Rationalisation of Profiles of Abstract Argumentation Frameworks

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Motivation

Central question in MAS research is how to aggregate diverse "views" of several agents. Also relevant: what diversity is actually possible?

We consider this second, less commonly asked question:

- we model "views" as abstract argumentation frameworks
- individual view is mix of "facts" and "preferences"
- can we *rationalise* diverse observations by disentangling them?

S. Airiau, E. Bonzon, U. Endriss, N. Maudet, and J. Rossit. Rationalisation of Profiles of Abstract Argumentation Frameworks. Proc. AAMAS-2016.

Talk Outline

- Background: *value-based* variant of *abstract argumentation*
- Concept: formal definition of the *rationalisability problem*
- Results: *single-agent case* and *multiagent case*

Value-Based Argumentation

An *argumentation framework* $AF = \langle Arg, \rightharpoonup \rangle$ consists of a finite set of *arguments* Arg and a binary *attack-relation* $\rightharpoonup$.

An *audience-specific value-based AF* $\langle Arg, \rightharpoonup, Val, val, \succcurlyeq \rangle$ consists of an AF $\langle Arg, \rightharpoonup \rangle$, a *labelling* $val : Arg \to Val$ of arguments with *values*, and a (reflexive and transitive) *preference order* $\succcurlyeq$ on Val.

Argument A *defeats* B ($A \rightleftharpoons B$) if $A \rightharpoonup B$ but $val(B) \not\succ val(A)$.
Note that $\langle Arg, \rightleftharpoons \rangle$ is itself just another AF.

P.M. Dung. On the Acceptability of Arguments and its Fundamental Role in NMR, LP and n-Person Games. *Artificial Intelligence*, 77(2):321–358, 1995.

T.J.M. Bench-Capon. Persuasion in Practical Argument Using Value-Based Argumentation Frameworks. *Journal of Logic and Computation*, 13(3):429–448, 2003.

The Rationalisability Problem

Given n *agents* and a *profile* of AF's $(\langle Arg_1, \rightharpoonup_1\rangle, \ldots, \langle Arg_n, \rightharpoonup_n\rangle)$ the *rationalisability problem* asks whether there exist:

- a master attack-relation $\rightharpoonup$ on $Arg = Arg_1 \cup \cdots \cup Arg_n$
- a set of values Val and a value-labelling $val : Arg \rightarrow Val$
- a profile of preference orders $(\succcurlyeq_1, \ldots, \succcurlyeq_n)$

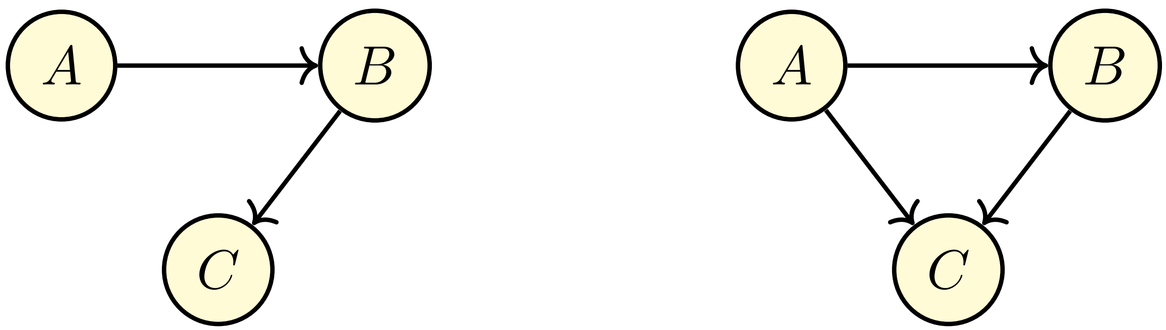
such that $A \rightharpoonup_i B$ iff $A \rightharpoonup B$ but $val(B) \not\succ_i val(A)$ [for all i, A, B].

We may also wish to impose certain *constraints* on allowed solutions.

The Single-Agent Case: Example

Let $Arg = \{A, B, C\}$. Suppose the master attack-relation $\rightharpoonup$ is fixed.

observed defeat-relation $\rightleftharpoons$ fixed master attack-relation $\rightharpoonup$



Can you rationalise $\rightleftharpoons$ in terms of $\rightharpoonup$ using ...

- up to *two* values?
- up to *three* values?
- up to *three* values and a *complete* preference order?

The Single-Agent Case: Results

Can you rationalise a given AF $\langle Arg, \rightharpoonup\!\!\!\!\!\!\!\rightharpoonup \rangle$ by means of some master attack-relation $\rightharpoonup$, value-labelling $val : Arg \to Val$, and preference $\succcurlyeq$?

Depends on the constraints:

- *No constraints* (or only on value-labelling): always *yes!*

    Just let $(\rightharpoonup) = (\rightleftharpoons)$*, use whatever value-labelling, and let* $\succcurlyeq$ *be indifferent between any two arguments.*

- *Fixed master attack-relation:* easy *polynomial* algorithm

    Assign unique value to each argument. Just need to check $(\rightleftharpoons) \subseteq (\rightharpoonup)$*, removed part* $(\rightharpoonup \setminus \rightleftharpoons)$ *is acyclic, and preference does not cancel too many attacks:* $(\rightleftharpoons) \cap (\rightharpoonup \setminus \rightleftharpoons)^+ = \emptyset$*.*

- *Bound on values* and *complete preference:* also *polynomial*

    Encode as integer program with 2 variables per inequality. »

For (possibly) *incomplete* preferences this is an *open problem*.

