Abstract argumentation semantics: from principles to design

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Dung's framework is (almost) nothing

Definition 2. An *argumentation framework* is a pair

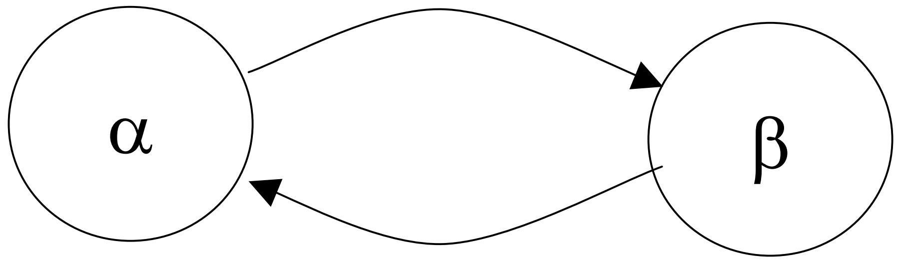
$$AF = \langle AR, attacks \rangle$$

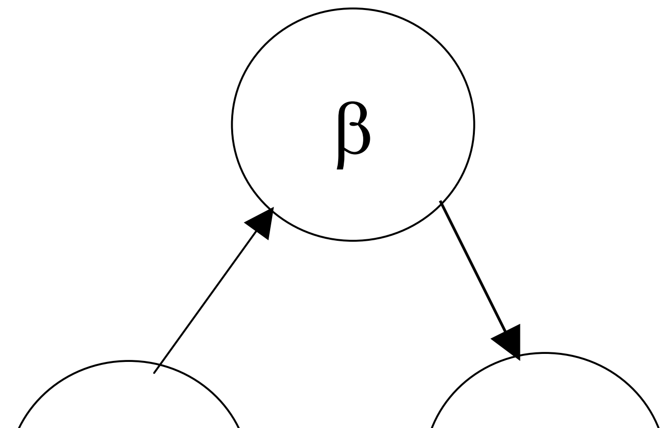
where AR is a set of arguments, and *attacks* is a binary relation on AR, i.e. $attacks \subseteq AR \times AR$.

- A directed graph (called *defeat graph*) where:
  - » arcs are interpreted as attacks
  - » nodes are called arguments "by chance" (let say historical reasons)

Here, an argument is an abstract entity whose role is solely determined by its relations to other arguments. No special attention is paid to the internal structure of the arguments.

Dung's framework is (almost) nothing





Dung's framework is (almost) nothing

- Risk of rediscovering graph-theoretical results under new names and/or in specialized versions
- Too poor to be actually useful?
- Several extensions have been considered to enhance its expressiveness:
  - » Value-based argumentation frameworks
  - » Preference-based argumentation frameworks
  - » Bipolar argumentation frameworks

Dung's framework is (almost) everything

- Conflicts are everywhere
- Conflict management is a fundamental need with potential spectacular/miserable failures both in real life and in formal contexts (e.g. in classical logic)
- A general abstract framework centered on conflicts has a wide range of potential applications

Dung's framework is (almost) everything

- The pervasiveness of Dung's framework and semantics is witnessed by the correspondences drawn in the original paper with a variety of other formal contexts:
  - » default logic
  - » logic programming with negation as failure
  - » defeasible reasoning
  - » N-person games
  - » stable-marriage problem
- Many extensions and variations of Dung's framework allow a translation procedure back to the original framework to exploit its basic features

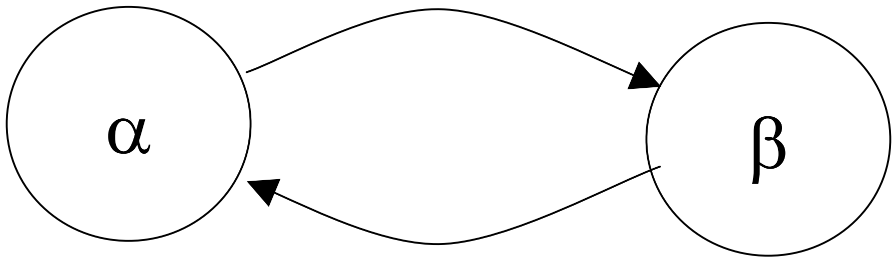
Abstract argumentation semantics

- A way to identify sets of arguments “surviving the conflict together” given the conflict relation only
- In general, several choices of sets of “surviving arguments” are possible
- Two main styles for semantics definition: extension-based and labelling-based

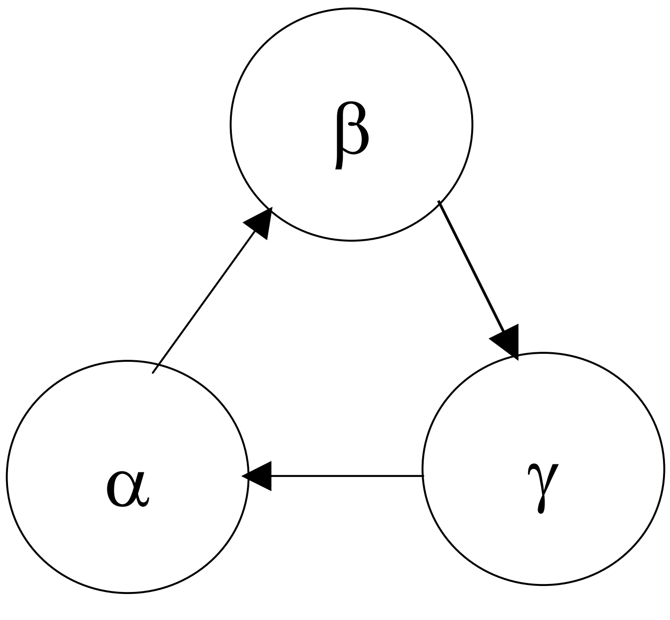
Extension-based semantics

- A set of extensions is identified
- Each extension is a set of arguments which can “survive together” or are “collectively acceptable” i.e. represent a reasonable viewpoint
- The justification status of each argument can be defined on the basis of its extension membership

