MACHINE ARGUING

Theories, Systems and Applications

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Context

Argumentation in AI = *Machine* arguing =
design and build *machines* that argue

- to resolve conflicts (within and across)
- to reason with incomplete information
- to explain

Outline - Theories

1. Abstract Argumentation (AA) frameworks = “webs of disagreement”
   - Semantics via extensions, labellings
2. Structured Argumentation = arguments have structure
   - Assumption-based Argumentation (ABA)
3. Bipolar Argumentation (BA) frameworks = AA + support
   - deductive and necessary support, bipolar ABA, gradual semantics
4. Argumentation with Preferences
   - AA with preferences (delete/reverse attacks)
   - (ABA+ = ABA with preferences via reverse attack)
5. Argumentation with Probabilities
   - probabilistic AA
   - (PABA = probabilistic ABA)

Outline - Systems

1. AA frameworks = "webs of disagreement"
   - ArgTeach (labellings)
2. ABA frameworks = arguments have structure
   - ABAplus (for **flat** ABA frameworks (with preferences))
3. BA frameworks = AA + support
   - Arg&Dec (gradual semantics)

An example: non-monotonic, defeasible reasoning

Am I eligible to claim for UK & European Breakdown & Recovery Assistance?

You need to think about whether the insurance meets your needs and whether you can claim when you need to.

You are covered for:

- ✔ UK and European Breakdown Assistance for account holder(s) in any private car that they are travelling in
- ✔ Anyone driving a private car registered to the account holder and which is being used with his/her permission. Where the account is in joint names then up to 2 private cars can be covered
- ✔ Assistance provided at home and on the roadside with national recovery and onward travel
- ✔ No call out limit
- ✔ No excess payable

You are not covered for:

- The cost of replacement parts and associated labour to repair the vehicle
- Private cars not registered to the account holder(s) unless the account holder(s) are in the vehicle at the time of the breakdown
- Motorcycles, motorhomes, caravanettes, commercial vehicles (all types), vans, pick up trucks and vehicles being used for hire and reward purposes (such as taxis)
- Vehicles that do not have a valid MOT or are not serviced or maintained in line with manufacturer guidelines
- Vehicles that are more than 7 metres in length, 2.3 metres wide, 3 metres high and weigh more than 3.5 tonnes when fully loaded

Nationwide

Argumentation/AA for the example: intuition

COVERED FOR: UK/EU Breakdown Assistance for account holder(s) in any private car they are travelling in
NOT COVERED FOR: private cars not registered to the account holder(s) unless in the vehicle at the time of the breakdown

Mary: account holder traveling in friend's car; car breaks down

- there is an **argument** $c(mary)$ for Mary covered (as travelling in private car)
- there is an objection (**attack**) against this argument, by an **argument** $nc(mary)$ for Mary not covered (as car not registered to Mary)
- there is an objection (**attack**) against this argument, by an **argument** $in(mary)$ for Mary in car at time of breakdown

$in(mary)$, $c(mary)$ are (dialectically) "good";
$in(mary)$ is (dialectically) "strongest".

AA frameworks

$\langle Args, attacks \rangle$ where

- $Args$ is a set (the *arguments*)
- $attacks \subseteq Args \times Args$ is a binary relation over $Args$

An AA framework can be represented as a directed graph

Example

$$c(mary) \longleftarrow nc(mary) \longleftarrow in(mary)$$

Notation

- "α attacks β" stands for $(\alpha, \beta) \in attacks$
- $A \subseteq Args$ attacks $B \subseteq Args$ iff there are $\alpha \in A, \beta \in B$ such that α attacks β
- $A \subseteq Args$ attacks $\beta \in Args$ iff A attacks $\{\beta\}$

Semantics for AA

"Recipes" for determining "good" sets of arguments (*extensions*)

