Assumption-Based Argumentation

Francesca Toni, Xiuyi Fan

Machine Arguing

Outline

1. Assumption-Based Argumentation (ABA) frameworks: arguments, attacks
2. Semantics of ABA frameworks: argument-level, assumption-level
3. Abstract argumentation vs ABA

Main References

- F. Toni, A tutorial on assumption-based argumentation, Argument & Computation, Special Issue: Tutorials on Structured Argumentation, 2014
- K. Cyras, X. Fan, C. Schulz, F. Toni: Assumption-based Argumentation: Disputes, Explanations, Preferences. FLAP 4(8), 2017

A simple illustrative example: at a picnic – in AA

α: let me go for the lasagna, it looks delicious, and eating it will make me happy!

β: but I am likely to have no fork and my hands will be dirty, let the others have it!

γ: who cares about the others, let me get the lasagna, I may have a fork after all...

Note: this decision-making problem can be represented as an AA framework:

$$\alpha \leftarrow \beta \leftarrow \gamma$$

$\{\alpha, \gamma\}$ is "acceptable" (under any AA semantics) and eating the lasagna is (dialectically) "good"

A simple illustrative example: at a picnic – in ABA

Language $\mathcal{L} = \{a, b, c, p, q, r, s, t\}$ (often omitted for simplicity)
Rules $\mathcal{R} = \{p \leftarrow q, a, \quad q \leftarrow, \quad r \leftarrow b, c\}$
Assumptions $\mathcal{A} = \{a, b, c\}$
Contraries: $\overline{a} = r$, $\overline{b} = s$, $\overline{c} = t$
where $p =$ 'happy', $a =$ 'eating', $q =$ 'good food', $r =$ 'not eating', $b =$ 'no fork', $c =$ 'dirty hands', $s =$ 'fork' and $t =$ 'clean hands'

Note: this ABA framework is a simple agent model:

- assumptions are either actions (a) or observations/defeasible premises (b and c)
- non-assumptions (in $\mathcal{L} \setminus \mathcal{A}$) are goals to be achieved or avoided (p, q and r).
- Contraries of assumptions are reasons against actions ($\overline{a} = r$) or defeaters of defeasible premises ($\overline{b} = s$, $\overline{c} = t$).

ABA frameworks

An ABA framework is a tuple $\langle \mathcal{L}, \mathcal{R}, \mathcal{A}, \overline{} \rangle$ where

- $\langle \mathcal{L}, \mathcal{R} \rangle$ is a deductive system, with $\mathcal{L}$ the **language** and $\mathcal{R}$ a set of **rules**, that we assume of the form $\sigma_0 \leftarrow \sigma_1, \ldots, \sigma_m (m \geq 0)$ with $\sigma_i \in \mathcal{L}$ $(i = 0, \ldots, m)$;
  - σ_0 is referred to as the *head* and $\sigma_1, \ldots, \sigma_m$ as the *body* of rule $\sigma_0 \leftarrow \sigma_1, \ldots, \sigma_m$;
- $\mathcal{A} \subseteq \mathcal{L}$ is a (non-empty) set, referred to as **assumptions**;
- $\overline{}$ is a total mapping from $\mathcal{A}$ into $\mathcal{L}$; $\overline{a}$ is referred to as the **contrary** of a.

An ABA framework is *flat* if no assumption is the head of a rule.

Unless otherwise specified all ABA frameworks will be flat from now on.

Deductions in ABA

- Rules can be chained to derive/deduce conclusions
- a *deduction for $\sigma \in \mathcal{L}$ supported by $S \subseteq \mathcal{L}$ and $R \subseteq \mathcal{R}$*, denoted $S \vdash^{R} \sigma$, is a (finite) tree with
  - nodes labelled by sentences in $\mathcal{L}$ or by τ
  - the root labelled by σ,
  - leaves either τ or sentences in S,
  - non-leaves σ' with, as children, the elements of the body of some rule in $\mathcal{R}$ with head σ' (τ if this body is empty), and
  - R the set of all such rules.

Examples of deductions

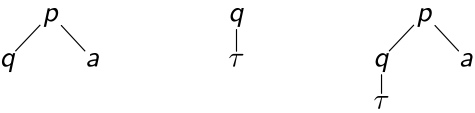
Given the ABA framework of slide 4, examples of deductions are:

$\{q, a\} \overset{R_1}{\vdash} p$ for $R_1 = \{p \leftarrow q, a\}$,

$\{\} \overset{R_2}{\vdash} q$ for $R_2 = \{q \leftarrow\}$,

$\{a\} \overset{R_3}{\vdash} p$ for $R_3 = R_1 \cup R_2$,

shown below as trees:



Note: $\{q, a, b\} \overset{R_1}{\vdash} p$ is not a deduction, due to the presence of b in the support. Indeed, b is “irrelevant” to p, given $R_1 = \{p \leftarrow q, a\}$.