Sets of extensions



E = {{α},{β}}

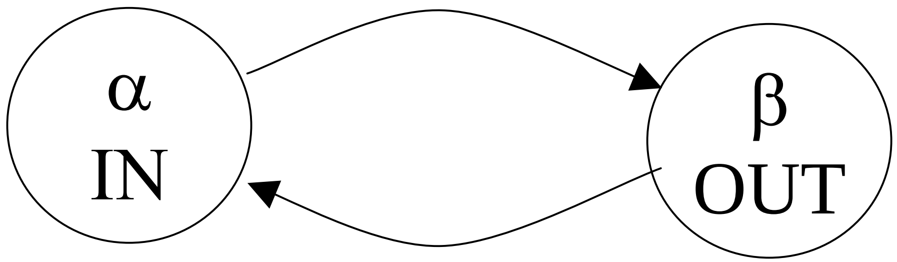


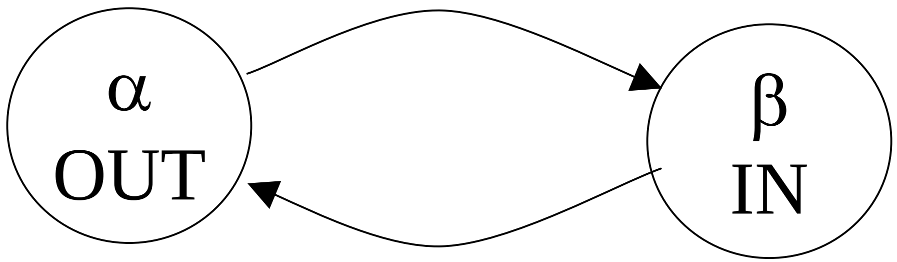
E_1 = {{α},{β},{γ}}
E_2 = {∅}

Labelling-based semantics

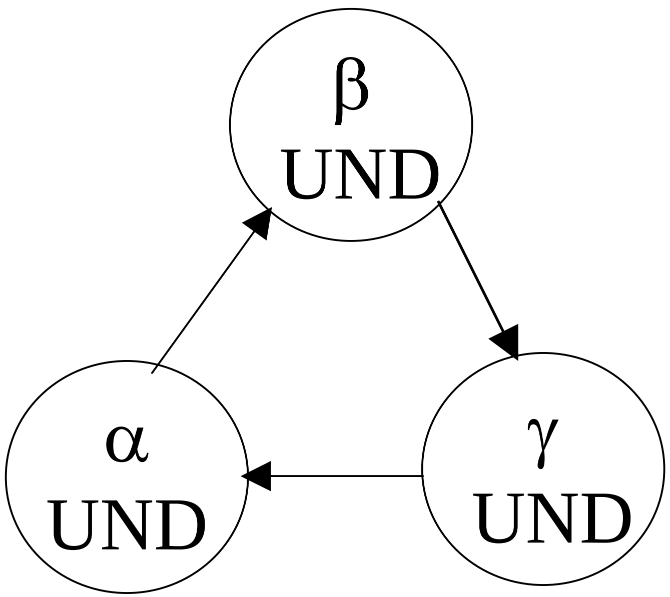
- A set of labels is defined (e.g. IN, OUT, UNDECIDED) and criteria for assigning labels to arguments are given
- Several alternative labellings are possible
- The justification status of each argument can be defined on the basis of its labels