$A \subseteq Args$ is

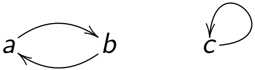
- **conflict-free** (c-f) iff it does not attack itself
- **admissible** iff it is c-f and attacks each attacking argument
- **preferred** iff it is maximal (wrt $\subseteq$) admissible
- **complete** iff it is admissible and contains all arguments it *defends* (by attacking all attacks against them)
- **stable** iff it is c-f and attacks each argument not in it

Example

$$c(mary) \longleftarrow nc(mary) \longleftarrow in(mary)$$

$\{nc(mary)\}$ is conflict-free, $\{c(mary), nc(mary)\}$ is not
$\{in(mary)\}$ is admissible, $\{nc(mary)\}$ is not
$\{c(mary), in(mary)\}$ is preferred/complete/stable, $\{in(mary)\}$ is not

Semantics for AA: differences



- no stable extension
- two preferred extensions: $\{a\}$ and $\{b\}$
- three complete extensions: $\{\}$, $\{a\}$ and $\{b\}$

(more) Semantics for AA

"Recipes" for determining "good" sets of arguments (*extensions*)

$A \subseteq Args$ is

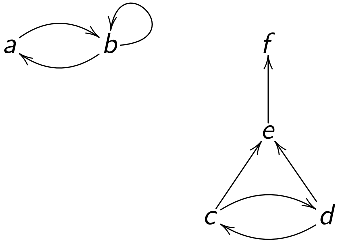
- **grounded** iff it is minimally (wrt $\subseteq$) complete;
- **sceptically preferred** iff it is the intersection of all preferred extensions;
- **ideal** iff it is maximal (wrt $\subseteq$) such that
  - (i) it is admissible and
  - (ii) it is contained in all preferred extensions

Example

$$c(mary) \longleftarrow nc(mary) \longleftarrow in(mary)$$

$\{c(mary), in(mary)\}$ is grounded/sceptically preferred/ideal, $\{\}$ is not

Semantics for AA: (more) differences



- grounded extension: $\{\}$
- ideal extension: $\{a\}$
- sceptically preferred extension: $\{a, f\}$

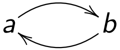
Credulous vs sceptical semantics

Credulous semantics

Possibly several alternative “good” extensions:
admissible, preferred, complete, stable

Sceptical semantics

One single “good” extension (taking no chances):
grounded, ideal, sceptically preferred



AA semantics via Labellings

- semantics via extensions = sets of "winning" arguments
- semantics via labellings = "winning" (IN), "losing" (OUT), or "undecided" (UNDEC) arguments

in one-to-one correspondence!

Example: Complete Labelling

For every argument $\alpha \in \mathit{Args}$:

1. α is labelled `IN` iff every argument attacking α is labelled `OUT`.
2. α is labelled `OUT` iff some argument attacking α is labelled `IN`.

$\Rightarrow$ α is labelled `UNDEC` iff at least one attacker of α is labelled `UNDEC` and no attacker is labelled `IN`.

AA labellings: hands on

- ArgTeach (http://argteach.herokuapp.com/)

Structured Argumentation

Arguments and attacks can be obtained from other "information"
Argument have a structure - normally premises and claim
Attacks are directed - normally - at premises or claims of arguments

- ABA
- ASPIC(+)
- DeLP
- Deductive argumentation

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 $\sigma_i \in \mathcal{L}$ $(i = 0, \ldots, m)$;
- $\mathcal{A} \subseteq \mathcal{L}$ 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.

COVERED FOR: UK/EU Breakdown Assistance for account holder(s) in any private car they are travelling in

NOT COVERED FOR: private cars not registered to the account holder(s) unless in the vehicle at the time of the breakdown

