Current Trends in Argumentation Dynamics

Jean-Guy Mailly

EASSS 2024 – 21/08/2024

Université Toulouse Capitole, IRIT

Who am I? What do I do?

Me, at KR'23 in Rhodes

Toulouse

- 2012-15: PhD in Computer Science
- 2015-16: Postdoc at TU Wien
- 2016-24: Associate Professor at Université Paris Cité
- 2024-...: Junior Professor at Université Toulouse Capitole

- Knowledge representation and reasoning
  - Somewhere between formal logic and computer engineering
- More precisely, argumentation
  - Connections to AAMAS

Feel free to...

- Ask questions during the talk
- Ask questions after the talk (`jean-guy.mailly@irit.fr`)
- Stay in touch :)
  - `https://www.linkedin.com/in/jeanguymailly/`

How to get the slides?

https://jgmailly.github.io/assets/pdf/EASSS2024_Mailly.pdf

Table of contents

Outline

What is Argumentation?

- Argumentation is an important part of human reasoning
  - Justifying one's own beliefs/decisions
  - Convincing someone else to believe something/do something
  - Analysing conflicting pieces of information
- Formal argumentation in AI studies:
  - Modeling of arguments and their relationships
  - Acceptability of arguments
  - Protocols for several agents using arguments in dialogues
- Two families of formal models
  - Structured/logic-based frameworks
  - Abstract frameworks

What is Argumentation?

- Argumentation is an important part of human reasoning
  - Justifying one's own beliefs/decisions
  - Convincing someone else to believe something/do something
  - Analysing conflicting pieces of information
- Formal argumentation in AI studies:
  - Modeling of arguments and their relationships
  - Acceptability of arguments
  - Protocols for several agents using arguments in dialogues
- Two families of formal models
  - Structured/logic-based frameworks
  - Abstract frameworks

What is Argumentation?

- Argumentation is an important part of human reasoning
  - Justifying one's own beliefs/decisions
  - Convincing someone else to believe something/do something
  - Analysing conflicting pieces of information
- Formal argumentation in AI studies:
  - Modeling of arguments and their relationships
  - Acceptability of arguments
  - Protocols for several agents using arguments in dialogues
- Two families of formal models
  - Structured/logic-based frameworks
  - Abstract frameworks

Abstract Argumentation

Dung's Abstract 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

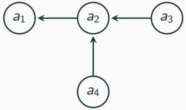
Dung's Abstract Argumentation Framework

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:
  - a_1: (John) "I'm hungry, let's go to this restaurant."
  - a_2: (Yoko) "I've seen on Tripadvisor that the food is bad, let's go somewhere else."
  - a_3: (John) "These grades are old, and there's a new chef, so it should be better now."
  - a_4: (John) "Moreover, the other restaurants in the streets are closed."

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



P. M. 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)

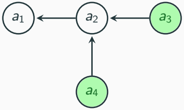
Dung's Abstract Argumentation Framework

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:
  - a_1: (John) "I'm hungry, let's go to this restaurant."
  - a_2: (Yoko) "I've seen on Tripadvisor that the food is bad, let's go somewhere else."
  - a_3: (John) "These grades are old, and there's a new chef, so it should be better now."
  - a_4: (John) "Moreover, the other restaurants in the streets are closed."

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



P. M. 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)

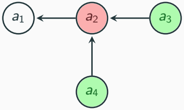
Dung's Abstract Argumentation Framework

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:
  - a_1: (John) "I'm hungry, let's go to this restaurant."
  - a_2: (Yoko) "I've seen on Tripadvisor that the food is bad, let's go somewhere else."
  - a_3: (John) "These grades are old, and there's a new chef, so it should be better now."
  - a_4: (John) "Moreover, the other restaurants in the streets are closed."

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



P. M. 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)

Abstract Argumentation

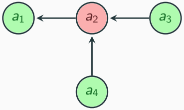
Dung's Abstract Argumentation Framework

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:
  - a_1: (John) "I'm hungry, let's go to this restaurant."
  - a_2: (Yoko) "I've seen on Tripadvisor that the food is bad, let's go somewhere else."
  - a_3: (John) "These grades are old, and there's a new chef, so it should be better now."
  - a_4: (John) "Moreover, the other restaurants in the streets are closed."

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



P. M. 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)

Abstract Argumentation

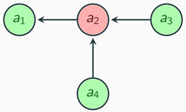
Dung's Abstract Argumentation Framework

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:
  - a_1: (John) "I'm hungry, let's go to this restaurant."
  - a_2: (Yoko) "I've seen on Tripadvisor that the food is bad, let's go somewhere else."
  - a_3: (John) "These grades are old, and there's a new chef, so it should be better now."
  - a_4: (John) "Moreover, the other restaurants in the streets are closed."

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



- It doesn't work if there are cycles $\rightarrow$ various semantics to remedy this issue

P. M. 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)

Abstract Argumentation: Semantics

Extension

Given $F = \langle A, R \rangle$, an extension is a set of jointly acceptable arguments

Abstract Argumentation: Semantics

Extension

Given $F = \langle A, R \rangle$, an extension is a set of jointly acceptable arguments

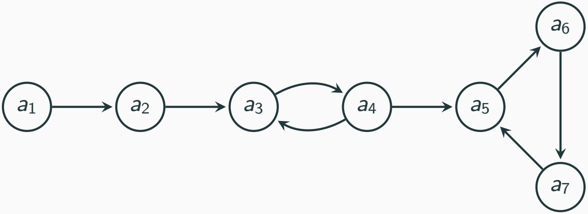
Extension-based Semantics

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

- *conflict-free* (**cf**) if there is no $a, b \in S$ s.t. $(a, b) \in R$
- *admissible* (**ad**) if $S \in \mathbf{cf}(F)$ and S defends all its elements
- *stable* (**st**) if $S \in \mathbf{cf}(F)$ and S attacks each argument in $A \setminus S$
- *complete* (**co**) if $S \in \mathbf{ad}(F)$ and S doesn't defend any argument in $A \setminus S$
- *preferred* (**pr**) if S is $\subseteq$-maximal in $\mathbf{ad}(F)$
- *grounded* (**gr**) if S is $\subseteq$-minimal in $\mathbf{co}(F)$

P. M. 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)

Example: Semantics Comparison



Semantics σ	σ-extensions	$cred_\sigma$	$skep_\sigma$
grounded	$\{\{a_1\}\}$	$\{a_1\}$	$\{a_1\}$
stable	$\{\{a_1, a_4, a_6\}\}$	$\{a_1, a_4, a_6\}$	$\{a_1, a_4, a_6\}$
preferred	$\{\{a_1, a_4, a_6\}, \{a_1, a_3\}\}$	$\{a_1, a_3, a_4, a_6\}$	$\{a_1\}$
complete	$\{\{a_1, a_4, a_6\}, \{a_1, a_3\}, \{a_1\}\}$	$\{a_1, a_3, a_4, a_6\}$	$\{a_1\}$

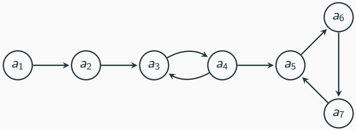
- $cred_\sigma(F) = \cup_{S \in \sigma(F)} S$: credulously accepted arguments
- $skep_\sigma(F) = \cap_{S \in \sigma(F)} S$: skeptically accepted arguments

Labellings

- 3-valued representation of extensions
- Given $F = \langle A, R \rangle$ an AF, and S a σ-extension,
  - $L_S(a) = IN$ iff $a \in S$,
  - $L_S(a) = OUT$ iff $\exists b \in S$ s.t. $(b, a) \in R$,
  - $L_S(a) = UNDEC$ otherwise