Labelling-based semantics

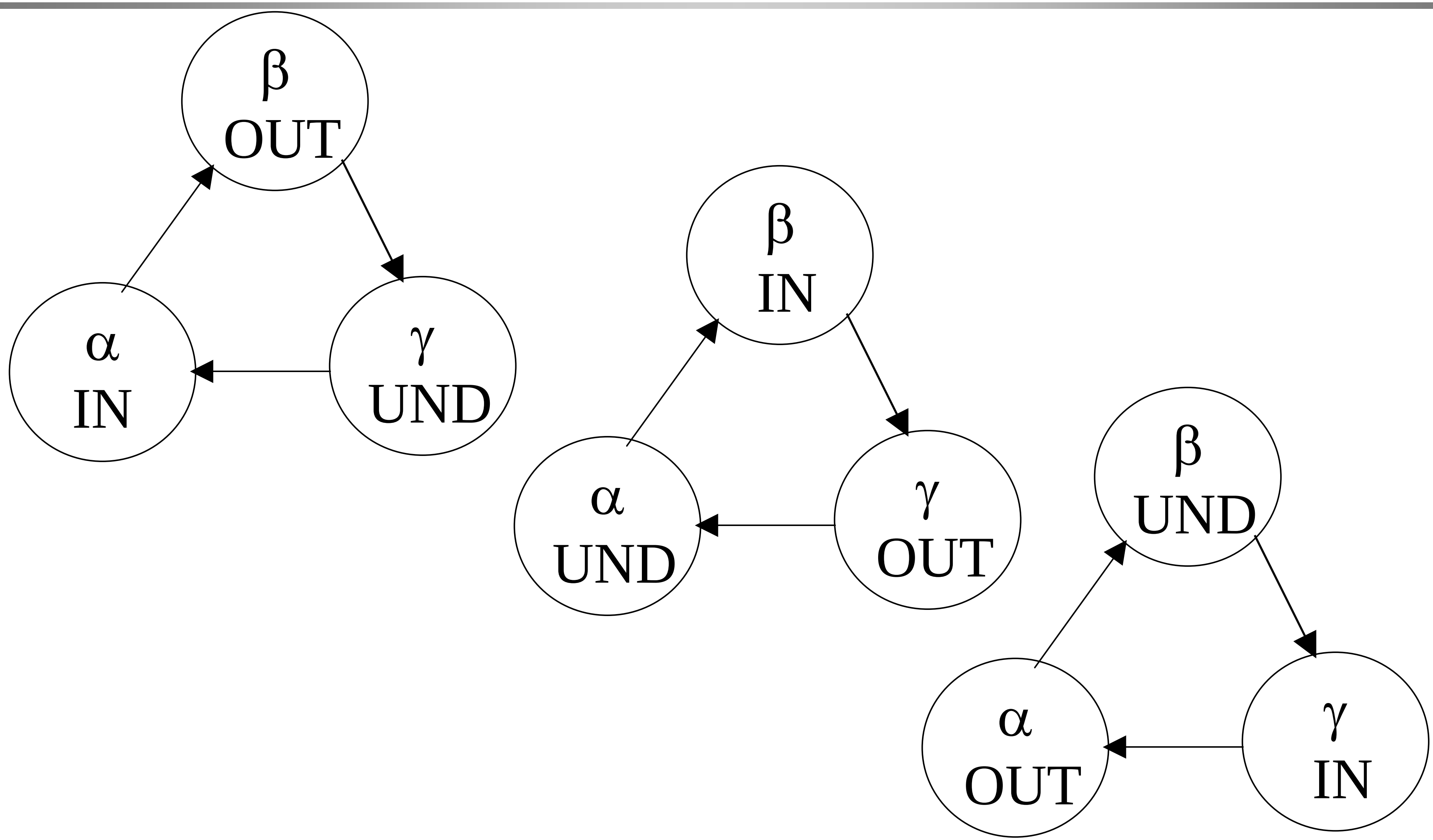




Labelling-based semantics



Labelling-based semantics



Dung's semantics

- Dung's original paper is focused on extension-based semantics (and so is this presentation)
- Relatively simple intuitions underlying semantics definitions
- Dung's semantics are partly based on ideas in other pre-existing and less abstract formalisms and are related each other

Dung's "traditional" semantics

- Admissible set: defends (i.e. attacks the attackers of) its elements
- Complete extension: includes all arguments it defends
- Grounded extension: least complete extension (provably unique)
- Preferred extension: maximal admissible set ≡ maximal complete extension (in general not unique)
- Stable extension: conflict-free set attacking any other argument

Some "non-traditional" semantics

- Stage extension: conflict-free set with maximal range (union of arguments and attacked arguments)
- Semi-stable extension: complete extension with maximal range
- Ideal extension: maximal admissible set included in all preferred extensions (provably unique)
- CF2 semantics: based on SCC decomposition of the defeat graph, can not be synthesized in a line
- Prudent semantics: variations of Dung's traditional semantics based on the notion of "indirect conflict" (odd-length attack path)

Searching for the Holy Grail …

- The best semantics for everyone . . .

- still to be found
  - » The “plethora” of semantics witnesses our inability to find the “right one”

- or still to be agreed upon
  - » The “plethora” of semantics witnesses the tendency of researchers to produce more and more variations (and papers) more or less useful

… or exploring a design space?

- Different semantics are appropriate for different contexts
- Wide (and possibly largely unexplored) design space to be investigated

- How to compare different semantics on a uniform basis? (pairwise comparisons are not enough)

- How to select the appropriate semantics for a given application context?

Answering the first question: principles

- Defining a set of principles, in terms of general abstract properties related to the notion of extensions
- Checking the satisfaction of principles by alternative semantics
- Drawing a comparison grid

Answering the second question: principles

- Characterizing the needs of an application domain in terms of abstract properties (never done before, as to our knowledge)
- Checking the need against the comparison grid
- Available choices: one, many or even none
- If there are many, use additional selection criteria (e.g. computational complexity)

Defining principles: properties of extensions

- Conflict-free principle
- Admissibility and strong admissibility
- Reinstatement (with weak and CF versions)

Conflict-free principle

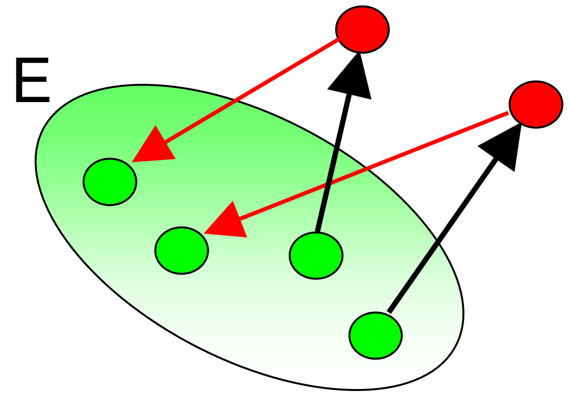
- A set E of arguments is conflict-free if no argument in E attacks another argument in E

