Explaining rational decision making by arguing

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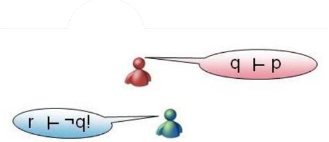


Argumentation in AI

Non-Monotonic Reasoning (NMR)

from late 1980s (e.g. Lin, Shoham, Dung, Kowalski, Kakas, Toni):
$\Rightarrow$ abstract (and bipolar) argumentation, ABA

Defeasible Reasoning as studied in philosophy

from late 1980s (e.g. Pollock, Nute):
$\Rightarrow$ DeLP, ASPIC, ASPIC+

Resolving inconsistencies (paraconsistent reasoning)

from mid 1990s (e.g. Cayrol, Amgoud, Hunter):
$\Rightarrow$ logic-based argumentation

Decision making

from early 1990s (e.g. Fox, Krause, Ambler):
$\Rightarrow$ Amgoud and Prade (2009), . . .

Outline

- Argumentative approaches to “explained” decision-making:
  - descriptive, rational/socially optimal, privacy preserving
- Essential background on argumentation
  - abstract, bipolar, value-based, assumption-based

Main references

- L. Carstens, X. Fan, Y. Gao, F. Toni: An Overview of Argumentation Frameworks for Decision Support. GKR 2015
- M. Aurisicchio, P. Baroni, D. Pellegrini, F. Toni: Comparing and Integrating Argumentation-Based with Matrix-Based Decision Support in Arg&Dec. TAFA 2015
- Y. Gao, F. Toni, H. Wang, F. Xu: Argumentation-Based Multi-Agent Decision Making with Privacy Preserved. AAMAS 2016

Collaborative MAS decisions vs Abstract Argumentation

- socially optimal and privacy preserving distributed constraint satisfaction
- explanations via related admissibility in abstract argumentation

Abstract Argumentation (AA) – [Dung 1995]

An AA framework is a pair $\langle Args, attacks \rangle$ where

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

Example (AA framework represented as a directed graph)

α: I love Toulouse because it is nice and small

β: Small? with 500k people? γ: It is small wrt London!

$$\alpha \longleftarrow \beta \longleftarrow \gamma$$

Semantics, e.g. $A \subseteq Args$ is

- **conflict-free** (c-f) iff it does not attack itself
- **admissible** iff it is c-f and attacks each attacking argument

Example

$\{\beta\}$ is conflict-free, $\{\gamma\}$, $\{\alpha, \gamma\}$ are admissible

Related admissible sets of arguments in AA [Fan&Toni 2015]

$A \subseteq Args$ is *related admissible* iff

$\exists a \in A$: A is admissible & A **r-defends** a (a is *a topic* of A), where

- $a \in Args$ *r-defends* $b \in Args$ iff
  $a = b$ or
  $\exists c \in Args$ s.t. a attacks c and c attacks b or
  $\exists c \in Args$ s.t. a r-defends c and c r-defends b
- $A \subseteq Args$ *r-defends* $a \in Args$ iff for each $b \in A$: b r-defends a

$A \subseteq Args$ is an *explanation* of $a \in Args$ iff

A is related admissible and a is a topic of A

Example

$$\omega \qquad\qquad \alpha \longleftarrow \beta \longleftarrow \gamma$$

$\{\alpha, \gamma\}$ is an explanation of α
$\{\alpha, \gamma, \omega\}$ is admissible but not an explanation of α

Privacy preserving decisions in collaborative MAS

Problems requiring information sharing, conflict resolution and privacy preservation.

Example (Variant of the battle of the sexes)

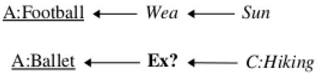
Alice (A): I definitely prefer ballet. **But will Bob's ex-wife be there**? Caroline (C) said that she will be hiking. . . . Bob (B): I definitely prefer football. **Does Alice like football?** She surely enjoys sports, as she enjoys tennis. Caroline (C) posted on Facebook that she is in the ballet hall with her mother. . . .