Labellings

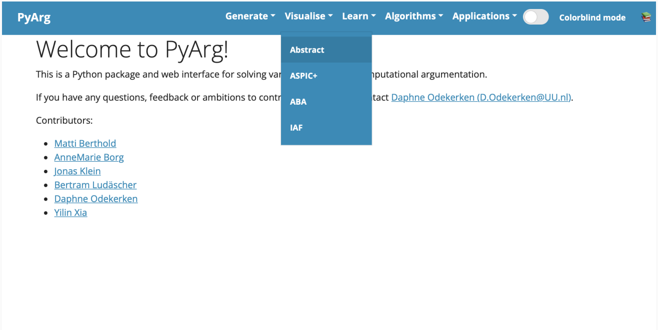
- 3-valued representation of extensions
- Given $F = \langle A, R \rangle$ an AF, and S a σ-extension,
  - $L_S(a) = \textcolor{green}{IN}$ iff $a \in S$,
  - $L_S(a) = \textcolor{red}{OUT}$ iff $\exists b \in S$ s.t. $(b, a) \in R$,
  - $L_S(a) = \textcolor{gray}{UNDEC}$ otherwise



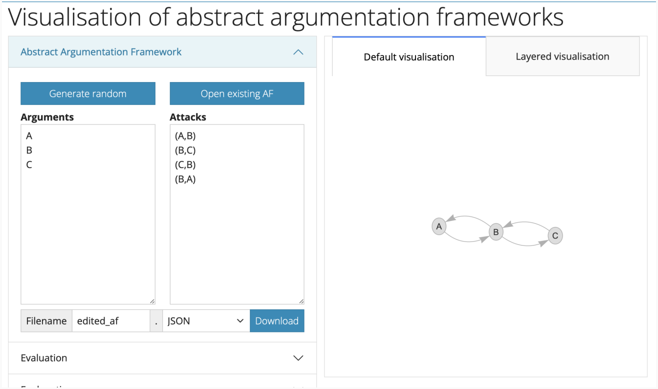
Semantics σ	σ-labellings
grounded	$\{\{\textcolor{green}{a_1}, \textcolor{red}{a_2}, \textcolor{gray}{a_3}, \textcolor{gray}{a_3}, \textcolor{gray}{a_5}, \textcolor{gray}{a_6}, \textcolor{gray}{a_7}\}\}$
stable	$\{\{\textcolor{green}{a_1}, \textcolor{red}{a_2}, \textcolor{red}{a_3}, \textcolor{green}{a_4}, \textcolor{red}{a_5}, \textcolor{green}{a_6}, \textcolor{red}{a_7}\}\}$
preferred	$\{\{\textcolor{green}{a_1}, \textcolor{red}{a_2}, \textcolor{red}{a_3}, \textcolor{green}{a_4}, \textcolor{red}{a_5}, \textcolor{green}{a_6}, \textcolor{red}{a_7}\}, \{\textcolor{green}{a_1}, \textcolor{red}{a_2}, \textcolor{green}{a_3}, \textcolor{red}{a_4}, \textcolor{gray}{a_5}, \textcolor{gray}{a_6}, \textcolor{gray}{a_7}\}\}$
complete	$\{\{\textcolor{green}{a_1}, \textcolor{red}{a_2}, \textcolor{red}{a_3}, \textcolor{green}{a_4}, \textcolor{red}{a_5}, \textcolor{green}{a_6}, \textcolor{red}{a_7}\}, \{\textcolor{green}{a_1}, \textcolor{red}{a_2}, \textcolor{green}{a_3}, \textcolor{red}{a_4}, \textcolor{gray}{a_5}, \textcolor{gray}{a_6}, \textcolor{gray}{a_7}\},$
	$\{\textcolor{green}{a_1}, \textcolor{red}{a_2}, \textcolor{gray}{a_3}, \textcolor{gray}{a_3}, \textcolor{gray}{a_5}, \textcolor{gray}{a_6}, \textcolor{gray}{a_7}\}\}$

PyArg

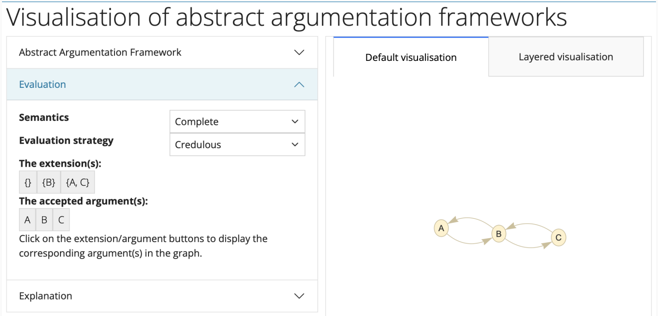
https://pyarg.npai.science.uu.nl



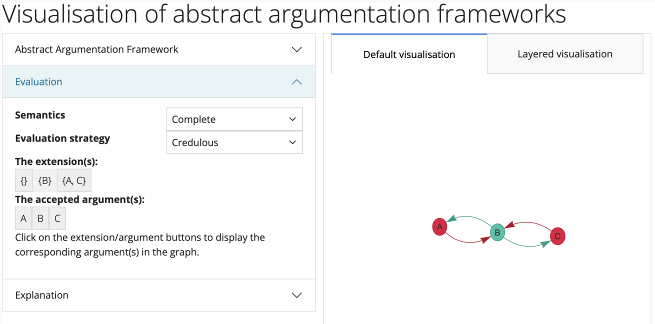
PyArg: Visualisation



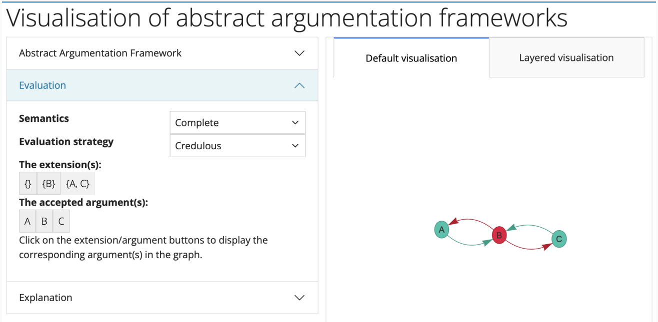
PyArg: Evaluation



PyArg: Evaluation (2)



PyArg: Evaluation (3)



Computational Complexity

- Reasoning with AFs is generally hard

Problem	Grounded	Stable	Preferred	Complete
σ-Exist	Trivial	NP-c	Trivial	Trivial
σ-Exist^{NT}	L	NP-c	NP-c	NP-c
σ-Verif	P-c	L	coNP-c	L
σ-Cred	P-c	NP-c	NP-c	NP-c
σ-Skep	P-c	coNP-c	Π_2^P-c	P-c

- σ-Exist: Given F, is $\sigma(F) \neq \emptyset$?
- σ-Exist^{NT}: Given F, is $\sigma(F) \neq \emptyset$ s.t. F has at least one non-empty extension?
- σ-Verif: Given F and S, is $S \in \sigma(F)$?
- σ-Cred: Given F and a, is $a \in cred_\sigma(F)$?
- σ-Skep: Given F and a, is $a \in skep_\sigma(F)$?

W. Dvorák, P. E.Dunne: Computational Problems in Formal Argumentation and their Complexity. Handbook of Formal Argumentation: 631–688 (2018)

Propositional Encoding of Semantics

Approach proposed in (Besnard and Doutre 04). Intuition:

- Encoding arguments' acceptance in Boolean variables
- Define a formula such that each model corresponds to an extension

Propositional Encoding of Semantics

Approach proposed in (Besnard and Doutre 04). Intuition:

- Encoding arguments' acceptance in Boolean variables
- Define a formula such that each model corresponds to an extension

Logical Encoding of Stable Semantics

For $F = \langle A, R \rangle$, $S \subseteq A$ is a stable extension of F iff S is a model of

$$\phi_{st}(F) = \bigwedge_{a \in A} (a \leftrightarrow \bigwedge_{(b,a) \in R} \neg b)$$

Similar encodings exist for conflict-freeness, admissibility and the complete semantics.