- A semantics S satisfies the conflict-free principle if for any argumentation framework its extensions are conflict free

- Underlying idea (shared by any existing semantics): the conflict has to be solved

Admissibility principle

- A conflict-free set E of arguments is admissible if it defends (attacks all the attackers of) its members



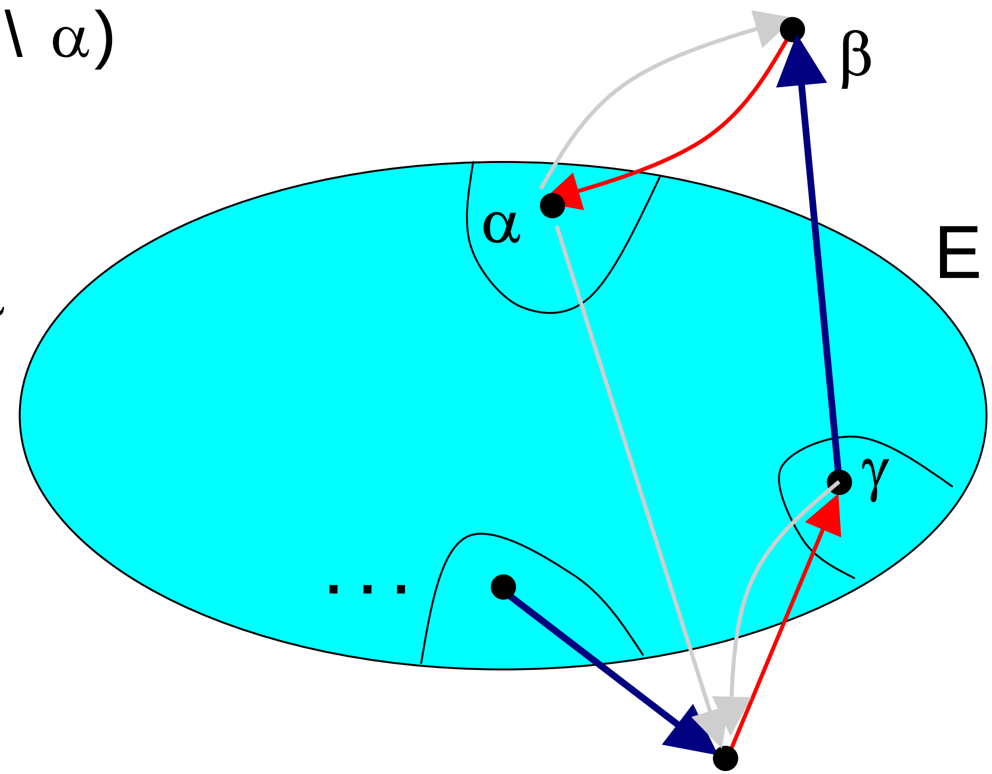
- A semantics S satisfies the admissibility principle if for any argumentation framework its extensions are admissible

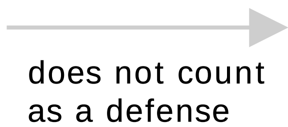
- Underlying idea: replying to attacks is necessary to survive

Strong defense

- A set E "strongly defends" an argument α if α has not attackers or every attacker of α is attacked by an element of E distinct from α and in turn strongly defended by (E \ α)

E strongly defends α





Strong admissibility principle

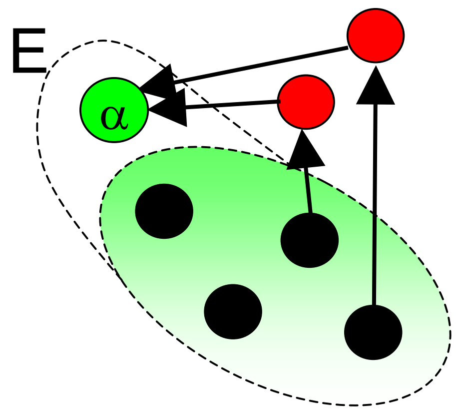
- A semantics S satisfies the strong admissibility principle if for any argumentation framework any extension strongly defends its elements

- Underlying idea: self-defense is not enough to survive

- Too strong requirement, but provides an alternative characterization of grounded semantics

Reinstatement principle

- A semantics S satisfies the reinstatement principle if for any argumentation framework any extension includes all arguments it defends



- Underlying idea: an argument acceptable with respect to the extension should not be left outside

Reinstatement variations

- A semantics S satisfies the weak reinstatement principle if for any argumentation framework any extension includes all arguments it strongly defends

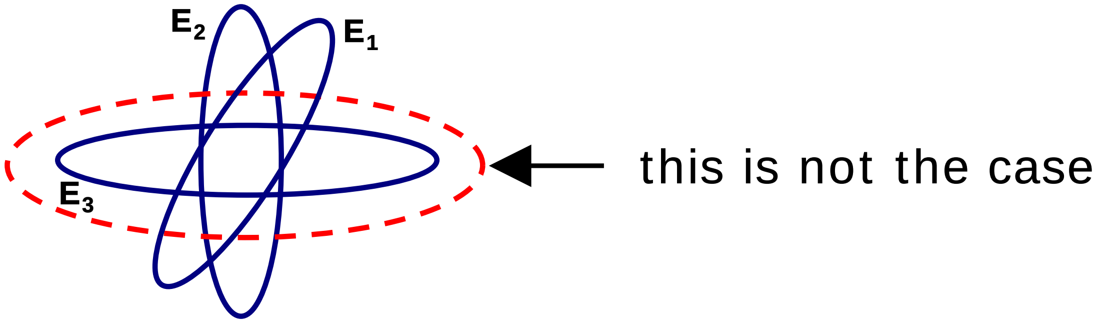
- A semantics S satisfies the CF reinstatement principle if for any argumentation framework any extension includes all arguments it defends and such that they are not in conflict with other arguments of the extension

