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On Incompleteness in Abstract Argumentation: Complexity and Expressiveness

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LIPADE

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Outline

1. Background: Abstract Argumentation
2. Incomplete AFs
   - Definitions and Complexity
   - The Disjunction Problem
3. Rich Incomplete AFs
4. Constrained Incomplete AFs
   - Definition
   - Expressiveness of CIAFs
   - CIAFs and Extension Enforcement
5. Conclusion

Why Argumentation?

- a_1 "I'm hungry, let's go to this restaurant." (John)
- a_2 "The comments on Tripadvisor are bad, let's go somewhere else." (Yoko)
- a_3 "These are old comments, and there is a new chef, so the food is probably better now." (John)
- a_4 "Moreover, all the other restaurants in this street are closed." (John)

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Why Argumentation?

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a_4 "Moreover, all the other restaurants in this street are closed." (John)

Argumentation is useful when agents need to communicate about their (possibly incompatible) beliefs, goals, preferences,...

- strategic aspects: persuasion, negotiation,...

More generally, argumentation can be used to represent conflicting information and obtain reasonable outcome from it

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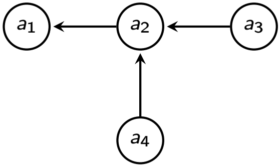
Abstract AFs

Dung's Argumentation Framework

Argumentation Framework (**AF** for short): $F = \langle A, R \rangle$ where

- A is a set of arguments
- $R \subseteq A \times A$ represents attacks between arguments

- Example: $F = \langle A, R \rangle$ with
  - $A = \{a_1, a_2, a_3, a_4\}$
  - $R = \{(a_2, a_1), (a_3, a_2), (a_4, a_2)\}$



Phan Minh Dung: On the Acceptability of Arguments and its Fundamental Role in Nonmonotonic Reasoning, Logic Programming and n-Person Games. Artif. Intell. 77(2): 321-358 (1995)

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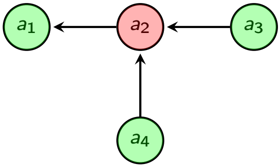
- Collective arguments acceptability



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Dung's Semantics

Basic properties

Given $F = \langle A, R \rangle$, $S \subseteq A$ is

- conflict-free (**cf**) w.r.t. F if $\nexists a_i, a_j \in S$ s.t. $(a_i, a_j) \in R$
- admissible (**ad**) w.r.t. F if S is **cf** and defends each $a_i \in S$

Classical semantics

Given $F = \langle A, R \rangle$, $S \subseteq A$ is

- complete (**co**) w.r.t. F if S is **ad** and contains all the arguments that it defends
- preferred (**pr**) w.r.t. F if S is a $\subseteq$-maximal **co** extension
- stable (**st**) w.r.t. F if S is **cf** and attacks every $a_j \in A \setminus E$
- grounded (**gr**) w.r.t. F if S is a $\subseteq$-minimal **co** extension

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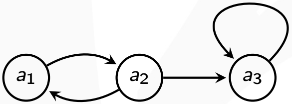
Semantics Example



Semantics	Extensions
Grounded	$\{\emptyset\}$
Stable	$\{\{a_2\}\}$
Preferred	$\{\{a_1\}, \{a_2\}\}$
Complete	$\{\emptyset, \{a_1\}, \{a_2\}\}$

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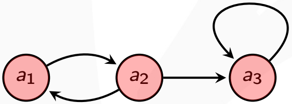

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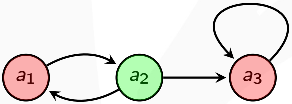

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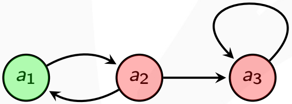

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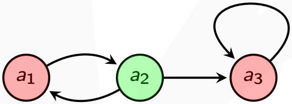

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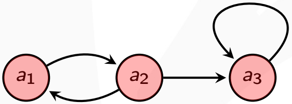