Mary (m): account holder traveling in friend's car (c); car breaks down

rules $\mathcal{R}$:

$$cov(m,c) \leftarrow ah(m), tr(m,c), pr(c), not\ \neg cov(m,c)$$
$$\neg cov(m,c) \leftarrow \neg reg(c,m), not\ cov'(m,c)$$
$$cov'(m,c) \leftarrow in(m,c)$$
$$ah(m) \leftarrow \qquad tr(m,c) \leftarrow \qquad pr(c) \leftarrow$$
$$\neg reg(c,m) \leftarrow \qquad in(m,c) \leftarrow$$

language $\mathcal{L}$: Herbrand base of $\mathcal{R}$ plus (all) NAF literals

assumptions $\mathcal{A}$: (all) NAF literals

contrary $\overline{not\ x} = x$ for all x in the Herbrand base of $\mathcal{R}$

Arguments and Attacks in flat ABA

Arguments are deductions of claims using rules and supported by sets of assumptions:

- *an argument for (the claim) $\sigma \in \mathcal{L}$ supported by $A \subseteq \mathcal{A}$* ($A \vdash \sigma$ in short) is a deduction for σ supported by A (and some $R \subseteq \mathcal{R}$)

Attacks 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.

Equivalently: ("good") extensions as sets of assumptions

- *a set of assumptions A attacks a set of assumptions A'* iff
  an argument supported by a subset of A (possibly the full A)
  attacks
  an argument supported by a subset of A' (possibly the full A').

("Good") Extensions in ABA: hands on

- ABAplus: http://www-abaplus.doc.ic.ac.uk/

The Handmaid's Tale

by Margaret Atwood (Goodreads Author)

goodreads

★★★★ 4.09 · Rating details · 928,857 Ratings · 50,360 Reviews

Offred is a Handmaid in the Republic of Gilead. She may leave the home of the Commander and his wife once a day to walk to food markets whose signs are now pictures instead of words because women are no longer allowed to read. She must lie on her back once a month and pray that the Commander makes her pregnant, because in an age of declining births, Offred and the other Ha ...more

Emily May rated it ★★★★★ — Dec 05, 2010

Shelves: dystopia-utopia, favourites, feminism

"Don't let the bastards grind you down."

There are only a small handful of books that have affected me in a REALLY personal way. In a way that I always try to put into words and always,

Victoria rated it ★★ · review of another edition — Jun 07, 2007

Shelves: fiction, sf-f, 2005

Not a very well written book. The writing itself is clumsy. It doesn't feel like you're reading a story; it feels like you're reading a piece of writing. Good

Bipolar Argumentation (BA)

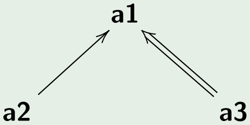
A *BA framework* is $\langle Args, attacks, supports \rangle$ where

- $\langle Args, attacks \rangle$ is an AA framework
- $supports \subseteq Args \times Args$ is a binary relation over *Args*

A BA framework can be represented as a (directed) graph (with two types of edges)
"α supports β" stands for $(\alpha, \beta) \in supports$

Example (Online reviews)

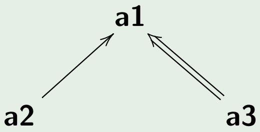
Read "The Handmaid's tale" (**a1**)
I disagree, not well written! (**a2**)
Very few books have affected me . . . (**a3**)



Semantics for BA

Various notions of "good" extensions by forming *coalitions* of arguments in "support chains"

Example (Online reviews)



$\{\mathbf{a1}, \mathbf{a3}\}$ is a coalition

a2 belongs to a "good" extension

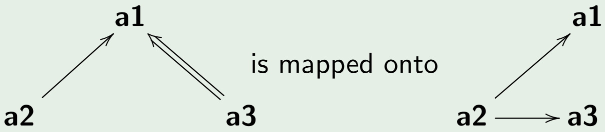
Several approaches, including:

1. BA frameworks where support is interpreted as *deductive*
2. BA frameworks where support is interpreted as *necessary* (Argumentation frameworks with necessities)

BA frameworks with deductive support

Idea: BA frameworks are first mapped onto AA frameworks, and then standard semantics are used

Example (Online reviews)

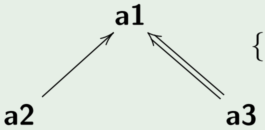


Argumentation frameworks with necessities (AFNs)

An AFN is a BA framework $\langle Args, attacks, supports \rangle$ where

supports is irreflexive and transitive.