Defining principles: properties of sets of extensions

- I-maximality
- Directionality
- Skepticism-adequacy
- Resolution-adequacy

I-maximality principle

- A set of extensions is I-maximal if none of it members is a strict subset of another one



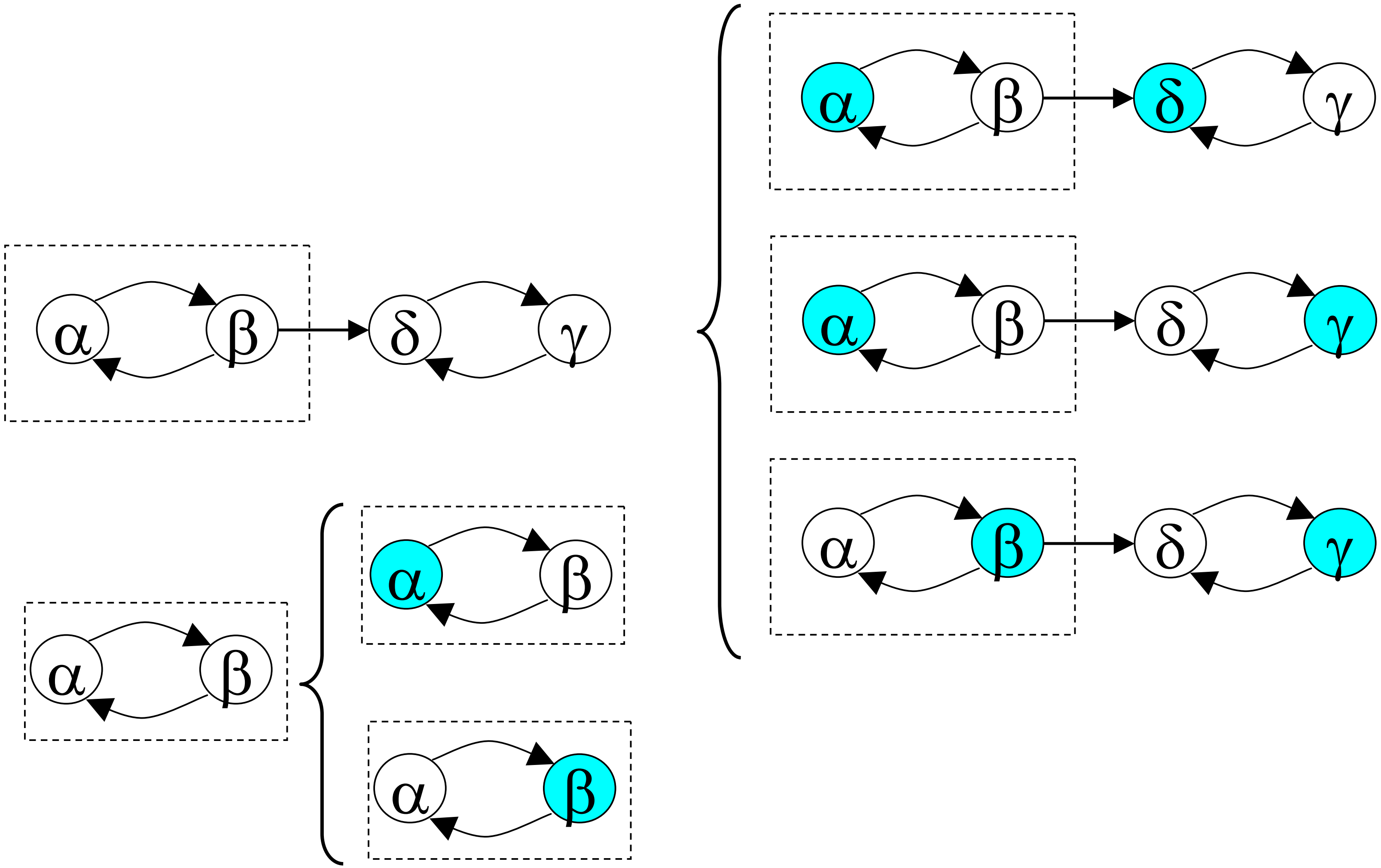
- A semantics S satisfies the I-maximality principle if for any argumentation framework the set of extensions is I-maximal
- Underlying idea: strict subsets do not count as extensions

Directionality principle

- A set of arguments is unattacked if it does not receive attacks from other arguments
- A semantics S satisfies the directionality principle if for any argumentation framework, for any unattacked set U, and for any extension E, $E \cap U$ is an extension of the argumentation framework restricted to U and viceversa

- Underlying idea: extension membership of an argument is determined exclusively by its ancestors in the defeat graph

