal Representation Models: Summary

- Six new argument schemes for practical reasoning;
- Improvement of the formalisms w.r.t. literature;
- New notion of critique scheme;
- Burden of proof and results of the critique explicitly considered.
Semi-formal Representation

Formal Representation and Computation

Infinite Argumentation Frameworks

Conclusions and Future works
Definition

An *argumentation framework* \((\mathcal{AF})\) is a pair \(\langle \mathcal{A}, \rightarrow \rangle\) where \(\mathcal{A}\) is a set of *arguments* and \(\rightarrow \subseteq \mathcal{A} \times \mathcal{A}\) is a binary relation of *attack* or *defeat* on it.

- \(\{A, E\}\) is a D-conflict-free set;
- \(E\) is D-acceptable w.r.t. (is defended by) \(\{C\}\);
- \(F(\{C\}) = \{C, E\}\) (D-characteristic function);
- \(\{A\}\) is a D-admissible set.
Background: Abstract Argumentation Framework

[Dung, 1995]

Definition

An *argumentation framework* \((AF)\) is a pair \(\langle A, \rightarrow \rangle\) where \(A\) is a set of *arguments* and \(\rightarrow \subseteq A \times A\) is a binary relation of *attack* or *defeat* on it.

- D-Grounded extension \(\triangleq\) the least fixed point of the D-characteristic function: \(\{C, E\}\);
- D-Preferred extension \(\triangleq\) a maximal (w.r.t. set inclusion) D-admissible sets: \(\{A, C, E\}, \{B, C, E\}\).
Definition

A value-based argumentation framework (VAF) is a 5-tuple \( VAF = \langle A_v, \rightarrow_v, V, val, P \rangle \) where \( \langle A_v, \rightarrow_v \rangle \) is a Dung’s AF, \( V \) is a non-empty set of values, \( val \) is a function which maps from elements of \( A_v \) to elements of \( V \); and \( P \) is the set of possible audiences (i.e. total orders on \( V \)).

Given \( val(A) = v_1, val(B) = v_2 \), if for an audience \( v_2 \succ v_1 \), then...
A value-based argumentation framework (VAF) is a 5-tuple \( \text{VAF} = \langle \mathcal{A}_V, \rightarrow_V, \mathcal{V}, \text{val}, \mathcal{P} \rangle \) where \( \langle \mathcal{A}_V, \rightarrow_V \rangle \) is a Dung’s AF, \( \mathcal{V} \) is a non-empty set of values, \( \text{val} \) is a function which maps from elements of \( \mathcal{A}_V \) to elements of \( \mathcal{V} \); and \( \mathcal{P} \) is the set of possible audiences (i.e. total orders on \( \mathcal{V} \)).

Given \( \text{val}(A) = v_1, \text{val}(B) = v_2 \), if for an audience \( v_2 \succ v_1 \), then the attack from \( A \) against \( B \) is not effective.
Definition

An $EAF$ is a tuple $\langle A, C, D \rangle$, where $\langle A, C \rangle$ is a Dung’s $AF$, $D \subseteq A \times C$, and if $(Z, (X, Y)), (Z', (Y, X)) \in D$ then $(Z, Z'), (Z', Z) \in C.$
Definition

An EAF is a tuple $\langle A, C, D \rangle$, where $\langle A, C \rangle$ is a Dung’s AF, $D \subseteq A \times C$, and if $(Z, (X, Y)), (Z', (Y, X)) \in D$ then $(Z, Z'), (Z', Z) \in C$. 
Definition

An EAF is a tuple \( \langle A, C, D \rangle \), where \( \langle A, C \rangle \) is a Dung’s AF, \( D \subseteq A \times C \), and if \((Z, (X, Y)), (Z', (Y, X)) \in D\) then \((Z, Z'), (Z', Z) \in C\).
Requirements:

- to provide a formal counterpart to argument and critique schemes shown before;
- to encompass an unrestricted recursive notion of attack to attack;
- to keep definitions for semantics extensions as simple as possible;
- to encompass Dung’s $AF$ as a special case of the proposed formalism;
- to ensure compatibility between the semantics notions in the proposed formalism and those in Dung’s $AF$. 
Definition (AFRA)

An Argumentation Framework with Recursive Attacks (AFRA) is a pair $\langle A, R \rangle$ where:

- $A$ is a set of arguments;
- $R$ is a set of attacks, namely pairs $(a, X)$ s.t. $a \in A$ and $(X \in R$ or $X \in A)$.