Example (Online reviews)



$\{\}$,$\{\mathbf{a2}\}$,$\{\mathbf{a3}\}$,$\{\mathbf{a2},\mathbf{a3}\}$ are admissible

$\{\mathbf{a2},\mathbf{a3}\}$ is preferred/stable

Bipolar ABA

An ABA framework $\langle \mathcal{L}, \mathcal{R}, \mathcal{A}, \overline{} \rangle$ is *bipolar* iff

every rule in $\mathcal{R}$ is of the form $\varphi \leftarrow \alpha$, where $\alpha \in \mathcal{A}$ and either $\varphi \in \mathcal{A}$ or $\varphi = \overline{\beta}$ for some $\beta \in \mathcal{A}$.

Thus a bipolar ABA framework may be *non-flat*.

$E \subseteq \mathcal{A}$ is *admissible* iff

E is "closed", conflict-free and E *attacks* every "closed" $A \subseteq \mathcal{A}$ attacking E.

$E \subseteq \mathcal{A}$ is *set-stable* iff

E is "closed", conflict-free and E *attacks* the closure of $\{\alpha\}$ for every $\alpha \in \mathcal{A} \setminus E$.

Deductive and necessary support in ABA

The *d-ABA framework corresponding to* BA framework with deductive support is $\langle \mathcal{L}, \mathcal{R}, \mathcal{A}, \overline{} \rangle$ with:

- $\mathcal{L} = Args \cup \{a^c \mid a \in Args\}$,
- $\mathcal{R} = \{b^c \leftarrow a \mid a\ attacks\ b\} \cup \{b \leftarrow a \mid a\ supports\ b\}$,
- $\mathcal{A} = Args$,
- $\bar{a} = a^c \quad \forall a \in \mathcal{A}$.

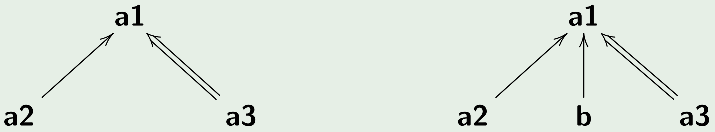
The *n-ABA framework corresponding to* AFN is $\langle \mathcal{L}, \mathcal{R}, \mathcal{A}, \overline{} \rangle$ with:

- $\mathcal{L} = Args \cup \{a^c \mid a \in Args\}$,
- $\mathcal{R} = \{b^c \leftarrow a \mid a\ attacks\ b\} \cup \{a \leftarrow b \mid a\ supports\ b\}$,
- $\mathcal{A} = Args$,
- $\bar{a} = a^c \quad \forall a \in \mathcal{A}$.

Considerations on deductive vs necessary support

- they sanction different extensions as "good"
- they are useful in different contexts:
  - **e**vidence *supports* **f**act: deductive interpretation (e.g. a reputable news distributor says X *supports* X holds)
  - **m**otive *supports* **e**vidence: necessary interpretation (e.g. politician has motive to say X *supports* politician says X)
- as in AA, neither semantics **accrue** (accrual="the fact of something increasing over a period of time"), e.g.:

Example (Online reviews)



{**a1**} equally not "good"