Directionality: an example

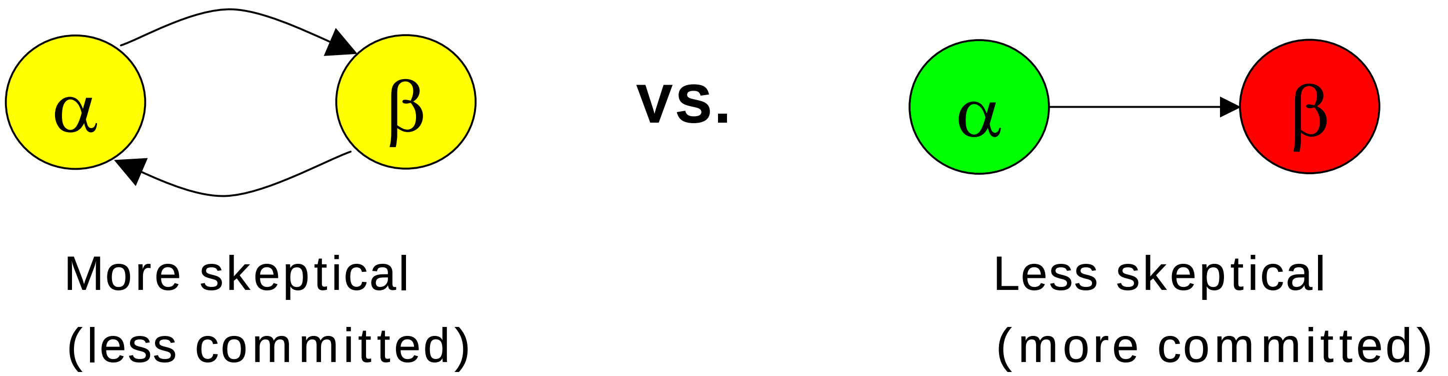


Adequacy principles

- A partial order of skepticism is defined over argumentation frameworks
- Several partial orders of skepticism are defined over sets of extensions
- Adequacy principles require a correspondence between skepticism relations of argumentation frameworks and skepticism relations of sets of extensions

Ordering argumentation frameworks by skepticism

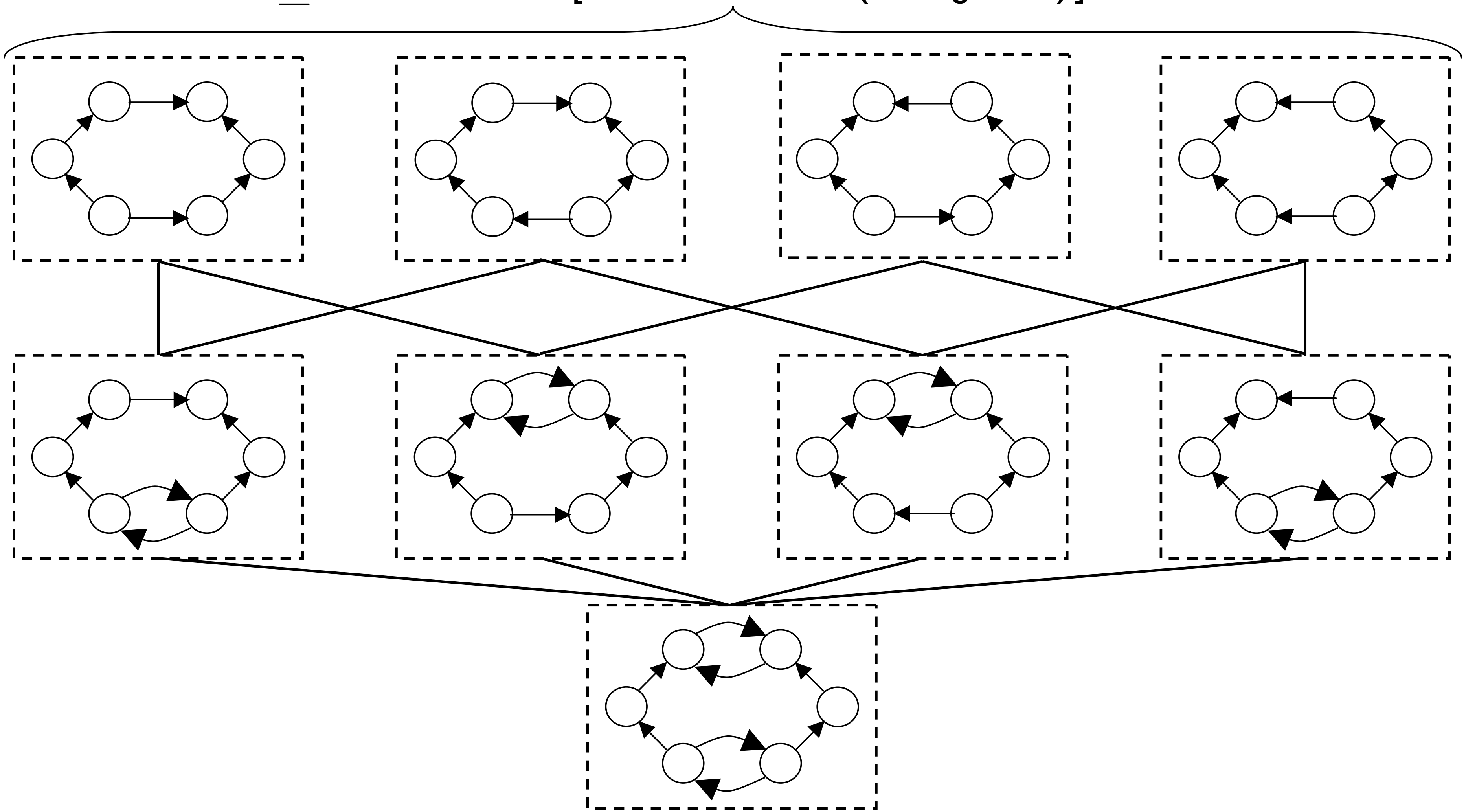
- Basic idea



- In general transforming a mutual attack into a unidirectional one gives rise to a less skeptical argumentation framework