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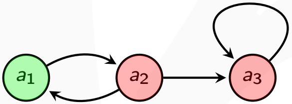

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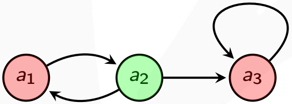

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Arguments Acceptability

Given $F = \langle A, R \rangle$ and σ a semantics,

- $a \in A$ is skeptically accepted (SA) by F w.r.t. σ iff $\forall S \in \sigma(F)$, $a \in S$
- $a \in A$ is credulously accepted (CA) by F w.r.t. σ iff $\exists S \in \sigma(F)$, s.t. $a \in S$

σ	σ-CA	σ-SA
ad	NP-c	trivial
st	NP-c	coNP-c
co	NP-c	P-c
gr	P-c	P-c
pr	NP-c	Π_2^P-c

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Incomplete AFs

Incomplete Argumentation Framework

Incomplete Argumentation Framework (**IAF** for short): $I = \langle A, A^?, R, R^? \rangle$ where

- A and R are arguments and attacks that certainly exist
- $A^?$ and $R^?$ are arguments and attacks that may exist, by maybe not

Dorothea Baumeister, Matti Järvisalo, Daniel Neugebauer, Andreas Niskanen, Jörg Rothe: Acceptance in incomplete argumentation frameworks. Artif. Intell. 295: 103470 (2021)

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Why incompleteness?

- ignorance about other agents knowledge/preferences in a debate
- ignorance about the truth of arguments premises

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Completions

Completion of an IAF $I = \langle A, A^?, R, R^? \rangle$: $F = \langle A^*, R^* \rangle$ where

- $A \subseteq A^* \subseteq A \cup A^?$
- $R \cap (A^* \times A^*) \subseteq R^* \subseteq (R \cup R^?) \cap (A^* \times A^*)$

$\rightarrow$ "classical" AF compatible with the uncertain knowledge contained in the IAF

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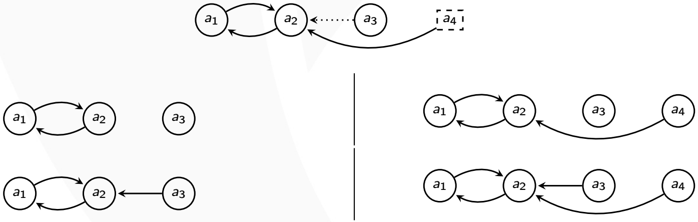

Dorothea Baumeister, Matti Järvisalo, Daniel Neugebauer, Andreas Niskanen, Jörg Rothe: Acceptance in incomplete argumentation frameworks. Artif. Intell. 295: 103470 (2021)

Classical Reasoning with IAFs

- Possible view: the property is true in some completion
- Necessary view: the property is true in each completion

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- a_3 is skeptically accepted in each completion

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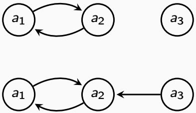

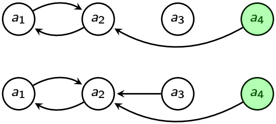

- a_3 is skeptically accepted in each completion
- a_4 is skeptically accepted in some completion

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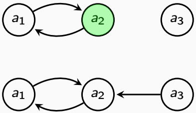

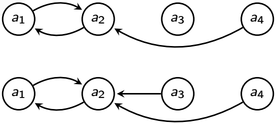

- a_3 is skeptically accepted in each completion
- a_4 is skeptically accepted in some completion
- a_2 is credulously accepted in some completion

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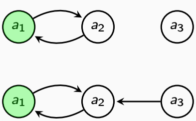

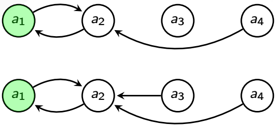

- a_3 is skeptically accepted in each completion
- a_4 is skeptically accepted in some completion
- a_2 is credulously accepted in some completion
- a_1 is credulously accepted in each completion

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Arguments Acceptability in IAFs

In the rest of the talk, mainly focus on:

- Possible credulous acceptability (PCA): a is in some extension of some completion
- Necessary skeptical acceptability (NSA): a is in each extension of each completion

σ	σ-PCA	σ-NSA
ad	NP-c	trivial
st	NP-c	coNP-c
co	NP-c	coNP-c
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Motivation: Revising/Merging AFs

Previous work:

- Extension-based revision of AFs

$$F, \phi \xrightarrow{\text{AGM revision}} Ext_\sigma(F \star \phi) \xrightarrow{\text{generation}} F \star \phi = \{F'_1, \ldots, F'_k\}$$

- Extension-based merging of AFs

$$P = \langle F_1, \ldots, F_k \rangle, \mu \xrightarrow{\text{Merging under constraint}} Ext_\sigma(\Delta_\mu(P)) \xrightarrow{\text{generation}} \Delta_\mu(P) = \{F'_1, \ldots, F'_k\}$$

Sylvie Coste-Marquis, Sébastien Konieczny, Jean-Guy Mailly, Pierre Marquis: On the Revision of Argumentation Systems: Minimal Change of Arguments Statuses. KR 2014

Jérôme Delobelle, Adrian Haret, Sébastien Konieczny, Jean-Guy Mailly, Julien Rossit, Stefan Woltran: Merging of Abstract Argumentation Frameworks. KR 2016: 33-42

Example

- Suppose that the result of revising an AF yields the extensions $\{\{a_1, a_2\}, \{a_1, a_2, a_3\}\}$
- It is not representable with a single AF: realizability issue

Paul E. Dunne, Wolfgang Dvorák, Thomas Linsbichler, Stefan Woltran: Characteristics of multiple viewpoints in abstract argumentation. Artif. Intell. 228: 153-178 (2015)

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- It is representable by two AFs:

- Or one single IAF:

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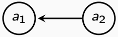
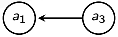
- It is representable by two AFs:

- Or one single IAF:

- **Question:** Can we represent any set of AFs/extensions by a single IAF?

AF Representation by Means of IAFs





- Can we represent these AFs with one IAF?

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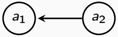

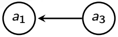

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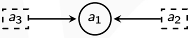
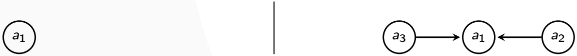


- Problem: this IAF has other completions



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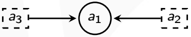

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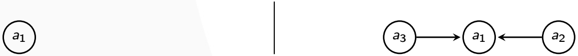

- **Question:** Can we generalize the IAF model to represent any set of AFs/extensions?

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Rich IAFs

Main idea:

- Add a new kind of attacks, where the uncertainty concerns the direction
- Borrowed from Control AFs (Dimopoulos et al 2018)
- This new kind of uncertainty can be mixed with uncertain arguments and uncertain attacks

Yannis Dimopoulos, Jean-Guy Mailly, Pavlos Moraitis:Control Argumentation Frameworks. AAAI 2018: 4678-4685

Jean-Guy Mailly: A Note on Rich Incomplete Argumentation Frameworks. CoRR abs/2009.04869 (2020)

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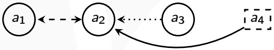

- There certainly is a conflict between a_1 and a_2, but we are not sure of the direction:
  - (a_1, a_2),
  - (a_2, a_1),
  - or both (a_1, a_2) and (a_2, a_1)

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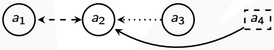
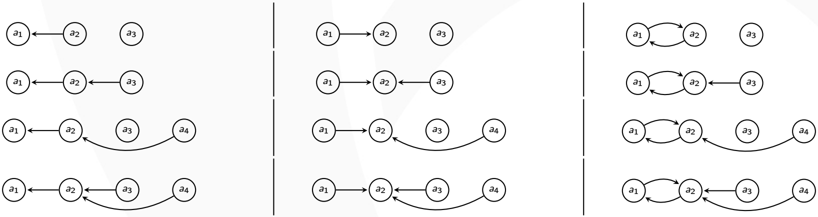
Completions of Rich IAFs