P. Besnard, S. Doutre: Checking the acceptability of a set of arguments. NMR 2004: 59-64

SAT-based Algorithms

- For $\sigma \in \{cf, ad, co, st\}$, $\text{mod}(\phi_\sigma(F)) = \sigma(F)$
  - Compute one/each extension = compute one/each model
  - Decide the credulous acceptability of a = check if $\phi_\sigma(F) \wedge a$ is SAT
  - Decide the skeptical acceptability of a = check if $\phi_\sigma(F) \wedge \neg a$ is UNSAT
- For $\sigma = gr$, computation is polynomial (can be done with unit propagation over $\phi_{co}(F)$)
- For $\sigma = pr$, need to use other techniques, e.g. CEGAR or MSS extraction

ICCMA and SAT-based Software

- Since 2015, the International Competition on Computational Models of Argumentation (ICCMA) evaluates the best solvers for argumentation problems
  - `https://argumentationcompetition.org`
  - Many available solvers
- μ-toskia: in C++
  - Winner of ICCMA 2019
  - `https://bitbucket.org/andreasniskanen/mu-toksia/src/master/`
- Crustabri: in Rust
  - Winner of several tracks at ICCMA 2023 (9 sub-tracks over 13 in the main track, and 3 sub-tracks over 3 in the dynamic track)
  - `https://www.cril.univ-artois.fr/software/crustabri/`
- pygarg : not an ICCMA solver, open-source Python implementation of the SAT-based algorithms from Crustabri
  - `pip install pygarg`
  - `https://github.com/jgmailly/pygarg`

Andreas Niskanen, Matti Järvisalo: μ-toksia: An Efficient Abstract Argumentation Reasoner. KR 2020: 800-804

J.-M. Lagniez, E. Lonca, J.-G. Mailly: A SAT-based Approach for Argumentation Dynamics. AAMAS 2024

J.-G. Mailly: pygarg: A Python engine for argumentation. Argument. Comput. 2024

If you like challenges, ICCMA 2025 will be announced soon (Sep. 17th, during SAFA 2024), and participation is open to everyone :)

`http://safa2024.argumentationcompetition.org`
`https://argumentationcompetition.org/2025/index.html`

Using Pygarg (1)

- Remember: installation with `pip install pygarg`

Parsers for standard file formats are provided

```
import pygarg.dung.apx_parser
import pygarg.dung.dimacs_parser

args, atts = pygarg.dung.apx_parser.parse("test.apx")
args2, atts2 = pygarg.dung.dimacs_parser.parse("test.dimacs")
```


```
p af 2
1 2
```

```
arg(a1).
arg(a2).
att(a1,a2).
```

You can also declare the list of arguments and the list of attacks directly:

```
args3 = ["a1", "a2"]
atts3 = [["a1", "a2"]]
```

Using Pygarg (2)

All interesting functions are in `pygarg.dung.solver`

- `credulous_acceptability(args, atts, argname, sem)`
- `skeptical_acceptability(args, atts, argname, sem)`
- `compute_some_extension(args, atts, sem)`
- `extension_enumeration(args, atts, sem)`
- `extension_counting(args, atts, sem)`

where sem is in `[‘CF’, ‘AD’, ‘ST’, ‘CO’, ‘PR’, ‘GR’, ‘ID’, ‘SST’]`
Example:

```
from pygarg.dung import solver as solver
from pygarg.dung import apx_parser as parser

args, atts = parser.parse("test.apx")
print(solver.extension_enumeration(args, atts, 'CO'))
```

prints `[['a1']]`

Two Aspects of Argumentation Dynamics

- Dynamic re-computation when an update occurs: when some arguments/attacks are added/deleted, can we re-compute the acceptability of arguments without running (naively) algorithms from scratch?

$$\left.\begin{array}{c} F = \langle A, R \rangle \\ \text{Acceptability of } a \in A \\ \text{New argument } x \\ \text{and attacks } R' \text{ from } x \end{array}\right\} \implies \text{Acceptability of } a \text{ in } F' = \langle A \cup \{x\}, R \cup R' \rangle$$

Two Aspects of Argumentation Dynamics

- Dynamic re-computation when an update occurs: when some arguments/attacks are added/deleted, can we re-compute the acceptability of arguments without running (naively) algorithms from scratch?

$$\left.\begin{array}{c} F = \langle A, R \rangle \\ \text{Acceptability of } a \in A \\ \text{New argument } x \\ \text{and attacks } R' \text{ from } x \end{array}\right\} \implies \text{Acceptability of } a \text{ in } F' = \langle A \cup \{x\}, R \cup R' \rangle$$

- Belief change/strategic aspect: How to change (minimally?) an AF in order to satisfy some property (e.g. regarding arguments acceptability)

$$\left.\begin{array}{c} F = \langle A, R \rangle \\ \text{Constraint} \end{array}\right\} \implies F' = \langle A', R' \rangle \text{ which satisfies the constraint}$$

Two main approaches

- When an AF is updated (addition/deletion of arguments/attacks), can we re-compute the acceptability of arguments without re-starting from scratch?
- Two approaches in the literature:
    - Identify the part of the graph which is impacted by the update, and re-compute only for this (smaller) part
    - Use incremental SAT solving to keep track of what the SAT solver has learnt in previous computation steps

$$\left.\begin{array}{c} F = \langle A, R \rangle \\ \text{Acceptability of } a \in A \\ \text{New argument } x \\ \text{and attacks } R' \text{ from } x \end{array}\right\} \implies \text{Acceptability of } a \text{ in } F' = \langle A \cup \{x\}, R \cup R' \rangle$$

Input:

- AF $F_0 = \langle A_0, R_0 \rangle$
- Attack update $u = \star(a, b)$, $\star \in \{+, -\}$
- Semantics σ
- Extension $E_0 \in \sigma(F_0)$

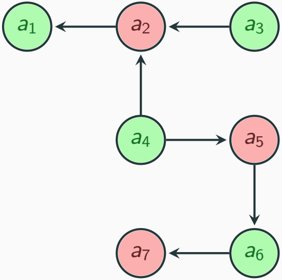
Functions used:

- $I(u, A_0, E_0)$ returns the set of arguments influenced by the update
- $R(U, A_0, E_0)$ returns the reduced AF
- $solve_\sigma(F)$ returns a σ-extension of an AF F if it exists, $\perp$ otherwise

$S = I(u, A_0, E_0)$
if $S = \emptyset$ **then**
  return E_0
else
  $F_1 = R(u, A_0, E_0)$
  $E_1 = solve_\sigma(F_1)$
  if $E_1 \neq \perp$ **then**
    return $(E_0 \setminus S) \cup E_1$
  else
    return $solve_\sigma(u(A_0))$
  end if
end if

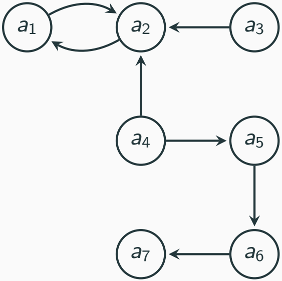
Gianvincenzo Alfano, Sergio Greco, Francesco Parisi: Efficient Computation of Extensions for Dynamic Abstract Argumentation Frameworks: An Incremental Approach. IJCAI 2017: 49-55

The Subgraph-based Approach: Example



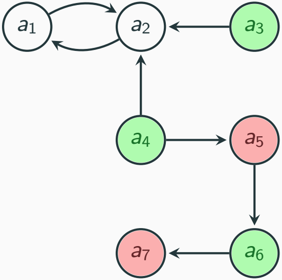
- $F_0 = \langle A, R \rangle$, $\sigma = st$, $E_0 = \{a_1, a_3, a_4, a_6\}$