Ordering argumentation frameworks by skepticism

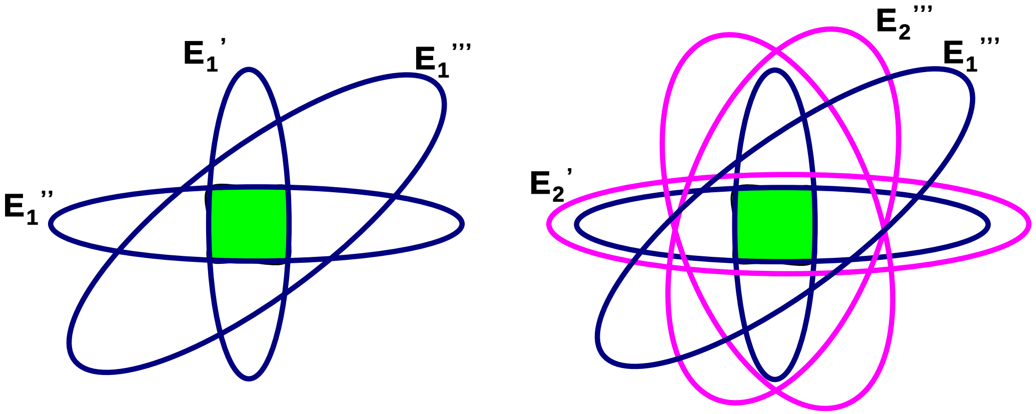
$\preceq^{A}$-maximal AF [resolutions in (Modgil 06)]



Ordering sets of extensions by skepticism

- Several skepticism relations are possible
- The simplest one is $\mathcal{E}_1 \preceq^{E}_{\cap} \mathcal{E}_2$: $\bigcap \mathcal{E}_1 \subseteq \bigcap \mathcal{E}_2$
- The most interesting one is

$$\mathcal{E}_1 \preceq^{E}_{W} \mathcal{E}_2 : \ \forall\, E_2 \in \mathcal{E}_2,\ \exists\, E_1 \in \mathcal{E}_1 : E_1 \subseteq E_2$$



Skepticism adequacy principle

- Given a skepticism relation $\preceq^E$ between sets of extensions a semantics S is $\preceq^E$-adequate if for any pair of argumentation frameworks ordered by skepticisms, the corresponding sets of extensions prescribed by S are ordered according to $\preceq^E$
- Underlying idea: the ordering of argumentation frameworks is reflected by extensions

Resolution adequacy principle

- Given a skepticism relation $\preceq^E$ between sets of extensions a semantics S is $\preceq^E$- resolution-adequate if for any argumentation framework AF, the union of the sets of extensions prescribed by S for all resolutions of AF is more skeptical (according to $\preceq^E$) than the set of extensions prescribed by S for AF

- Underlying idea: if an argument is in an extension in all the resolutions of AF then it should be in an extension of AF

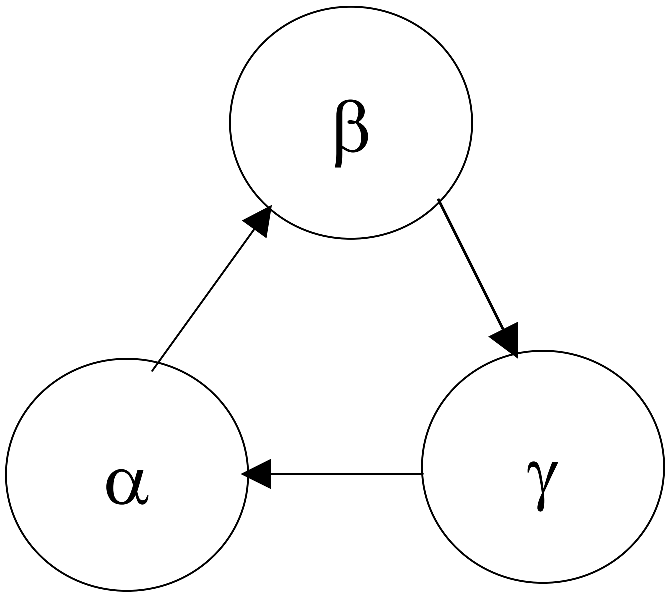
A plethora of principles?

- Are they all good?
- Are they too much?
- Are we missing anyone?

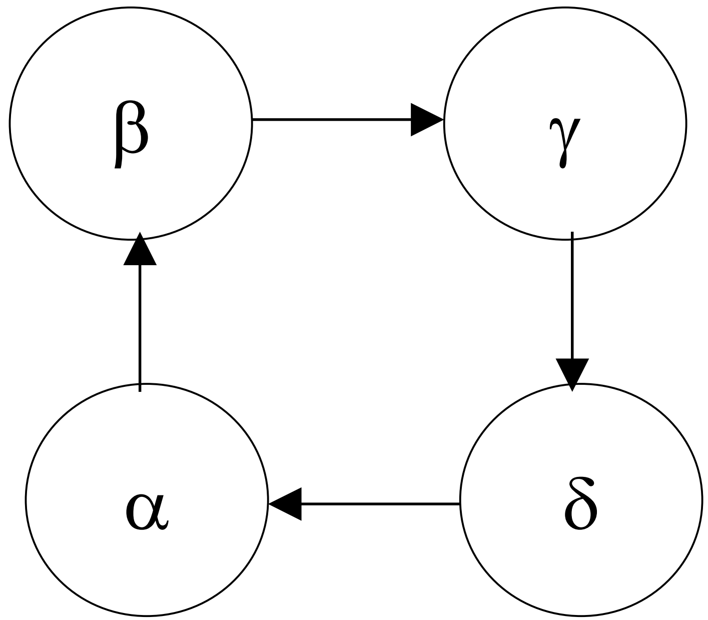
A possibly missing principle: symmetry in cycles