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Complexity of Rich IAFs

Main result:

- The complexity of all reasoning tasks is the same, compared to IAFs
- Intuition of the proofs: guessing a completion of an IAF or guessing a completion of a RIAF is the same thing. Then verifying whether the completion satisfies some properties is also similar

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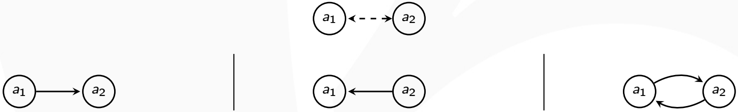
Expressiveness of Rich IAFs

- Rich IAFs a strictly more expressive than IAFs



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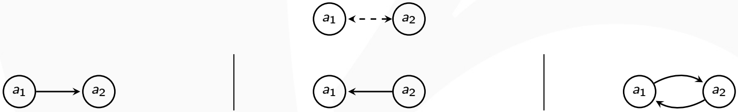
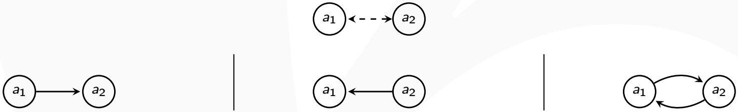


- There is no IAF with exactly these completions
- But Rich IAFs are not "maximally" expressive

- There is no (Rich) IAF with exactly these completions

Expressiveness of Rich IAFs

- Rich IAFs a strictly more expressive than IAFs



- There is no IAF with exactly these completions
- But Rich IAFs are not "maximally" expressive

- There is no (Rich) IAF with exactly these completions

Question

Can we have a framework more expressive than Rich IAFs?

Outline

1. Background: Abstract Argumentation
2. Incomplete AFs
   - Definitions and Complexity
   - The Disjunction Problem
3. Rich Incomplete AFs
4. Constrained Incomplete AFs
   - Definition
   - Expressiveness of CIAFs
   - CIAFs and Extension Enforcement
5. Conclusion

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Constrained Incomplete AFs

CIAF

$C = \langle A, A^?, R, R^?, \phi \rangle$ where

- $\langle A, A^?, R, R^? \rangle$ is a "classical" IAF
- ϕ is a constraint on the completions built on $Arg_{A \cup A^?} \cup Att_{A \cup A^?}$
  - $Arg_X = \{\text{arg}_a \mid a \in X\}$
  - $Att_X = \{\text{att}_{a,b} \mid (a, b) \in X \times X\}$

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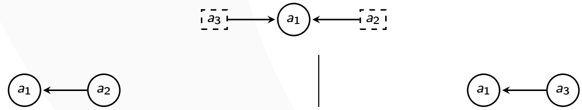
- Example: $C = \langle \{a_1\}, \{a_2, a_3\}, \{(a_2, a_1), (a_3, a_1)\}, \emptyset, \text{arg}_{a_2} \oplus \text{arg}_{a_3} \rangle$



Jean-Guy Mailly: Constrained Incomplete Argumentation Frameworks. ECSQARU 2021: 103-116

Mapping an AF to a Formula

Given $\mathcal{A}$ the set of all possible arguments and $F = \langle A, R \rangle$ with $A \subseteq \mathcal{A}$

$$\psi_F = (\bigwedge_{a \in A} \mathsf{arg}_a) \wedge (\bigwedge_{a \in \mathcal{A} \setminus A} \neg \mathsf{arg}_a) \wedge (\bigwedge_{(a,b) \in R} \mathsf{att}_{a,b}) \wedge (\bigwedge_{(a,b) \in (\mathcal{A} \times \mathcal{A}) \setminus R} \neg \mathsf{att}_{a,b})$$

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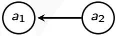

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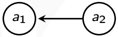

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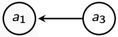
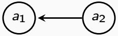
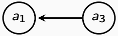