Solutions = *strategy profiles* which are:

- *feasible*: all actions are 'doable' according to all agents (e.g. attending ballet is not doable for A if B's ex-wife is there too)
- *acceptable*: all constraints are met (e.g. A and B want to be together)
- *socially optimal*: no other solution is "better" for any agent
- *secure*: **private information** is not (in)directly disclosed

"Battle of the sexes" example

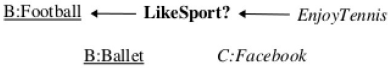
Alice's AA (internal) framework:



A:Football ← *Wea* ← *Sun*

A:Ballet ← **Ex?** ← *C:Hiking*

Bob's AA (internal) framework:



B:Football ← **LikeSport?** ← *EnjoyTennis*

B:Ballet

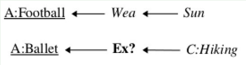
C:Facebook

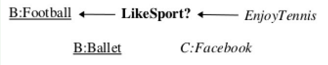
- several types of arguments: private practical, **private epistemic**, *disclosable epistemic*
- several restrictions over attacks: practical arguments are c-f, practical arguments do not attack epistemic ones, . . .
- there may be attacks across (between disclosable arguments), e.g. *C: Facebook* attacks *C: Hiking*

Solving collaborative MAS by arguing

- distributed constraints satisfaction algorithm (with backtracking), incorporating
- variant of TPI-dispute to exchange “compact reasons” drawn from explanations (guaranteed to be disclosable!)

Example





A: C says she will be hiking with your ex-wife today. . .
({*C: Hiking*,A:Ballet} is the only explanation for A:Ballet)

B: But she has just posted on Facebook that they are at the ballet now.

A: I see. Shall we go and watch football?

B: if I’m not mistaken, you enjoy watching sport, right?
({*B: EnjoyTennis*,B:Football} is the only explanation for B:Football)

Collaborative MAS decisions vs Value-Based Argumentation

- Reinforcement Learning agents - converging to optimal policy
- actions are supported by arguments, which promote values; preferences over values

Value-based Argumentation (VbA) [Bench-Capon 2003]

Example

- Consider the AA framework $a \leftrightarrow b$ where

  a: Let's have dinner at home today
  b: Let's have dinner in a restaurant today

- $\{a\}$ and $\{b\}$ are both admissible

VbA uses **preferences over values promoted by arguments**

Example ($a \leftrightarrow b$)

- Consider **values**

  $v1$: Money-saving, where a **promotes** $v1$
  $v2$: Time-saving, where b **promotes** $v2$

- if $v1 > v2$ then $a \rightarrow b$: $\{a\}$ is admissible, $\{b\}$ is not
- if $v2 > v1$ then $a \leftarrow b$: $\{b\}$ is admissible, $\{a\}$ is not

VbA for Cooperative Multi-Agent Decisions (CMAD)

Decisions = actions:

- "Internal conflicts": each agent may have multiple alternative actions to take, but can only choose one at a time
- "External conflicts": multiple agents may want to perform the same action, but this action can/should be performed by one agent only

RoboCup

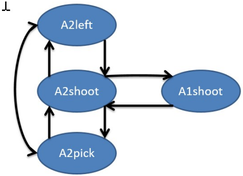
Exit	Ag2 (gold)	Wumpus	Ag1	

Multi-agent wumpus world

Example of VbA for CMAD

Exit	Ag2 (gold)	Wumpus	Ag1	

⇒



- **A1shoot**: Ag1 should do *shoot_left* because there is a Wumpus next to Ag1, on its left
- **A2left**: Ag2 should do *go_left* because the exit is on its left
- **A2pick**: Ag2 should do *pickup* because gold is in its square.