The Subgraph-based Approach: Example



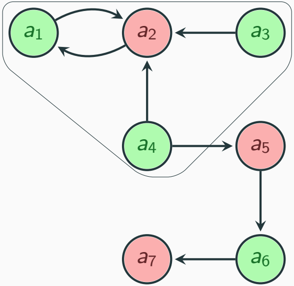
- $F_0 = \langle A, R \rangle$, $\sigma = st$,
  $E_0 = \{a_1, a_3, a_4, a_6\}$
- $u = +(a_1, a_2)$

The Subgraph-based Approach: Example



- $F_0 = \langle A, R \rangle$, $\sigma = st$, $E_0 = \{a_1, a_3, a_4, a_6\}$
- $u = +(a_1, a_2)$
- Influenced set $I(u, A_0, E_0) = \{a_1, a_2\}$

The Subgraph-based Approach: Example



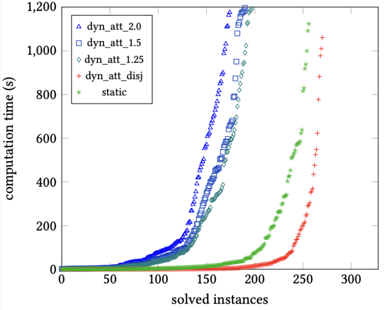
- $F_0 = \langle A, R \rangle$, $\sigma = st$,
  $E_0 = \{a_1, a_3, a_4, a_6\}$
- $u = +(a_1, a_2)$
- Influenced set
  $I(u, A_0, E_0) = \{a_1, a_2\}$
- Re-computation is localized to a smaller graph $R(U, A_0, E_0)$

The Subgraph-based Approach: Other Work

- In structured argumentation: Gianvincenzo Alfano, Sergio Greco, Francesco Parisi, Gerardo Ignacio Simari, Guillermo Ricardo Simari: An Incremental Approach to Structured Argumentation over Dynamic Knowledge Bases. KR 2018: 78-87
- In bipolar AFs: Gianvincenzo Alfano, Sergio Greco, Francesco Parisi: A meta-argumentation approach for the efficient computation of stable and preferred extensions in dynamic bipolar argumentation frameworks. Intelligenza Artificiale 12(2): 193-211 (2018)
- For arguments skeptical acceptability: Gianvincenzo Alfano, Sergio Greco, Francesco Parisi: An Efficient Algorithm for Skeptical Preferred Acceptance in Dynamic Argumentation Frameworks. IJCAI 2019: 18-24
- In higher-order bipolar AFs: Gianvincenzo Alfano, Andrea Cohen, Sebastian Gottifredi, Sergio Greco, Francesco Parisi, Guillermo Ricardo Simari: Credulous acceptance in high-order argumentation frameworks with necessities: An incremental approach. Artif. Intell. 333: 104159 (2024)

Incremental SAT-based Computation

- Incremental SAT-based approach implemented in Crustabri, won all sub-tracks of the dynamic track at ICCMA 2023
- Idea: use the assumption mechanism of SAT solvers over variables representing the disjunction of attackers. Allows to easily update the set of attacks and the set of arguments



(a) Results for the DC-CO track

- Red: Crustabri approach
- Green: re-computation from scratch
- Blue: various versions of μ-toksia approach

- Future work: combine our approach with "subgraph-based" approach

J.-M. Lagniez, E. Lonca, J.-G. Mailly: A SAT-based Approach for Argumentation Dynamics. AAMAS 2024

Outline

Extension Enforcement: Intuition

$$\left.\begin{array}{c} F = \langle A, R \rangle \\ E \subseteq A \\ \text{should be (part of)} \\ \text{an extension} \end{array}\right\} \Longrightarrow \begin{array}{c} F' = \langle A', R' \rangle \text{ with } E \\ \text{(part of) an extension} \end{array}$$

Different approaches

- (Baumann and Brewka) No change of the existing attacks, new arguments and attacks can be added
- (Coste-Marquis et al) The existing attacks can be modified
- (Doutre and Mailly) The semantics can be modified

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

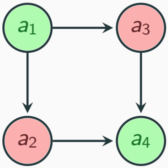
S. Coste-Marquis, S. Konieczny, J.-G. Mailly, P. Marquis: Extension Enforcement in Abstract Argumentation as an Optimization Problem. IJCAI 2015: 2876-2882

S. Doutre, J.-G. Mailly: Semantic Change and Extension Enforcement in Abstract Argumentation. SUM 2017: 194-207

Example of Strong Enforcement

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

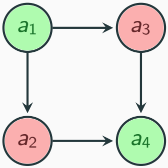
- How to enforce $E = \{a_2, a_3\}$ in F?

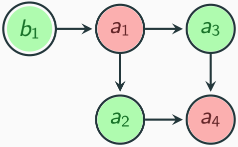


Example of Strong Enforcement

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

- How to enforce $E = \{a_2, a_3\}$ in F?

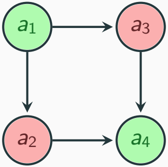




Example of Argument-fixed Enforcement

S. Coste-Marquis, S. Konieczny, J.-G. Mailly, P. Marquis: Extension Enforcement in Abstract Argumentation as an Optimization Problem. IJCAI 2015: 2876-2882

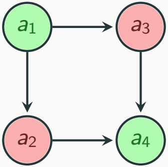
- How to enforce $E = \{a_2, a_3\}$ in F?



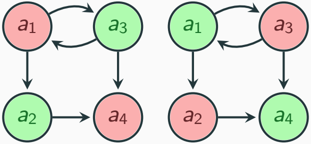
Example of Argument-fixed Enforcement

S. Coste-Marquis, S. Konieczny, J.-G. Mailly, P. Marquis: Extension Enforcement in Abstract Argumentation as an Optimization Problem. IJCAI 2015: 2876-2882

- How to enforce $E = \{a_2, a_3\}$ in F?



Two extensions:



Enforcement as SAT

- Example: stable semantics
- Idea: generalize the propositional encoding to take into account the attack relation

$$\phi_{st}(F) = \bigwedge_{a \in A}(a \leftrightarrow \bigwedge_{(b,a) \in R} \neg b)$$

$$\phi'_{st}(A) = \bigwedge_{a \in A}(acc_a \leftrightarrow \bigwedge_{b \in A}(att_{b,a} \rightarrow \neg acc_b))$$

S. Coste-Marquis, S. Konieczny, J.-G. Mailly, P. Marquis: Extension Enforcement in Abstract Argumentation as an Optimization Problem. IJCAI 2015: 2876-2882

Enforcement as SAT

- Example: stable semantics
- Idea: generalize the propositional encoding to take into account the attack relation

$$\phi_{st}(F) = \bigwedge_{a \in A}(a \leftrightarrow \bigwedge_{(b,a) \in R} \neg b) \qquad \Bigg| \qquad \phi'_{st}(A) = \bigwedge_{a \in A}(acc_a \leftrightarrow \bigwedge_{b \in A}(att_{b,a} \rightarrow \neg acc_b))$$

- If $F = \langle A, R \rangle$ is known, $\phi'_{st}(A) \wedge \bigwedge_{(a,b) \in R} att_{a,b} \wedge \bigwedge_{(a,b) \notin R} \neg att_{a,b}$ corresponds to $\phi_{st}(F)$

S. Coste-Marquis, S. Konieczny, J.-G. Mailly, P. Marquis: Extension Enforcement in Abstract Argumentation as an Optimization Problem. IJCAI 2015: 2876-2882

Enforcement as SAT

- Example: stable semantics
- Idea: generalize the propositional encoding to take into account the attack relation

$$\phi_{st}(F) = \bigwedge_{a \in A} (a \leftrightarrow \bigwedge_{(b,a) \in R} \neg b) \qquad \Bigg| \qquad \phi'_{st}(A) = \bigwedge_{a \in A} (acc_a \leftrightarrow \bigwedge_{b \in A} (att_{b,a} \rightarrow \neg acc_b))$$