Gradual semantics for arguments: accrual

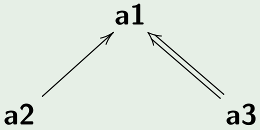
Semantics	Choices					Principles			
	QBAF	$\mathbb{I}$	τ	$*$	$\ll$	B	SB	M	SM
h-Categorizer	aQBAF	$(0,1]$	1	$\sigma\perp$	$<$	✓	✓	✓	✓
Inverse Equational System	aQBAF	$[0,1]$	1	$\sigma\not\perp$	$<_0$	✓	✓	✓	✓
Suspect Equational System	aQBAF	$[0,1]$	1	$\sigma\not\perp$	$<_0$	✓	·	·	·
Max Equational System	aQBAF	$[0,1]$	1	$\sigma\perp$	$<$	✓	✓	✓	·
GTAA	aQBAF	$[0,1]$	1	$\sigma\perp$	$<$	✓	✓	·	·
GTBA	QBAF	$[0,1]$	0.5	–	–	·	·	·	·
LocMax	QBAF	$[-1,1]$	0	$\sigma\not\perp$	$<_0$	✓	·	✓	·
LocSum	QBAF	$[-1,1]$	0	$\sigma\not\perp$	$<$	✓	·	✓	✓
Social Models	aQBAF	ordered set	–	$\sigma\not\perp$	$<$	✓	✓	✓	✓
Weighted Max-Based	aQBAF	$[0,1]$	–	$\sigma\not\perp$	$<$	✓	✓	✓	·
Weighted Card-Based	aQBAF	$[0,1]$	–	$\sigma\perp$	$<$	✓	✓	✓	✓
Weighted h-Categorizer	aQBAF	$[0,1]$	–	$\sigma\not\perp$	$<$	✓	✓	✓	✓
Top-Based Support	sQBAF	$[0,1]$	–	$\sigma\not\perp$	$<_\top$	✓	✓	✓	·
Reward-Based Support	sQBAF	$[0,1]$	–	$\sigma\not\perp$	$<_\top$	✓	✓	✓	✓
Aggregation-Based Support	sQBAF	$[0,1]$	–	$\sigma\not\perp$	$<_\top$	✓	✓	✓	✓
QuAD	QBAF	$[0,1]$	–	$\sigma\not\perp$	–	·	·	✓	·
DF-QuAD	QBAF	$[0,1]$	–	$\sigma\not\perp$	$\leq$	✓	·	✓	·
Restricted Euler-based	QBAF	$[0,1]$	–	$\sigma\not\perp$	$<_{\perp,\top}$	✓	·	✓	✓
Complete Labellings	aQBAF	$\{\mathsf{in},\mathsf{out},\mathsf{und}\}$	in	$\sigma\not\perp$	$<$	✓	✓	✓	·

Gradual semantics for arguments: DF-QuAD

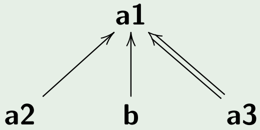
Given a *BA* (tree) framework $\langle Args, attacks, supports \rangle$

and a *base score* for arguments $\mathcal{BS} : Args \rightarrow [0, 1]$
determine the *strength* of arguments $\mathcal{S} : Args \rightarrow [0, 1]$
by **aggregating**
the strengths of attackers against and the strengths of supporters for these arguments

Example (Online reviews (for all $\alpha \in Args : \mathcal{BS}(\alpha) = 0.5$) - DF-QuAD)



$\mathcal{S}(\mathbf{a1}) = 0.5$



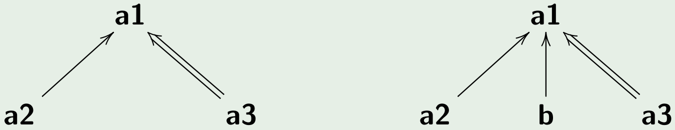
$\mathcal{S}(\mathbf{a1}) = 0.375$

DF-QuAD: effect of base score

Given a *BA* (tree) framework $\langle Args, attacks, supports \rangle$

and a *base score* for arguments $\mathcal{BS} : Args \rightarrow [0,1]$
determine the *strength* of arguments $\mathcal{S} : Args \rightarrow [0,1]$
by **aggregating**
the strengths of attackers against and the strengths of supporters for these arguments

Example (Online reviews ($\mathcal{BS}(\mathbf{a1}) = \mathcal{BS}(\mathbf{a3}) = \mathcal{BS}(\mathbf{b}) = 0.5$, $\mathcal{BS}(\mathbf{a2}) = 0.9$) - DF-QuAD)