Rationalisation with Bound on Number of Values

Can you rationalise $\langle Arg, \rightharpoonup\!\!\!\!\!\rightharpoondown \rangle$ by means of master attack-relation $\rightharpoonup$, some $val : Arg \to Val$ with $|Val| \leqslant k$, and some *complete* $\succcurlyeq$?

Suppose master attack-relation $\rightharpoonup$ is given [if not: $(\rightharpoonup) = (\rightleftharpoons)$ is best]. W.l.o.g., assume $(\rightleftharpoons) \subseteq (\rightharpoonup)$ [otherwise: not rationalisable].

W.l.o.g., let $Val = \{1, \ldots, k\}$ and let $\succcurlyeq$ be $\geqslant$ on the natural numbers.

For every $A \in Arg$, introduce *integer variable* x_A with $1 \leqslant x_A \leqslant k$. Construct an integer program with these inequalities:

- $x_A < x_B$ whenever $A \rightharpoonup B$ but not $A \rightleftharpoons B$
- $x_B \leqslant x_A$ whenever $A \rightleftharpoons B$ [and thus also $A \rightharpoonup B$]

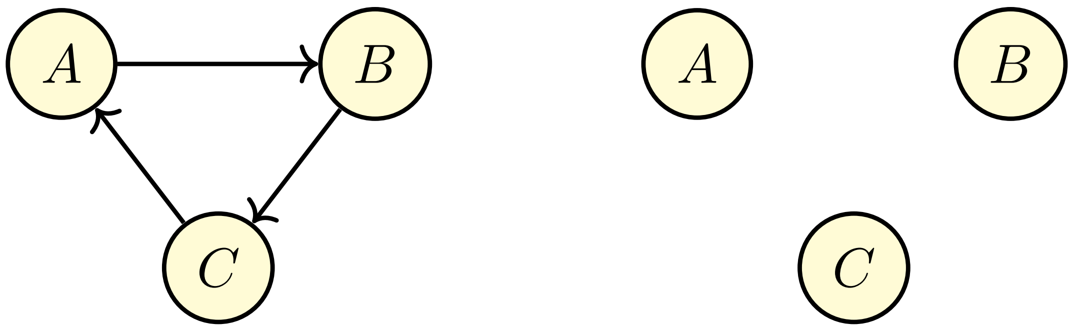
Deciding feasibility of IP's with *2 variables per inequality* is polynomial!

<u>Crucial:</u> modelling $val(B) \not\succ val(A)$ as $x_B \leqslant x_A$ rather than $x_B \not> x_A$ is ok *only* due to the *completeness* requirement!

Multiagent Rationalisation: Example

Let $Arg = \{A, B, C\}$ and $n = 2$. Try to rationalise the following profile.

first defeat-relation $\rightharpoonup_1$ second defeat-relation $\rightharpoonup_2$



A few hints:

- Rationalisable <u>if</u> rationalisable with $(\rightharpoonup) = (\rightharpoonup_1) \cup (\rightharpoonup_2) = (\rightharpoonup_1)$.
- Rationalisable <u>if</u> rationalisable with one value for each argument.
- Now try to build $\succcurlyeq_2$ (preference order of second agent) ...

Multiagent Rationalisation: Easy Cases

In our example, it was *impossible to decompose* the problem and to consider rationalisability separately for each agent.

But when all constraints are of these types, then you *can decompose:*

- the master attack-relation $\rightharpoonup$ is fixed
- the value-labelling $val : (Arg_1 \cup \cdots \cup Arg_n) \to Val$ is fixed*

So multiagent rationalisability *reduces* to single-agent rationalisability! Thus, multiagent rationalisability is *polynomial* in these cases:

- no constraints
- only the master attack-relation is fixed
- only the value-labelling is fixed
- master attack-relation and value-labelling are fixed

*Single-agent rationalisability is also easy [case not discussed before].

Multiagent Rationalisation: Hard (and Easy) Cases

Bad news: Let $k \geqslant 3$. For constraint $|Val| \leqslant k$, rationalisability is *NP-complete* (whether or not the master attack-relation is given).

- Proof by reduction from GRAPH COLOURING.
- Open problem whether also NP-complete for $Arg_1 = \cdots = Arg_n$.

Good news: for $k = 2$ there is a *polynomial* algorithm [not in paper].

Good news: for *"large" bounds* it's also *polynomial*: $k \in \Omega(|Arg|)$.

Last Slide

We have introduced the *rationalisability problem* for a given profile of argumentation frameworks, one for each agent in a multiagent system:

- identified various cases that admit *polynomial algorithms*
- but multiagent case with bound on values is *NP-complete*
- several *open problems* regarding complexity

Definition of the rationalisability problem in terms of Bench-Capon's *value-based* argumentation frameworks, but basic idea is general.

Possible *application* scenarios:

- to determine relevant profiles for research on aggregating AF's
- if rationalisable, we can use preference aggregation instead
- to spot inconsistencies in online debating platforms

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