- If $F = \langle A, R \rangle$ is known, $\phi'_{st}(A) \wedge \bigwedge_{(a,b) \in R} att_{a,b} \wedge \bigwedge_{(a,b) \notin R} \neg att_{a,b}$ corresponds to $\phi_{st}(F)$
- To enforce, $E \subseteq A$, search a model of $\phi'_{st}(A) \wedge \bigwedge_{a \in E} acc_a \wedge \bigwedge_{a \notin E} \neg acc_a$: the values of the $att_{a,b}$ variables correspond to an AF

S. Coste-Marquis, S. Konieczny, J.-G. Mailly, P. Marquis: Extension Enforcement in Abstract Argumentation as an Optimization Problem. IJCAI 2015: 2876-2882

Minimal Enforcement as PB and MaxSAT

$$\left.\begin{array}{c} F = \langle A, R \rangle \\ E \subseteq A \\ \text{should be (part of)} \\ \text{an extension} \end{array}\right\} \implies \begin{array}{c} F' = \langle A', R' \rangle \text{ with } E \\ \text{(part of) an extension and} \\ F' \text{ as close as possible to } F \end{array}$$

Minimal Enforcement as PB and MaxSAT

$$\left.\begin{array}{c} F = \langle A, R\rangle \\ E \subseteq A \\ \text{should be (part of)} \\ \text{an extension} \end{array}\right\} \implies \begin{array}{c} F' = \langle A', R'\rangle \text{ with } E \\ \text{(part of) an extension and} \\ F' \text{ as close as possible to } F \end{array}$$

- (Coste-Marquis et al) translate the SAT encoding in pseudo-Boolean constraints, optimize w.r.t. an objective function (distance between F and F')

S. Coste-Marquis, S. Konieczny, J.-G. Mailly, P. Marquis: Extension Enforcement in Abstract Argumentation as an Optimization Problem. IJCAI 2015: 2876-2882

Minimal Enforcement as PB and MaxSAT

$$\left.\begin{array}{c} F = \langle A, R\rangle \\ E \subseteq A \\ \text{should be (part of)} \\ \text{an extension} \end{array}\right\} \Longrightarrow \begin{array}{c} F' = \langle A', R'\rangle \text{ with } E \\ \text{(part of) an extension and} \\ F' \text{ as close as possible to } F \end{array}$$

- (Coste-Marquis et al) translate the SAT encoding in pseudo-Boolean constraints, optimize w.r.t. an objective function (distance between F and F')
- (Wallner et al) translate into partial MaxSAT: the SAT encoding of enforcement corresponds to hard clauses, and unit clauses corresponding to the $att_{a,b}$ variables correspond to the soft clauses. CEGAR algorithm for second level of the polynomial hierarchy
    - Available software: `https://bitbucket.org/andreasniskanen/pakota/src/master/`
- Scalability: up to 350 arguments for NP-complete problems, 200 arguments for Σ_2^P-complete problems ($\simeq$ 10 seconds for most instances)

S. Coste-Marquis, S. Konieczny, J.-G. Mailly, P. Marquis: Extension Enforcement in Abstract Argumentation as an Optimization Problem. IJCAI 2015: 2876-2882

J. P. Wallner, A. Niskanen, M. Järvisalo: Complexity Results and Algorithms for Extension Enforcement in Abstract Argumentation. J. Artif. Intell. Res. 60: 1-40 (2017)

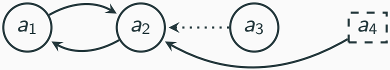
Incomplete Argumentation Framework (IAF)

$I = \langle A, A^?, R, R^? \rangle$ where

- $A, A^?$ are disjoint sets of arguments
- $R, R^?$ are disjoint sets of attacks over $A \cup A^?$

such that

- A, R are certain arguments and attacks
- $A^?, R^?$ are uncertain arguments and attacks



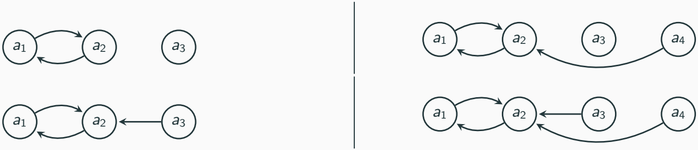
J.-G. Mailly: Yes, no, maybe, I don't know: Complexity and application of abstract argumentation with incomplete knowledge. Argument Comput. 13(3): 291-324 (2022)

Completions of an IAF

Completions $=$ AFs compatible with the incomplete knowledge encoded in the IAF
$\simeq$ possible worlds

Possible and Necessary Reasoning

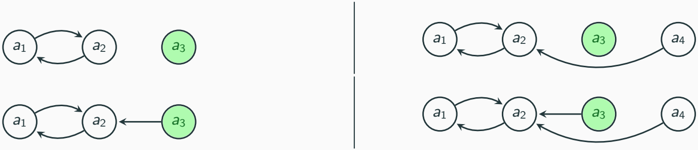
- Possible reasoning: some property is true for some completion of the IAF
- Necessary reasoning: some property is true for each completion of the IAF



D. Baumeister, M. Järvisalo, D. Neugebauer, A. Niskanen, J. Rothe: Acceptance in incomplete argumentation frameworks. Artif. Intell. 295: 103470 (2021)

Possible and Necessary Reasoning

- Possible reasoning: some property is true for some completion of the IAF
- Necessary reasoning: some property is true for each completion of the IAF

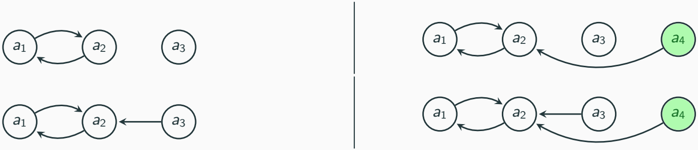


- a_3 is skeptically accepted in each completion $\rightarrow$ necessarily skeptically accepted

D. Baumeister, M. Järvisalo, D. Neugebauer, A. Niskanen, J. Rothe: Acceptance in incomplete argumentation frameworks. Artif. Intell. 295: 103470 (2021)

Possible and Necessary Reasoning

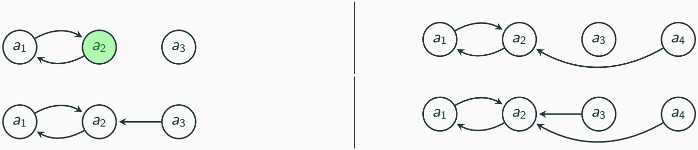
- Possible reasoning: some property is true for some completion of the IAF
- Necessary reasoning: some property is true for each completion of the IAF



- a_3 is skeptically accepted in each completion $\rightarrow$ necessarily skeptically accepted
- a_4 is skeptically accepted in some completion $\rightarrow$ possibly skeptically accepted

D. Baumeister, M. Järvisalo, D. Neugebauer, A. Niskanen, J. Rothe: Acceptance in incomplete argumentation frameworks. Artif. Intell. 295: 103470 (2021)

- Possible reasoning: some property is true for some completion of the IAF
- Necessary reasoning: some property is true for each completion of the IAF

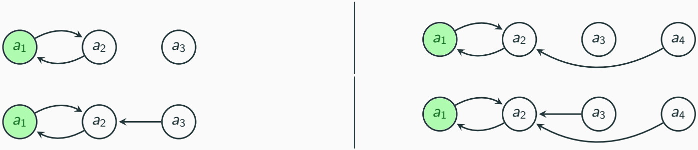


- a_3 is skeptically accepted in each completion $\rightarrow$ necessarily skeptically accepted
- a_4 is skeptically accepted in some completion $\rightarrow$ possibly skeptically accepted
- a_2 is credulously accepted in some completion $\rightarrow$ possibly credulously accepted

D. Baumeister, M. Järvisalo, D. Neugebauer, A. Niskanen, J. Rothe: Acceptance in incomplete argumentation frameworks. Artif. Intell. 295: 103470 (2021)