Examples of arguments

Given the ABA framework of slide 4, the arguments are

$\{\} \vdash q$	(supported by $R = \{q \leftarrow\}$ and $A = \{\}$)
$\{a\} \vdash p$	(supported by $R \neq \{\}$ and $A \neq \{\}$)
$\{b, c\} \vdash r$	(supported by $R \neq \{\}$ and $A \neq \{\}$)
$\{a\} \vdash a$	(supported by $R = \{\}$)
$\{b\} \vdash b$	(supported by $R = \{\}$)
$\{c\} \vdash c$	(supported by $R = \{\}$)

Note: no other arguments exist for this ABA framework, e.g.

- $\{a, b\} \vdash p$ is not an argument, as it is not a deduction
- $\{q, a\} \vdash p$ is not an argument, as $\{q, a\} \not\subseteq \mathcal{A}$

"Support-minimality" of ABA arguments

- Various possible definitions of "support-minimality": $A \vdash^{R} \sigma$ is
  - *assumption-$\subseteq$-minimal* iff there is no $A' \vdash^{R'} \sigma$ with $A' \subset A$
  - *assumption-$\#$-minimal* iff there is no $A' \vdash^{R'} \sigma$ with $\#A' < \#A$
  - *rule-$\subseteq$-minimal* iff there is no $A' \vdash^{R'} \sigma$ with $R' \subset R$
  - *rule-$\#$-minimal* iff there is no $A' \vdash^{R'} \sigma$ with $\#R' < \#R$
- ABA arguments are not "support-minimal" in any sense:
  - given $\mathcal{R} = \{p \leftarrow a, \quad p \leftarrow a, b\}$, $\mathcal{A} = \{a, b\}$,
    both $\{a\} \vdash p$ and $\{a, b\} \vdash p$ are arguments, but $\{a, b\} \vdash p$ is neither assumption-$\subseteq$-minimal nor assumption-$\#$-minimal
  - given $\mathcal{R} = \{p \leftarrow a, q, \quad q \leftarrow p, \quad q \leftarrow\}$, $\mathcal{A} = \{a\}$,
    both $\{a\} \vdash^{R'} p$ (with $R' = \{p \leftarrow a, q, \quad q \leftarrow\}$) and $\{a\} \vdash^{\mathcal{R}} p$ are arguments, but $\{a\} \vdash^{\mathcal{R}} p$ is neither rule-$\subseteq$-minimal nor rule-$\#$-minimal

Attacks between arguments in ABA

...are directed at the assumptions in the support of arguments:

- *an argument* $A_1 \vdash \sigma_1$ attacks an argument $A_2 \vdash \sigma_2$ iff σ_1 is the contrary of one of the assumptions in A_2.

Examples of attacks between arguments

Given the ABA framework of slide 4:

$\{b, c\} \vdash r$ attacks $\{a\} \vdash p$

$\{b, c\} \vdash r$ attacks $\{a\} \vdash a$

Note:

- arguments may be attacked by the same arguments if they share assumptions in their support
- there is no attack against $\{\} \vdash q$
- there is no attack against $\{b, c\} \vdash r$
- there are no attacks against $\{b\} \vdash b$ and $\{c\} \vdash c$

Examples of attacks between sets of assumptions

Given the ABA framework of slide 4:

- $\{b, c\}$ attacks $\{a\}$
- A attacks A' for any $A \subseteq \mathcal{A}$ and $A' \subseteq \mathcal{A}$ such that $\{b, c\} \subseteq A$ and $\{a\} \subseteq A'$.

Note: the assumption-level attacks from any such A to any such A' corresponds to the argument-level attacks from $\{b, c\} \vdash r$ to $\{a\} \vdash p$ and $\{a\} \vdash a$.

Attacks between arguments vs Attacks between sets of assumptions

- If an argument α attacks an argument α' then the set of assumptions supporting α attacks the set of assumptions supporting α'.
- If a set of assumptions A attacks a set of assumptions A' then some argument supported by a subset of A attacks some argument supported by a subset of A'.

From ABA to AA

Each ABA framework $\langle \mathcal{L}, \mathcal{R}, \mathcal{A}, \overline{} \rangle$ gives a corresponding AA framework $(Args, Att)$ where

- $Args$ is the set of all arguments in $\langle \mathcal{L}, \mathcal{R}, \mathcal{A}, \overline{} \rangle$
- $(\alpha, \beta) \in Att$ iff α attacks β in $\langle \mathcal{L}, \mathcal{R}, \mathcal{A}, \overline{} \rangle$

For example, the AA framework corresponding to the ABA framework of slide 4 is (graphically):

$$
\begin{tikzcd}
\{b\} \vdash b & \{b, c\} \vdash r \arrow[r] \arrow[d] & \{a\} \vdash p & \{\} \vdash q \\
\{c\} \vdash c & \{a\} \vdash a & &
\end{tikzcd}
$$

Comparing AA frameworks for the picnic example

The original AA framework for the picnic example (see slide 3) is different from the AA framework (on slide 14) corresponding to the ABA framework on slide 4.