$\mathcal{S}(\mathbf{a1}) = 0.3$

$\mathcal{S}(\mathbf{a1}) = 0.275$

DF-QuAD: hands-on

Arg&Dec (www.arganddec.com)

Argumentation with Preferences: AA

Example

R: The Economist: Remain
L: The Daily Mail: Leave
The Economist is more trustworthy than The Daily Mail

- $Args = \{R, L\}$
- $attacks = \{(L, R), (R, L)\}$ $\quad R \longleftrightarrow L$
- $L < R$ (L is *less preferred* than R)

Ignoring preference:

- grounded/ideal extension: $\{\}$;
- stable/preferred extensions: $\{R\}$ and $\{L\}$.

Taking preferences into account:

- intuitively accept (only) $\{R\}$. How? Modify *attacks*

AA with Preferences: Deleting Attacks

An *AA framework with preferences* (AAP framework) is $\langle Args, attacks, < \rangle$ where

- $\langle Args, attacks \rangle$ is an AA framework
- $<$ is a transitive binary (*preference*) relation on *Args*

An AAP framework yields an AA framework $\langle Args, attacks' \rangle$ where

- $(\alpha, \beta) \in attacks'$ iff $(\alpha, \beta) \in attacks$ and $\alpha \not< \beta$.

Extensions of $\langle Args, attacks, < \rangle$ are extensions of $\langle Args, attacks' \rangle$

Example

$R \longleftrightarrow L$ with $L < R$ yields $R \longrightarrow L$

AA with Preferences: Reversing Attacks

An *AA framework with preferences* (AAP framework) is $\langle Args, attacks, < \rangle$ where

- $\langle Args, attacks \rangle$ is an AA framework
- $<$ is a transitive binary (*preference*) relation on *Args*

An AAP framework yields an AA framework $\langle Args, attacks'' \rangle$ where

- $(\alpha, \beta) \in attacks''$ iff $(\alpha, \beta) \in attacks$ and $\alpha \not< \beta$ or $(\beta, \alpha) \in attacks$ and $\beta < \alpha$

Extensions of $\langle Args, attacks, < \rangle$ are extensions of $\langle Args, attacks'' \rangle$

Example

$R \longleftrightarrow L$ with $L < R$ yields $R \longrightarrow L$

Structured Argumentation with Preferences

preferences over "building blocks" (rules, assumptions)

- ASPIC+ : deleting attacks
- ABA+ : reversing attacks; ABAplus: http://www-abaplus.doc.ic.ac.uk/

(DeLP: preferences via specificity)

AA with probabilities

A *probabilistic AA* framework is $(\langle Args, attacks \rangle, \Pi, \vdash)$ where

- $\langle Args, attacks \rangle$ is an AA framework
- $\Pi = (\mathcal{W}, P)$ is a probability space
- $\vdash \subseteq \mathcal{W} \times Args$ specifies arguments' *applicability* in Π's worlds

For $w \in \mathcal{W}$:

- the *AA framework w.r.t. w* is $\langle Args_w, attacks_w \rangle$ where
  $Args_w = \{\alpha \in Args \mid w \vdash \alpha\}$
  $attacks_w = attacks \cap (Args_w \times Args_w)$
- let $\mathcal{G}_w$ be the grounded extension of $\langle Args_w, attacks_w \rangle$; then the *grounded probability* of $\alpha \in Args$ is

$$Prob_{\mathcal{G}}(\alpha) = \sum_{w \in \mathcal{W} : \alpha \in \mathcal{G}_w} P(w).$$

Structured Argumentation with Probabilities

probabilities over "building blocks" (assumptions)

- PABA
- http://ict.siit.tu.ac.th/ hung/Prengine

Conclusion

- (Basics of) AA, BA, Structured argumentation (flat ABA, bipolar ABA), AA with preferences, probabilistic AA
- Omissions
    - Computation
    - Properties
    - Instances
    - Dialogical Argumentation
    - ...

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