Possible and Necessary Reasoning

- Possible reasoning: some property is true for some completion of the IAF
- Necessary reasoning: some property is true for each completion of the IAF



- a_3 is skeptically accepted in each completion $\rightarrow$ necessarily skeptically accepted
- a_4 is skeptically accepted in some completion $\rightarrow$ possibly skeptically accepted
- a_2 is credulously accepted in some completion $\rightarrow$ possibly credulously accepted
- a_1 is credulously accepted in each completion $\rightarrow$ necessarily credulously accepted

D. Baumeister, M. Järvisalo, D. Neugebauer, A. Niskanen, J. Rothe: Acceptance in incomplete argumentation frameworks. Artif. Intell. 295: 103470 (2021)

Complexity of Reasoning with IAFs

- Possible Credulous Acceptability: a is in some extension of some completion
- Possible Skeptical Acceptability: a is in each extension of some completion
- Possible Verification: S is an extension of some completion
- Necessary Credulous Acceptability: a is in some extension of each completion
- Necessary Skeptical Acceptability: a is in each extension of each completion
- Necessary Verification: S is an extension of each completion

Semantics	PCA	PSA	PV	NCA	NSA	NV
ad	NP-c	trivial	NP-c	Π_2^P-c	trivial	P
st	NP-c	Σ_2^P-c	NP-c	Π_2^P-c	coNP-c	P
co	NP-c	NP-c	NP-c	Π_2^P-c	coNP-c	P
gr	NP-c	NP-c	NP-c	coNP-c	coNP-c	P
pr	NP-c	Σ_3^P-c	Σ_2^P-c	Π_2^P-c	Π_2^P-c	coNP-c

- SAT-based algorithms, CEGAR for second/third level of PH

D. Baumeister, M. Järvisalo, D. Neugebauer, A. Niskanen, J. Rothe: Acceptance in incomplete argumentation frameworks. Artif. Intell. 295: 103470 (2021)

Control Argumentation Framework (CAF)

A CAF is an argumentation framework where arguments are divided in three parts: *fixed*, *uncertain* and *control*.

fixed background knowledge about a static environment

uncertain changes that may occur in the environment

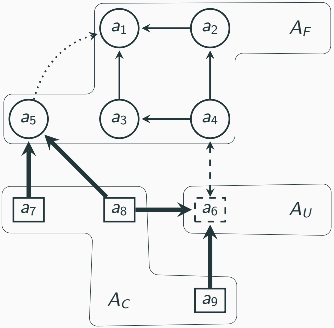
control possible actions of the agent

CAFs generalize IAFs in two directions:

- a new kind of uncertainty about the direction of attacks
- the control part representing how the agent can react to uncertain "threats"

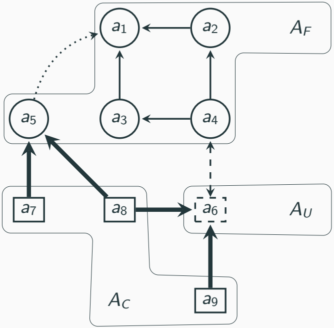
Y. Dimopoulos, J.-G. Mailly, P. Moraitis: Control Argumentation Frameworks. AAAI 2018: 4678-4685

A Picture is Worth a Thousand Words



- Fixed part: circle arguments + plain arrows
- Uncertain part:
  - dashed arguments
  - dotted arrows
  - two-heads dashed arrows
- Control part: square arguments + bold arrows

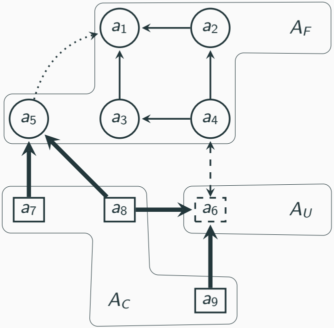
A Picture is Worth a Thousand Words



- certain knowledge: always exist

- Fixed part: circle arguments + plain arrows
- Uncertain part:
  - dashed arguments
  - dotted arrows
  - two-heads dashed arrows
- Control part: square arguments + bold arrows

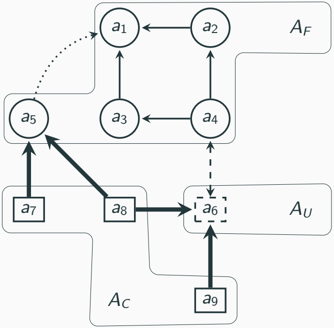
A Picture is Worth a Thousand Words



- the argument could exist, or not

- Fixed part: circle arguments + plain arrows
- Uncertain part:
  - dashed arguments
  - dotted arrows
  - two-heads dashed arrows
- Control part: square arguments + bold arrows

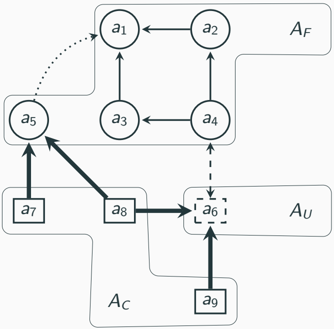
A Picture is Worth a Thousand Words



- the attack could exist, or not

- Fixed part: circle arguments + plain arrows
- Uncertain part:
  - dashed arguments
  - dotted arrows
  - two-heads dashed arrows
- Control part: square arguments + bold arrows

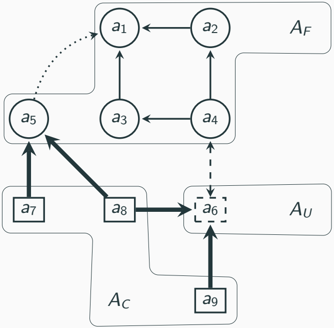
A Picture is Worth a Thousand Words



- Fixed part: circle arguments + plain arrows
- Uncertain part:
  - dashed arguments
  - dotted arrows
  - two-heads dashed arrows
- Control part: square arguments + bold arrows

- the attack exists (if both arguments exist), but we are not sure of the direction

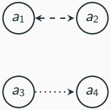
A Picture is Worth a Thousand Words



- Fixed part: circle arguments + plain arrows
- Uncertain part:
  - dashed arguments
  - dotted arrows
  - two-heads dashed arrows
- Control part: square arguments + bold arrows
  - exist only if the agent selects the arguments

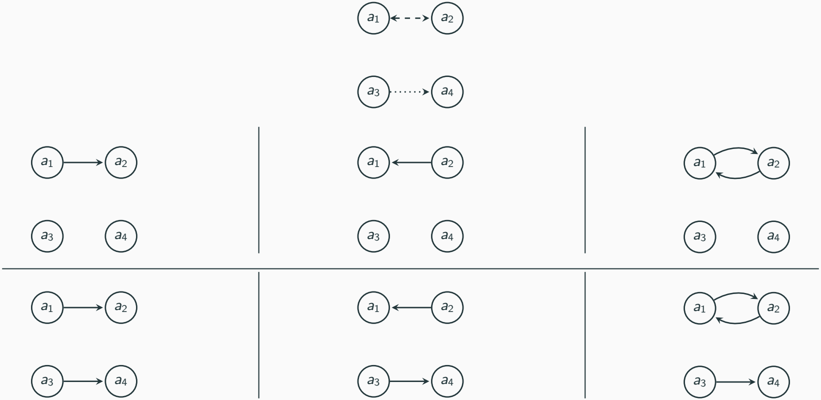
Completion

- Generalizes the notion of completion from IAFs, with 3 possible options for each "unknown direction conflict"



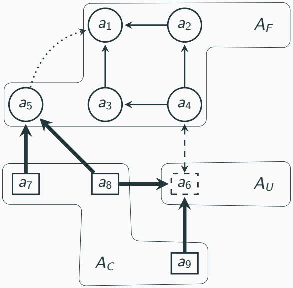
Completion

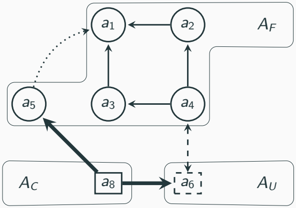
- Generalizes the notion of completion from IAFs, with 3 possible options for each "unknown direction conflict"



Control Configuration

- A control configuration is a subset $cc \subseteq A_C$
- A configured CAF: remove from the initial CAF the arguments $A_C \setminus cc$ (and their attacks)





Example: In the CAF configured by $cc = \{a_8\}$, $T = \{a_1\}$ is accepted whatever the completion

Formal Definition of Controllability

Given

- a target $T \subseteq A_F$
- a semantics σ

CAF is skeptically (resp. credulously) *controllable* w.r.t. T and σ if $\exists cc \subseteq A_C$ s.t.