Vsafe: agents' safety

Vmoney: money-making

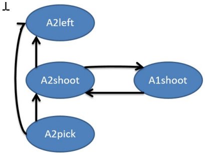
Vexit: exit wumpus world

A1shoot and **A2shoot** promote *Vsafe*

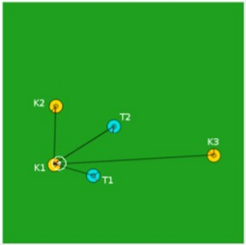
A2pick promotes *Vmoney*

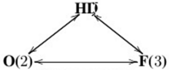
A2left promotes *Vexit*

$Vmoney > Vsafe > Vexit \Rightarrow$

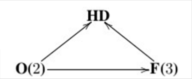


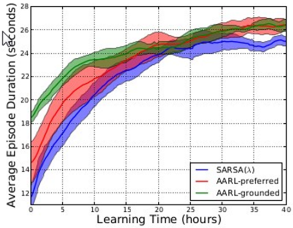
VbA+Reinforcement Learning for RoboCup [Gao&Toni 2014]





(a) Keepaway game





(a) 2-Keepaway

Decision matrices vs Bipolar Argumentation

- matrices: selection criteria for decisions/concept variants
- debates in Bipolar Argumentation (attack and support) over selection criteria and decisions

Bipolar Argumentation (BA) [Cayrol&Lagasquie-Schiex 2005], ...

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

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

Example (BA framework represented as a directed graph)

γ: Toulouse is small wrt London! δ: London has over 10M people

$$\alpha \longleftarrow \beta \longleftarrow \gamma \Longleftarrow \delta$$

Semantics, e.g.

- $A \subseteq Args$ is **admissible** iff ...
- the (dialectical) **strength** of $a \in Args$ is ...

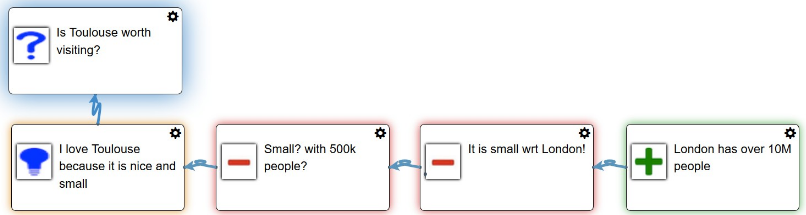
Example

$\{\alpha, \gamma, \delta\}$ is "admissible", $\{\beta\}$ is not
α has strength 0.4375, β has strength 0.125 (within [0,1])

QuAD (Quantitative Argumentation Debates) for Bipolar Argumentation

Arg&Dec (`www.arganddec.com`)

$$\alpha \longleftarrow \beta \longleftarrow \gamma \Longleftarrow \delta$$



Is Touloue worth visiting?

I love Toulouse because it is nice and small

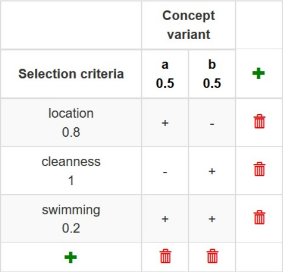
Small? with 500k people?

It is small wrt London!

London has over 10M people

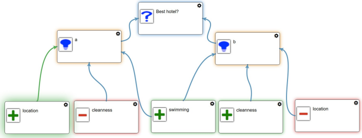
QuAD and DF-QuAD methods for determining “strength”