Given an attack $\alpha = (a, X) \in R$, we say that $a$ is the source of $\alpha$, denoted as $src(\alpha) = a$ and $X$ is the target of $\alpha$, denoted as $trg(\alpha) = X$. 
Semantics for AFRA

- $\alpha$ directly defeats $B$ ($B = \text{trg}(\alpha)$);
- $\alpha$ indirectly defeats $\beta$ ($\text{src}(\beta) = \text{trg}(\alpha)$);
- $\alpha \rightarrow_R B$, $\alpha \rightarrow_R \beta$;
- $\{\gamma, \beta\}$ is a conflict-free set (no defeats among the elements in the set);
- $\delta$ is acceptable w.r.t. $\{\varepsilon\}$;
- $\mathbb{F}(\{\varepsilon\}) = \{A, C, D, \delta\}$ (characteristic function);
- $\{\eta, \gamma\}$ is an admissible set.
Semantics for AFRA

Let $\Gamma = \langle A, R \rangle$ be an AFRA, $S \subseteq A \cup R$:

- the grounded extension of $\Gamma$ is the least fixed point of $F_\Gamma$ (e.g. $\{A, D, \eta, \gamma\}$);
- $S$ is a preferred extension of $\Gamma$ iff it is a maximal (w.r.t. set inclusion) admissible set (e.g. $\{A, D, \eta, \gamma, \beta, B\}$ and $\{A, D, \eta, \gamma, \alpha\}$);
...and the Two Preferred Extensions
...and the Two Preferred Extensions
Moral Dilemmas in Practical Reasoning: an Example

- Fred, a system administrator, receives a helpdesk request from Eve who asks for the release of an email accidentally blocked by security filters;
- Fred finds out that it is a legal email from Eve’s lover, and thus he releases the email;
- Since Eve is his best friend’s wife, he is wondering whether to inform his friend (and thus promoting the value of Friendship) or not (according to the Law);
- This can give rise to an (infinite) monologue during which Fred continuously goes back and forth between the value of friendship and the value of law...
A Formal Representation of Moral Dilemmas in Practical Reasoning

Each value is committed to protect the associated practical argument in order to make it prevail over the other practical argument.
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A Formal Representation of Moral Dilemmas in Practical Reasoning

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Each value is committed to protect the associated practical argument in order to make it to prevail over the other practical argument.
A Formal Representation of Moral Dilemmas in Practical Reasoning
1. Providing suitable mechanisms for representing infinite AFRA.s through formal languages and for computing semantics extensions on such formalisms;

2. Extend the approach developed in the case of AFRA also for dealing with infinite Dung’s AFs.

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Representing an Infinite AFRA

**Definition**

Given an AFRA \( \langle \mathcal{X}, \mathcal{R} \rangle \) where \( \mathcal{R} \subseteq \mathcal{X}^* \) is a regular language represented as a DFA \( \mathcal{M} \), its \( \text{DFA}^+ \) is a representation of \( \langle \mathcal{X}, \mathcal{R} \rangle \) as a single DFA \( \mathcal{M}^+ = \langle \mathcal{X}, Q_{\mathcal{M}^+}, q_0, F_{\mathcal{M}^+}, \delta^+ \rangle \) such that for any \( w \in \mathcal{X}^* \) it holds \( w \in L(\mathcal{M}^+) \) if and only if \( w \in \mathcal{X} \cup \mathcal{R} \).
Computing the Grounded Extension of an Infinite AFRA

1: **Input:** $\text{DFA}^+ \mathcal{M}^+ = \langle X, Q_{\mathcal{M}+}, q_0, F_{\mathcal{M}+}, \delta^+ \rangle$ with $\alpha \in L(\mathcal{M}^+) \iff \alpha \in X \cup \mathcal{R}$.

2: **Output:** $\text{DFA} \mathcal{M}_G = \langle X, Q_G, q_0, F_G, \delta_G \rangle$ with $\alpha \in L(\mathcal{M}_G) \iff \alpha \in GE(\langle \tilde{X}, \tilde{\mathcal{R}} \rangle)$

3: $i := 0$

4: $\mathcal{M}_i := \text{csplit}(\mathcal{M}^+)$; with $\mathcal{M}_i = \langle X, Q_i, q_0, F_i, \delta_i \rangle$

5: **repeat**

6: $i := i + 1; \mathcal{M}_i := \mathcal{M}_{i-1}$;

7: For each (unmarked) unattacked state $q$ of $\mathcal{M}_i$ mark $q$ as in$(i)$.

8: for each unattacked state $q$ and every $q' \in \text{state} - \text{in}(q) \cap F_i$ do

9: Mark $q'$ as out and remove $q'$ from $F_i$.

10: end for

11: for each $x \in X$ s.t. argst$(x)$ is marked out do

12: For each state $q \in F_i$ with $x \in \text{sym} - \text{in}(q)$ mark $q$ as out and remove $q$ from $F_i$.