- CAF' is the result of configuring CAF by cc
- T is included in every (resp. some) σ-extension of every completion of CAF'

Y. Dimopoulos, J.-G. Mailly, P. Moraitis: Control Argumentation Frameworks. AAAI 2018: 4678-4685

Formal Definition of Controllability

Given

- a target $T \subseteq A_F$
- a semantics σ

CAF is skeptically (resp. credulously) *controllable* w.r.t. T and σ if $\exists cc \subseteq A_C$ s.t.

- CAF' is the result of configuring CAF by cc
- T is included in every (resp. some) σ-extension of every completion of CAF'

Y. Dimopoulos, J.-G. Mailly, P. Moraitis: Control Argumentation Frameworks. AAAI 2018: 4678-4685

- Possible controllability: replace "every completion" by "some completion"

J.-G. Mailly: Possible Controllability of Control Argumentation Frameworks. COMMA 2020: 283-294

Complexity and Computation

	Possible		Necessary	
	Skeptical	Credulous	Skeptical	Credulous
Grounded	NP-c	NP-c	Σ_2^P-c	Σ_2^P-c
Complete	NP-c	NP-c	Σ_2^P-c	Σ_3^P-c
Stable	Σ_2^P-c	NP-c	Σ_2^P-c	Σ_3^P-c
Preferred	Σ_3^P-c	NP-c	Σ_3^P-c	Σ_3^P-c

- QBF encodings proposed in (Dimopoulos et al, Mailly)
- CEGAR algorithms proposed in (Niskanen et al)

Y. Dimopoulos, J.-G. Mailly, P. Moraitis: Control Argumentation Frameworks. AAAI 2018: 4678-4685

J.-G. Mailly: Possible Controllability of Control Argumentation Frameworks. COMMA 2020: 283-294

A. Niskanen, D. Neugebauer, M. Järvisalo: Controllability of Control Argumentation Frameworks. IJCAI 2020: 1855-1861

Outline

Automated Negotiation

- Context: several agents have their own knowledge/beliefs, preferences and goals
- Objective: reach an agreement between them (*e.g.* about an action to perform, a product to buy, some allocation of resources/tasks, etc)
- Example:
  - The car sellers knows the different cars and their features, and wants to sell the most expensive one
  - The potential buyer knows his needs (small car, family car, big trunk,. . .) and preferences (color of the car, heating seats,. . .), and wants to buy a car that meets these needs, as cheap as possible

Using Arguments for Negotiating

- Argumentation: activity that aims at increasing (or decreasing) the acceptance degree of a controversial point of view
- Arguments: pieces of information that justify (or defeat) a point of view
- Using argumentation in negotiation improves the chances to reach an agreement (Sycara 1990)
    - An offer supported by a good argument is more likely to be accepted
    - An agent can modify its goals and preferences when he receives arguments

K. Sycara: Persuasive argumentation in negotiation. Theory and Decision 28(3):203-242, 1990.

CAFs and Automated Negotiation

- If available, opponent modeling is a great tool to improve the issue of negotiation
  - possibility to choose offers/arguments that the opponent is likely to accept
  - anticipate what he will say
  - use his own arguments to convince him
- CAFs are a good way to model the knowledge of an agent about the other agent
  - Fixed part: certain knowledge about the opponent
  - Uncertain part: uncertain knowledge about the opponent
  - Control part: possible actions of the agent to convince the opponent

Y. Dimopoulos, J.-G. Mailly, Pavlos Moraitis: Arguing and negotiating using incomplete negotiators profiles. Auton. Agents Multi Agent Syst. 35(2): 18 (2021)

Protocol Summary

- No fixed role: both agent act as proponent and opponent in turn
- Each agent has a (incomplete and uncertain) representation of its opponent's theory: fixed and uncertain part of the CAF
- In the CAF, control arguments come from the agent's own theory: persuasive arguments
- The proponent selects the best offer w.r.t. his own theory, but uses arguments from the opponent's theory to defend the offer $\rightarrow$ facilitates persuasion

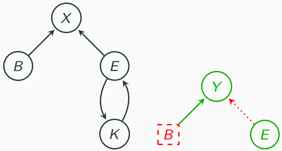
Y. Dimopoulos, J.-G. Mailly, Pavlos Moraitis: Arguing and negotiating using incomplete negotiators profiles. Auton. Agents Multi Agent Syst. 35(2): 18 (2021)

Negotiation theory of an agent α: $\mathcal{T} = \langle \mathcal{O}, \mathcal{T}^{\alpha}, \mathcal{C}^{\alpha,\beta}, \mathcal{F}^{\alpha} \rangle$ with

- $\mathcal{O}$: set of offers
  - Can be "simple" objects (mono-issue negotiation): $\{\mathit{car}_1, \mathit{car}_2, \ldots, \mathit{car}_n\}$
  - Or "complex" objects (multi-issue negotiation): $\{(\mathit{car}_1, \mathit{price}_1, \mathit{delivery}_1), \ldots, (\mathit{car}_n, \mathit{price}_m, \mathit{delivery}_k)\}$
- $\mathcal{T}^{\alpha}$: the agent's AF
- $\mathcal{C}^{\alpha,\beta}$: the knowledge of α about his opponent β
  - $\mathcal{C}^{\alpha,\beta}$ is made from $\mathcal{T}^{\beta}$: there is uncertainty, there is ignorance, but there is no mistake or lie
- $\mathcal{F}^{\alpha} : \mathcal{O} \rightarrow 2^{{A_p}^{\alpha}}$ maps offers to the set of practical arguments supporting them

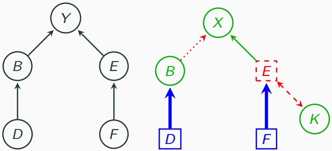
Example of Negotiation Theories

Agent α: X supports O



(a) $\mathcal{T}^{\alpha}$ **(b)** $\mathcal{C}^{\alpha,\beta}$

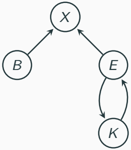
Agent β: Y supports O



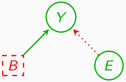
(c) $\mathcal{T}^{\beta}$ **(d)** $\mathcal{C}^{\beta,\alpha}$

Bidding Strategy

Agent α: X supports O

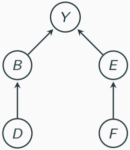


(a) $\mathcal{T}^{\alpha}$

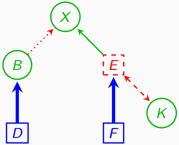


(b) $\mathcal{C}^{\alpha,\beta}$

Agent β: Y supports O



(c) $\mathcal{T}^{\beta}$

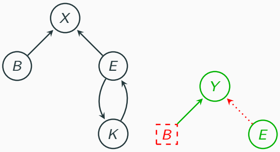


(d) $\mathcal{C}^{\beta,\alpha}$

α's turn: X is not accepted in $\mathcal{T}^{\alpha}$, so α cannot support the (unique) offer O $\rightarrow$ the token goes to β