- $\psi_{F'} = \text{arg}_{\mathbf{a_1}} \wedge \text{arg}_{\mathbf{a_3}} \wedge \neg \text{arg}_{\mathbf{a_2}} \wedge \text{att}_{\mathbf{a_3},\mathbf{a_1}} \wedge (\bigwedge_{(a,b) \in (\mathcal{A} \times \mathcal{A}) \setminus R} \neg \text{att}_{a,b})$

Mapping AFs to a CIAF





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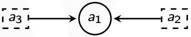

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Proposition

Any set of AFs $\mathcal{F}$ can be mapped to a CIAF s.t. its completions correspond to $\mathcal{F}$

Jean-Guy Mailly: Constrained Incomplete Argumentation Frameworks. ECSQARU 2021: 103-116

Mapping Extensions to a CIAF

- Given $\mathcal{E} = \{E_1, \dots, E_n\}$, each $E_i \subseteq \mathcal{A}$ can be mapped to $F_i = \langle \mathcal{A}, R_i \rangle$ with $R_i = \{(a, b) \mid a \in E_i, b \in \mathcal{A} \setminus E_i\}$

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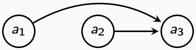

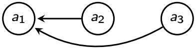

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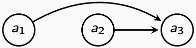

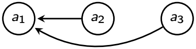

- Then, $\mathcal{F} = \{F_1, \dots, F_n\}$ can be mapped to a CIAF (see previous result)

Proposition

Any set of extensions $\mathcal{E}$ can be mapped to a CIAF s.t. the extensions of its completions correspond to $\mathcal{E}$

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Open Question

How can we build the "best" CIAF?

- Best graph $\langle A, A^?, R, R^? \rangle$: minimize the distance w.r.t. some input
  Sylvie Coste-Marquis, Caroline Devred, Sébastien Konieczny, Marie-Christine Lagasquie-Schiex, Pierre Marquis: On the merging of Dung's argumentation systems. Artif. Intell. 171(10-15): 730-753 (2007)

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- Best formula ϕ (w.r.t. size, computational property): knowledge compilation?
  Adnan Darwiche, Pierre Marquis: A Knowledge Compilation Map. J. Artif. Intell. Res. 17: 229-264 (2002)

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Complexity Issues

- Possible credulous acceptability: *a* is in some extension of some completion
- Necessary skeptical acceptability: *a* is in each extension of each completion
- Complexity is the same as in classical IAFs
    - Intuition: checking whether a completion satisfies the constraint is polynomial

σ	σ-PCA	σ-NSA
ad	NP-c	trivial
st	NP-c	coNP-c
co	NP-c	coNP-c
gr	NP-c	coNP-c
pr	NP-c	Π_2^P-c

Unpublished (but almost certain) claim:

- other acceptability problems (PSA, NCA) have the same complexity for CIAFs and standard IAFs
- verification problems are NP/coNP-c for CIAFs when they are polynomial for standard IAFs (or remain the same when they are already intractable for IAFs)

Extension Enforcement

$$\left.\begin{array}{c} F = \langle A, R \rangle \\ E \subseteq A \end{array}\right\} \implies F' = \langle A', R' \rangle$$

such that E is (included in) an extension of F' for a given semantics

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such that E is (included in) an extension of F' for a given semantics

- Normal expansion: new AF which adds new arguments and attacks, but does not change the attacks between former arguments

Ringo Baumann, Gerhard Brewka: Expanding Argumentation Frameworks: Enforcing and Monotonicity Results. COMMA 2010: 75-86

Extension Enforcement: Possibility Results

- Possibility results based on (sometimes unrealistic) examples

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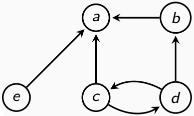

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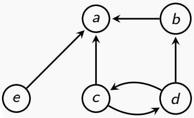

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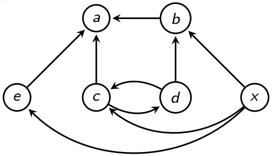