- Cycles are a rather specific but significant topology
- Most semantics treat "differently" odd and even-length cycles

$E = \{\emptyset\}$



$E = \{\{\alpha,\gamma\},\{\beta,\delta\}\}$



A possibly missing principle: non emptyness

- The empty extension satisfies trivially many principles
- Reinstatement entails that the grounded extension is included in any extension
- I-maximality tends to exclude the empty extension
- Is there a more explicit and possibly more general way of avoiding the triviality of the empty set when possible?

The principles at work

	Grounded	Preferred	Stable	Complete
CF-principle	Yes	Yes	Yes	Yes
Admissibility	Yes	Yes	Yes	Yes
Reinstatement	Yes	Yes	Yes	Yes
Weak reinstatement	Yes	Yes	Yes	Yes
CF-reinstatement	Yes	Yes	Yes	Yes
I-maximality	Yes	Yes	Yes	No
Directionality	Yes	Yes	No	Yes
Skepticism Adequacy	Yes	No	Yes	Yes
Resolution Adequacy	No	Yes	Yes	No

The principles at work

	Ideal	CF2	Semistable	Stage
CF-principle	Yes	Yes	Yes	Yes
Admissibility	Yes	No	Yes	No
Reinstatement	Yes	No	Yes	No
Weak reinstatement	Yes	Yes	Yes	No
CF-reinstatement	Yes	Yes	Yes	Yes
I-maximality	Yes	Yes	Yes	Yes
Directionality	Yes	Yes	No	No
Skepticism Adequacy	No	Yes	No	??
Resolution Adequacy	No	No	Yes	??

The principles at work

	Grounded Prudent	Complete Prudent	Stable Prudent	Preferred Prudent
CF-principle	Yes	Yes	Yes	Yes
Admissibility	Yes	Yes	Yes	Yes
Reinstatement	No	No	Yes	No
Weak reinstatement	No	No	Yes	No
CF-reinstatement	No	No	Yes	No
I-maximality	Yes	No	Yes	Yes
Directionality	Yes	No	No	No
Skepticism Adequacy	No	No	No	No
Resolution Adequacy	No	No	Yes	No

An embarassing finding?

- None of the semantics mentioned before satisfies all principles
- A limit of current semantics?
- An inherent incompatibility of the proposed principles?

From principles to design

- Trying to define a new semantics letting the principles drive the design
- First step: a parametric (i.e. defined in terms of another arbitrary semantics S) family of semantics (called resolution-based)

Definition 21 *Given an argumentation semantics* $\mathcal{S}$ *which is universally defined, its resolution-based version is the semantics* $\mathcal{S}^\star$ *such that for any argumentation framework* $\mathrm{AF} = \langle \mathcal{A}, \rightarrow \rangle$ $\mathcal{E}_{\mathcal{S}^\star}(\mathrm{AF}) = \mathcal{MIN}(\mathcal{UR}(\mathrm{AF}, \mathcal{S}))$, *where given a set* $\mathcal{E}$ *of subsets of* $\mathcal{A}$, $\mathcal{MIN}(\mathcal{E})$ *denotes the set of the minimal (with respect to set inclusion) elements of* $\mathcal{E}$.

From principles to design

- Any resolution-based semantics satisfies:
  - » I-maximality
  - » skepticism-adequacy
  - » resolution-adequacy

- Putting relatively mild requirements on S we obtain also:
  - » admissibility
  - » reinstatement (all forms of)

From principles to design

- Second step: identify an instance of this family able to satisfy the only missing principle (directionality)
- The result has been achieved using the traditional grounded semantics as S i.e. with “resolution-based grounded semantics”
  [Baroni&Giacomin, COMMA 08]

A laboratory monster …

- We initially called this family of semantics “synthetic” since it was obtained in a sort of “unnatural” way
- The definition is quite complicated and looks like the product of a purely theoretical exercise …
- which promises in particular an abnormous computational complexity

… or ugly duckling?

- A reasonably efficient implementation is possible without following the definition literally

- Computational complexity analysis shows that “resolution-based grounded semantics” is better than other multiple-status semantics from this viewpoint [Baroni, Dunne, Giacomin, IJCAI 09]

The moral of the story…

- A systematic investigation at an abstract level can be quite fruitful
- Principles can be useful not only for a posteriori evaluation but also for design
- There is still a lot of work to do

Homework

- Defining principles for labeling-based semantics (simply borrowing those defined for extension-based is not allowed)
- Analyzing the needs of some significant application domain in terms of principles (either extension-based or labelling-based)
- Designing a principle-driven labelling semantics

Warning

- Be careful when going directly from natural language examples to abstract framework “representation”
- A big gap to be covered misunderstandings and long discussions may arise

Some references

Dung's framework and extension-based semantics

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