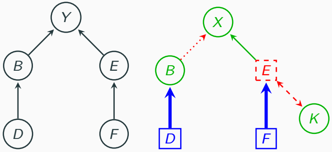
Bidding Strategy

Agent α: X supports O



(a) $\mathcal{T}^{\alpha}$ **(b)** $\mathcal{C}^{\alpha,\beta}$

Agent β: Y supports O

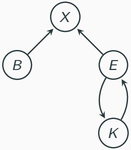


(c) $\mathcal{T}^{\beta}$ **(d)** $\mathcal{C}^{\beta,\alpha}$

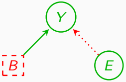
β's turn: best offer according to β's personnal AF is O because the supporting argument Y is accepted in $\mathcal{T}^{\beta}$

Bidding Strategy

Agent α: X supports O

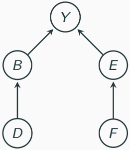


(a) $\mathcal{T}^{\alpha}$

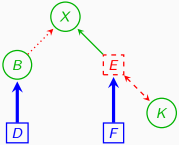


(b) $\mathcal{C}^{\alpha,\beta}$

Agent β: Y supports O



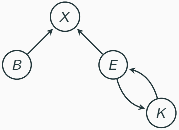
(c) $\mathcal{T}^{\beta}$



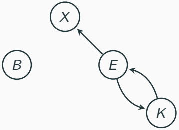
(d) $\mathcal{C}^{\beta,\alpha}$

β's turn: support argument for O in α's theory is X

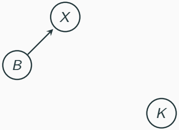
β's Proposal without Control



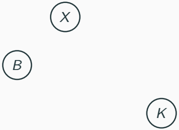
(a) Completion 1



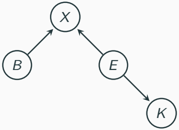
(b) Completion 2



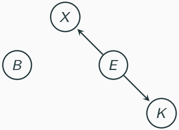
(c) Completion 3



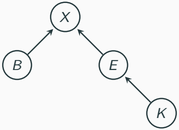
(d) Completion 4



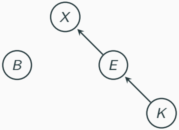
(e) Completion 5



(f) Completion 6



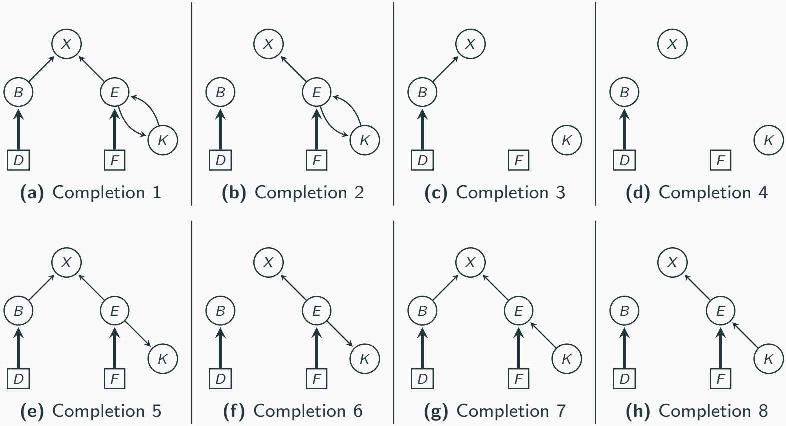
(g) Completion 7



(h) Completion 8

- X is not accepted in each completion (*e.g.* Completion 1)

β's Proposal with Control

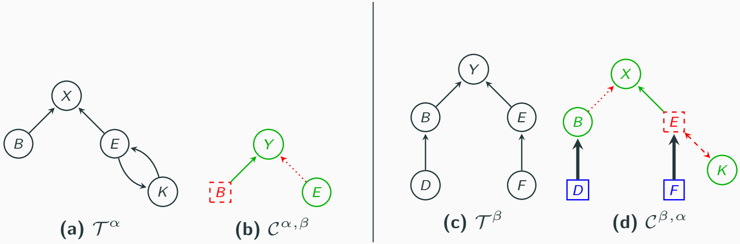


(a) Completion 1 **(b)** Completion 2 **(c)** Completion 3 **(d)** Completion 4

(e) Completion 5 **(f)** Completion 6 **(g)** Completion 7 **(h)** Completion 8

- X is accepted in each completion

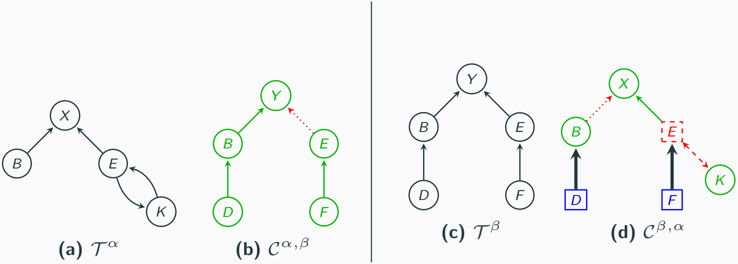
Acceptance Strategy



(a) $\mathcal{T}^{\alpha}$ **(b)** $\mathcal{C}^{\alpha,\beta}$ **(c)** $\mathcal{T}^{\beta}$ **(d)** $\mathcal{C}^{\beta,\alpha}$

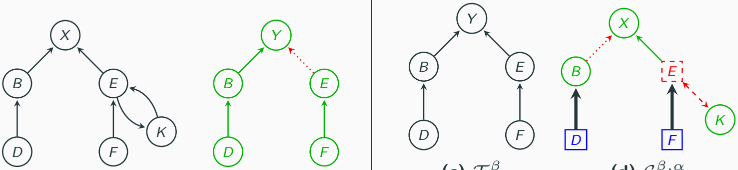
β's turn: proposal is offer O, supported by argument X, defended by D and F

Acceptance Strategy



(a) $\mathcal{T}^{\alpha}$ **(b)** $\mathcal{C}^{\alpha,\beta}$ **(c)** $\mathcal{T}^{\beta}$ **(d)** $\mathcal{C}^{\beta,\alpha}$

α updates its CAF: uncertainty decreases



(a) $\mathcal{T}^{\alpha}$ **(b)** $\mathcal{C}^{\alpha,\beta}$ **(c)** $\mathcal{T}^{\beta}$ **(d)** $\mathcal{C}^{\beta,\alpha}$

α updates its own theory. X is now accepted: **agreement**

Negotiation Outcome

- If both agents end with no available offer, then the negotiation fails
- Otherwise, the outcome of the negotiation is the proponent's offer from the last round of the dialogue
- Experiments have shown the interest of using CAFs: better agreement rate if agents have enough information on their opponent and enough control arguments

Outline

Conclusion

Summary

- Argument-based reasoning is computationally hard, but can be solved thanks to SAT-based techniques and various algorithmic tricks (*e.g.* subgraph selection in dynamic argumentation)
- Argumentation under uncertainty/in dynamics scenarios has theoretical interest, and practical interest (e.g. automated negotiation)

Future work

- Multi-issue negotiation: how can agent make concessions?
  - Work in progress with a PhD student
- Richer frameworks (supports, collective attacks, weighted, higher order relations, etc)
- Other kinds of semantics (ranking, gradual)
- Real world applications (e.g. online dispute resolution)

Conclusion

Summary

- Argument-based reasoning is computationally hard, but can be solved thanks to SAT-based techniques and various algorithmic tricks (*e.g.* subgraph selection in dynamic argumentation)
- Argumentation under uncertainty/in dynamics scenarios has theoretical interest, and practical interest (e.g. automated negotiation)

Future work

- Multi-issue negotiation: how can agent make concessions?
  - Work in progress with a PhD student
- Richer frameworks (supports, collective attacks, weighted, higher order relations, etc)
- Other kinds of semantics (ranking, gradual)
- Real world applications (e.g. online dispute resolution)

Thanks for your attention!