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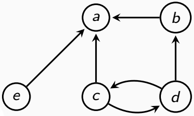

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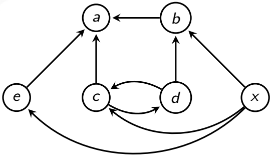

- The existence of an "ultimate attacker" like x is not plausible in real debates

Parameterized Expansion

Given

- $F = \langle A, R \rangle$ an AF
- $\mathcal{A}$ a set of available arguments s.t. $A \cap \mathcal{A} = \emptyset$
- $\mathcal{R} \subseteq ((A \cup \mathcal{A}) \times (A \cup \mathcal{A})) \setminus (A \times A)$

we say that $F' = \langle A', R' \rangle$ is a $\mathcal{A}$-$\mathcal{R}$-parameterized expansion of F iff

- F' is a normal expansion of F,
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$\mathcal{A}$ and $\mathcal{R}$ encode the possible actions of the agent in the debate

Parameterized Enforcement

From $F = \langle A, R \rangle$, $\mathcal{A}$ and $\mathcal{R}$

- we call "possible action" any F' that is a $\mathcal{A}$-$\mathcal{R}$-parameterized expansion of F
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- Research on CIAFs provides means for implementing realistic methods for enforcing extensions in argument-base dialogue

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Related Work: Constraining the completions

- Independently of our work, Herzig and Yuste-Ginel defined a framework equivalent to our CIAFs (using the same name), and proved that it is "maximally" expressive
- Fazzinga et al. studied Argument-Incomplete AFs (IAFs with $R^? = \emptyset$) and Attack-Incomplete AFs (IAFs with $A^? = \emptyset$) with correlations, which are special cases of our constraints ($X \rightarrow Y$, $X \vee Y$, $\neg(X \wedge Y)$, $X \oplus Y$), and focus on the possible verification problem
  - Given an IAF with correlations I and a set of arguments S, is S an extension of some completion of I?

Andreas Herzig, Antonio Yuste-Ginel: Abstract Argumentation with Qualitative Uncertainty: An Analysis in Dynamic Logic. CLAR 2021: 190-208

Bettina Fazzinga, Sergio Flesca, Filippo Furfaro: Reasoning over Argument-Incomplete AAFs in the Presence of Correlations. IJCAI 2021: 189-195

Bettina Fazzinga, Sergio Flesca, Filippo Furfaro: Reasoning over Attack-incomplete AAFs in the Presence of Correlations. KR 2021: 301-311

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Related Work: IAFs without completions

- Semantics have been defined for reasoning with Partial AFs ($\simeq$ Attack-Incomplete AFs, i.e. IAFs with $A = \emptyset$) without using the set of completions (Cayrol et al 2007), by adapting the definitions of conflict-freeness and defense to this setting
- Recent work: generalization to the work by (Cayrol et al 2007) to IAFs, with more semantics studied (Mailly 2021, Mailly 2023)
  - Same complexity as in Dung's framework
  - Available SAT-based solver

Claudette Cayrol, Caroline Devred, Marie-Christine Lagasquie-Schiex: Handling Ignorance in Argumentation: Semantics of Partial Argumentation Frameworks. ECSQARU 2007: 259-270

Jean-Guy Mailly: Extension-Based Semantics for Incomplete Argumentation Frameworks. CLAR 2021: 322-341

Jean-Guy Mailly: Extension-based Semantics for Incomplete Argumentation Frameworks: Properties, Complexity and Algorithms. JLC, (2023?), To Appear

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Summary

- CIAFs increase the expressivity of IAFs without increasing the complexity for
  - possible credulous acceptability
  - necessary skeptical acceptability
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Future work

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More details:

Jean-Guy Mailly: On Incompleteness in Abstract Argumentation: Complexity and Expressiveness. SUM 2022: 19–33

Jean-Guy Mailly: Yes, no, maybe, I don't know: Complexity and application of abstract argumentation with incomplete knowledge. Argument. Comput. 13(3): 291–324.