Arg&Dec for decision-making

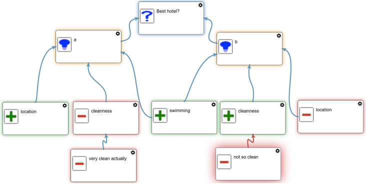


	Concept variant		
Selection criteria	a 0.5	b 0.5	✚
location 0.8	+	-	🗑
cleanness 1	-	+	🗑
swimming 0.2	+	+	🗑
✚	🗑	🗑	

b "better than" a



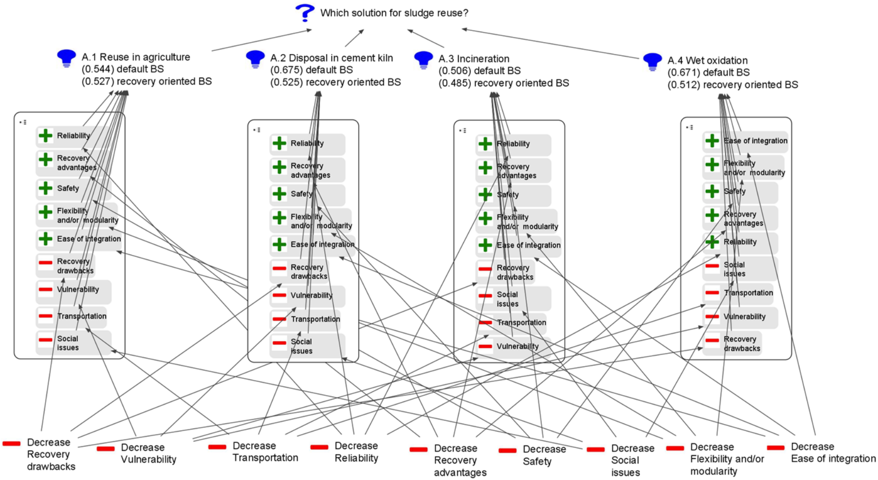
b stronger than a



a stronger than b

a "better than" b

BA/QuAD: applications



Which solution for sludge reuse?

A.1 Reuse in agriculture
(0.544) default BS
(0.527) recovery oriented BS

- + Reliability
- + Recovery advantages
- + Safety
- + Flexibility and/or modularity
- + Ease of integration
- − Recovery drawbacks
- − Vulnerability
- − Transportation
- − Social issues

A.2 Disposal in cement kiln
(0.675) default BS
(0.525) recovery oriented BS

- + Reliability
- + Recovery advantages
- + Safety
- + Flexibility and/or modularity
- + Ease of integration
- − Recovery drawbacks
- − Vulnerability
- − Transportation
- − Social issues

A.3 Incineration
(0.506) default BS
(0.485) recovery oriented BS

- + Reliability
- + Recovery advantages
- + Safety
- + Flexibility and/or modularity
- + Ease of integration
- − Recovery drawbacks
- − Social issues
- − Transportation
- − Vulnerability

A.4 Wet oxidation
(0.671) default BS
(0.512) recovery oriented BS

- + Ease of integration
- + Flexibility and/or modularity
- + Safety
- + Recovery advantages
- + Reliability
- − Social issues
- − Transportation
- − Vulnerability
- − Recovery drawbacks

− Decrease Recovery drawbacks
− Decrease Vulnerability
− Decrease Transportation
− Decrease Reliability
− Decrease Recovery advantages
− Decrease Safety
− Decrease Social issues
− Decrease Flexibility and/or modularity
− Decrease Ease of integration

Optimal decisions vs Assumption-based Argumentation

- decisions (have attributes that) fulfil goals, (possibly) preferences over goals, various notions of optimal decisions
- structured argumentation, debate trees as explanations

Assumption-based Argumentation (ABA) [Bondarenko et al 1997]

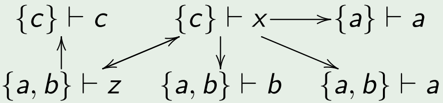
- a form of *structured* argumentation:
  - arguments are constructed from *rules*, and supported by *assumptions*
  - attacks are on the assumptions supporting arguments, by arguments for *contraries* of these assumptions

Example (Flat ABA frameworks give AA frameworks)

An ABA framework with

- rules $\mathcal{R} = \{x \leftarrow c, \quad z \leftarrow b, \quad a \leftarrow b\}$,
- assumptions $\mathcal{A} = \{a, b, c\}$,
- contraries $\overline{a} = x, \overline{b} = y, \overline{c} = z$

gives the AA framework:



$\{c\} \vdash c$

$\{c\} \vdash x$

$\{a\} \vdash a$

$\{a, b\} \vdash z$

$\{a, b\} \vdash b$

$\{a, b\} \vdash a$

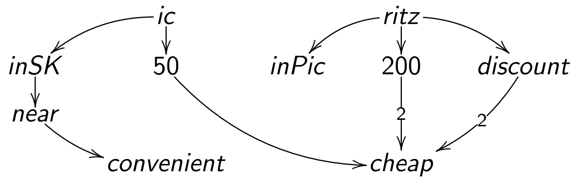
ABA for Multi-Criteria Decision Making

- from decision frameworks to (flat) ABA frameworks: "optimal decisions" form admissible sets of arguments
- "dispute trees" explain (optimality of) decisions:
  1. each node of a dispute tree $\mathcal{T}$ is labelled by some $\chi \in Args$ and is by the *proponent* 🟢 or the *opponent* 🔴
  2. for each 🟢 node *n*, labelled by some $\beta \in Args$, and for every $(\gamma, \beta) \in attacks$ there is a 🔴 child of *n* labelled by γ
  3. for each 🔴 node *n*, labelled by some $\beta \in Args$, there is *exactly* one child of *n* which is by 🟢 and labelled by some γ such that $(\gamma, \beta) \in attacks$
  4. there are no other nodes in $\mathcal{T}$

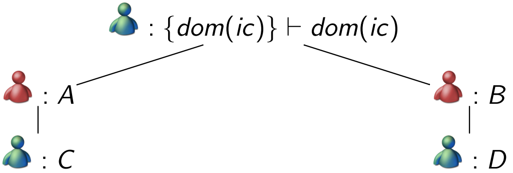
The set of all 🟢 arguments in *admissible dispute trees* (where no argument labels both 🟢 and 🔴 nodes) is admissible.

Example: ABA for decision graphs and "dominant" decisions

- decision graph:



- dominant decision: ic (meets all goals: convenient and cheap)
- ABA dispute tree:



: $\{dom(ic)\} \vdash dom(ic)$

: A

: B

: C

: D

$A = \{notMet(ic, convenient)\} \vdash notDom(ic)$

$B = \{notMet(ic, cheap)\} \vdash notDom(ic)$

$C = \{\ldots\} \vdash met(ic, convenient)$ $D = \{\ldots\} \vdash met(ic, cheap)$

Summary

- AA and VbA for cooperative MAS decisions
- BA and QuAD for matrix-based decisions
- ABA for multi-attribute decisions

rational, explainable decisions, supported by tools for computational argumentation

AA-CBR

Case-based Reasoning (CBR):

- Given *past cases* (S, o) (S features, $o \in \{+, -\}$ outcome)

  e.g. $(\{ensuite, wireless\}, +)$, $(\{small\}, -)$
- a default outcome $d \in \{+, -\}$

  e.g. $d =+$
- Determine the outcome of new case (with features) N

  e.g. $N =\{ensuite, small\}$

CBR by mapping onto AA:

- Arguments: past cases, $(N, ?)$, $(\emptyset, d)$

  e.g. $(\{ensuite, wireless\}, +)$, $(\{small\}, -)$, $(\{ensuite, small\}, ?)$, $(\emptyset, +)$
- Attack by $\neq$outcome&specificity&coincision/irrelevance:

  e.g. $(\{small\}, -)$ attacks $(\emptyset, +)$, $(\{ensuite, small\}, ?)$ attacks $(\{ensuite, wireless\}, +)$
- outcome of N is d ($\overline{d}$) if $(\emptyset, d)$ is (not) in grounded extension

  e.g. the outcome for $N =\{ensuite, small\}$ is $-$
- dispute trees as explanations of outcomes