- Modify the ABA framework on slide 4 so that the corresponding AA framework "matches" the original AA framework.

- A set of arguments is "acceptable" in $\langle \mathcal{L}, \mathcal{R}, \mathcal{A}, \overline{} \rangle$ iff it is "acceptable" in the AA framework corresponding to $\langle \mathcal{L}, \mathcal{R}, \mathcal{A}, \overline{} \rangle$ (any notion of "acceptable" in AA can be chosen here, e.g. admissible)

E.g. given the ABA framework of slide 4

$$\mathtt{A} = \{\{b, c\} \vdash r, \{b\} \vdash b, \{c\} \vdash c, \{\} \vdash q\}$$

- is admissible, preferred, sceptically preferred, complete, grounded, ideal and stable
- each $\mathtt{A}' \subset \mathtt{A}$ is also admissible
- there are no other complete, preferred, stable sets

ABA semantics – assumption-level view

A set of assumptions is[1]

- *admissible* iff it does not attack itself and it attacks all sets of assumptions that attack it;
- *preferred* iff it is maximally (w.r.t. $\subseteq$) admissible;
- *sceptically preferred* iff it is the intersection of all preferred sets of assumptions;
- *complete* iff it is admissible and contains all assumptions it *defends*, where A defends a iff A attacks all sets of assumptions that attack a;
- *grounded* iff it is minimally (w.r.t. $\subseteq$) complete;
- *ideal* iff it is maximally (w.r.t. $\subseteq$) admissible *and* contained in all preferred sets of assumptions;
- *stable* iff it does not attack itself and it attacks all assumptions it does not contain.

[1] A set of assumptions A attacks an assumption a iff A attacks $\{a\}$.

Example of ABA semantics – assumption-level view

Given the ABA framework of slide 4:

- $\{b, c\}$ is admissible, preferred, sceptically preferred, complete, grounded, ideal and stable
- $\{\}$, $\{b\}$, $\{c\}$ are also admissible
- there are no other preferred, complete or stable sets

Argument-level view vs Assumption-level view

- If a set $\mathtt{A}$ of arguments is admissible/preferred/sceptically preferred/complete/ grounded/ideal/stable, then the union of all sets of assumptions supporting the arguments in $\mathtt{A}$ is admissible/preferred/sceptically preferred/complete/ grounded/ideal/stable (respectively).
- If a set A of assumptions is admissible/preferred/sceptically preferred/complete/ grounded/ideal/stable, then the union of all arguments supported by any subset of A is admissible/preferred/sceptically preferred/complete/grounded/ideal/ stable (respectively).

ABA semantics – sentence-level view

- Given an "acceptable" set of arguments, a sentence is deemed "acceptable" if it is the claim of an argument in the set.
- Given an "acceptable" set of assumptions, a sentence is deemed "acceptable" if it is the claim of an argument supported by a set of assumptions contained in the set.

An "acceptable" sentence may be a belief held by an agent, an action to be executed by an agent, a joint action by several agents, a decision, etc, depending on the area of application.

Example of ABA semantics – sentence-level view

Given the ABA framework of slide 4, all notions of "acceptability" coincide, in that they sanction the same sentences as "acceptable":

- r is admissible, grounded, etc.
- p is not admissible, grounded, etc.

Summary

- Assumption-Based Argumentation (ABA) frameworks: arguments, attacks
- Semantics of ABA frameworks: argument-level, assumption-level, sentence level

From here:

- from AA to ABA

From AA to ABA

- Each AA framework can be mapped onto an "equivalent" (flat) ABA framework
- For example, the AA framework with arguments $\{a, b\}$ and attacks $\{(a, a), (b, a), (a, b)\}$ can be mapped onto the ABA framework with

  $\mathcal{R} = \{a^c \leftarrow a, \quad a^c \leftarrow b, \quad b^c \leftarrow a\}$
  $\mathcal{A} = \{a, b\}$
  $\overline{a} = a^c$, $\overline{b} = b^c$

Summary (on ABA vs abstract argumentation)

- Assumption-Based Argumentation (ABA) is a powerful knowledge representation and reasoning formalism, equipped with correct computational counterparts
- flat ABA and AA are equivalent (in the sense that you can get each from the other) but ABA is finer-grained

Not covered: *Non-flat* ABA

- K. Cyras, C. Schulz and F. Toni, Capturing Bipolar Argumentation in Non-flat Assumption-Based Argumentation, PRIMA 2017