13: end for

14: **until** $\mathcal{M}_i = \mathcal{M}_{i-1}$

15: for any $q \in F_i$ which is not marked in$(i)$ do

16: remove $q$ from $F_i$

17: end for

18: return $\langle X, Q_i, q_0, F_i, \delta_i \rangle$
Computing the Grounded Extension of an Infinite AFRA

1: \textbf{Input:} 
\[ Df a^+ M^+ = \langle X, Q^{M^+}, q_0^+, F^{M^+}, \delta^{M^+} \rangle \] 
with \( \alpha \in L(M^+) \iff \alpha \in X \cup R. \) 
\[ L(M_G) \iff \alpha \in \text{GE}(\langle \tilde{X}, \tilde{R} \rangle) \]

2: \textbf{Output:} 
\[ Df a^+ M_G = \langle X, Q^G, q_0^G, F^G, \delta^G \rangle \] 
with \( \alpha \in L(M_G^+) \iff \alpha \in \text{GE}(\langle \tilde{X}, \tilde{R} \rangle) \)

3: \( i := 0 \)
4: \( M_i := \text{csplit}(M^+) \); with \( M_i = \langle X, Q_i, q_0^+, F_i, \delta_i \rangle \)
5: \textbf{for each unmarked unattacked state} \( q \) of \( M_i \) mark \( q \) as \textbf{in}(i).
6: \textbf{for each unattacked state} \( q \) and each \( q' \in \text{state-in}(q) \cap F_i \) do
7: mark \( q' \) as \textbf{out} and remove \( q' \) from \( F_i \).
8: \textbf{for each} \( x \in X \) s.t. \( \text{argst}(x) \) is marked \textbf{out} do
9: \textbf{for each state} \( q \in F_i \) with \( x \in \text{sym-in}(q) \) mark \( q \) as \textbf{out} and remove \( q \) from \( F_i \).
10: \textbf{end for}
11: \textbf{end for}
12: \textbf{until} \( M_i = M_{i-1} \)
13: \textbf{for any} \( q \in F_i \) which \textbf{end for}
14: \textbf{remove} \( q \) from \( F_i \)
15: \textbf{end for}
16: \textbf{return} \( \langle X, Q_i, q_0^+, F_i, \delta_i \rangle \)

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Computing the Grounded Extension of an Infinite AFRA

**Theorem**

Let $\mathcal{M}^+ = \langle X, Q_{\mathcal{M}^+}, q_0, F_{\mathcal{M}^+}, \delta^+ \rangle$ with $\alpha \in L(\mathcal{M}^+) \iff \alpha \in X \cup R$ be a DFA$^+$ describing the AFRA, $\langle X, R \rangle$ with corresponding AF $\langle \tilde{X}, \tilde{R} \rangle$. It is possible to construct in polynomial time a DFA $\mathcal{M}_G = \langle X, Q_G, q_0, F_G, \delta_G \rangle$ with $\alpha \in L(\mathcal{M}_G) \iff \alpha \in GE(\langle \tilde{X}, \tilde{R} \rangle)$. 
Describing Infinite Dung’s Framework

- Argument Encoding: a regular language over an alphabet;
- Attack Expression: a sentence considering the symbols of the alphabet, an identity symbol, concatenation symbol, . . .

If we can represent the set of arguments through some finite automaton (i.e. a regular language), and we can write an attack expression that for each word (argument) returns the set of attackers, then there are effective algorithms:

1. for deciding if a set of arguments is D-conflict-free, D-admissible, a D-stable, or a D-complete extension;
2. for computing whether an argument is D-acceptable w.r.t. a set, and the result of the application of the characteristic function on a set of arguments;
3. for determining (in some cases) the D-grounded extension.

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Formal languages provide suitable mechanisms for describing infinite argumentation frameworks (both AFRA and AF);

Using formal languages there are effective algorithms for computing several semantics concepts (e.g. we provided a polynomial algorithm for computing the grounded extension of an AFRA even if it has an infinite set of attacks . . . ).
Semi-formal Representation
Formal Representation and Computation
Infinite Argumentation Frameworks

Conclusions and Future works
Conclusions

- The Argumentation System for Practical Reasoning comprising argument, critique, evaluation, and dialogue schemes;
- Six new argument schemes specifically designed for practical reasoning;
- The new concept of critique scheme as a presumption in favour of a critique between argumentation elements;
- The Argumentation Framework with Recursive Attacks, a new formalism:
  - for formal representing instances of practical reasoning argument and critique schemes and for computing the decision outcomes;
  - for encompassing an unrestricted recursive notion of attack to attack;
  - with bijective correspondence with Dung’s AF semantics notions;
- Innovative proposal for computing with infinite frameworks, both in the case of AFR\(A\) and of AF;
- Preliminary proposal of dialogue schemes considering HCI issues.
Future works

- Development of the fourth component: complete proposal of dialogue schemes encompassing our argumentation-based approach for practical reasoning;
- Implementation of the whole system:
  - Adoption in real practical reasoning contexts and proving the validity of the approach;
  - May suggest further theoretical development;
- Theoretical developments in computing with infinite structures (in particular completing the study of standard decision and construction problems).
Argumentation-Based Practical Reasoning
New Models and Algorithms
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References I


References II
