Abstract Argumentation

- *Guillermo R. Simari*

LIDIA

Laboratorio de Investigación y Desarrollo en Inteligencia Artificial (LIDIA)

Instituto de Ciencias e Ingeniería de la Computación

Departamento de Ciencias e Ingeniería de la Computación

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Phan Minh Dung: *On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games.*
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Artificial Intelligence

On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games*

Phan Minh Dung*

Division of Computer Science, Asian Institute of Technology, GPO Box 2754, Bangkok 10501, Thailand

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Abstract

The purpose of this paper is to study the fundamental mechanism, humans use in argumentation, and to explore ways to implement this mechanism on computers.

We do so by first developing a theory for argumentation whose central notion is the acceptability of arguments. Then we argue for the "correctness" or "appropriateness" of our theory with two strong arguments. The first one shows that most of the major approaches to nonmonotonic reasoning in AI and logic programming are special forms of our theory of argumentation. The second argument illustrates how our theory can be used to investigate the logical structure of many practical problems. This argument is based on a result showing that our theory captures naturally the solutions of the theory of n-person games and of the well-known stable marriage problem.

By showing that argumentation can be viewed as a special form of logic programming with negation as failure, we introduce a general logic-programming-based method for generating meta-interpreters for argumentation systems, a method very much similar to the compiler-compiler idea in conventional programming.

Keywords: Argumentation; Nonmonotonic reasoning; Logic programming; n-person games; The stable marriage problem

"The true basis of the logic of existence and universality lies in the human activities of seeking and finding"
Jaakko Hintikka [24, p. 33]

* The results in this paper (except those of Sections 3 and 4.3.2) have been published in condensed form in [15].

* E-mail: dung@cs.ait.ac.th.

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Abstract Argumentation Frameworks

Abstract Argumentation Frameworks

- *The formalism considers a set of <u>atomic</u> arguments and an attack relation.*
- *The abstraction comes from assuming these two things without providing an explanation about how the arguments are built or the way the attack relation is defined.*
- *Thus, the theory is simplified to the point where the details arising from the attack interaction can be studied carefully, with the sole purpose of defining the status of the set of arguments.*

Conceptual View

Definition of Status of Arguments
Definition of Defeat among Arguments
Definition of Conflict among Arguments
Definition of Argument
Definition of the Underlying (Logical) Language

Returning to the conceptual view, abstracting away all but the definition used to decide the status of arguments, we can characterize a fascinating and rich formal structure.

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An *Abstract Argumentation Framework* AF is a pair:

$$< AR, \mathcal{R} >$$

$AR =$ Set of Arguments

$\mathcal{R} \subseteq AR \times AR$

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Abstract Argumentation Frameworks

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Definition of Status of Arguments

Conflict = Defeat Among Arguments

Set of Arguments

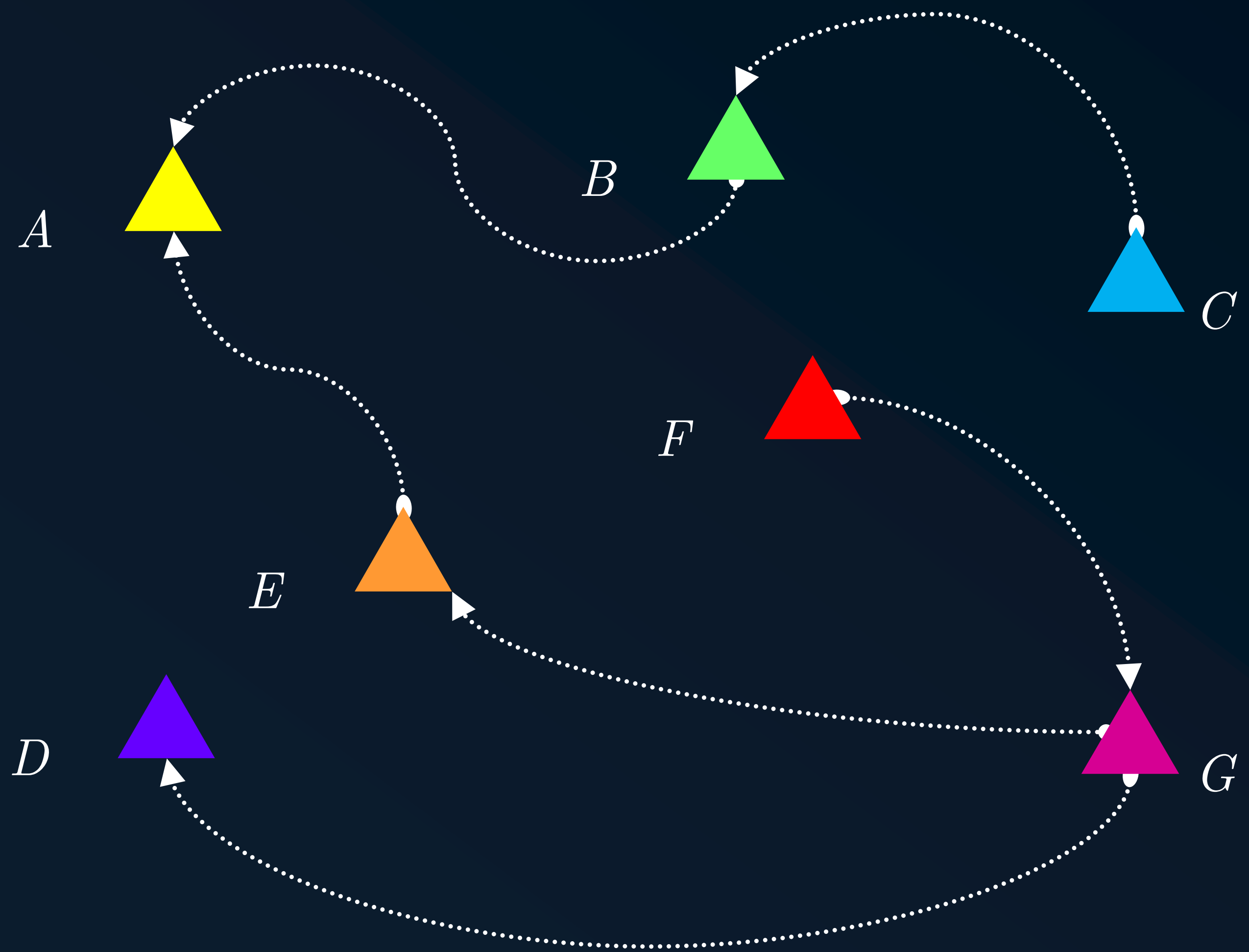
In the conceptual view two steps are necessary:

- *Define conflict between arguments, and*
- *then define how conflicts are resolved creating a defeat relation.*

In this formalism the attack always succeeds, i.e., every attack is in fact a defeat.

Definition of the Status of Arguments: Argumentation Semantics

Abstract Argumentation



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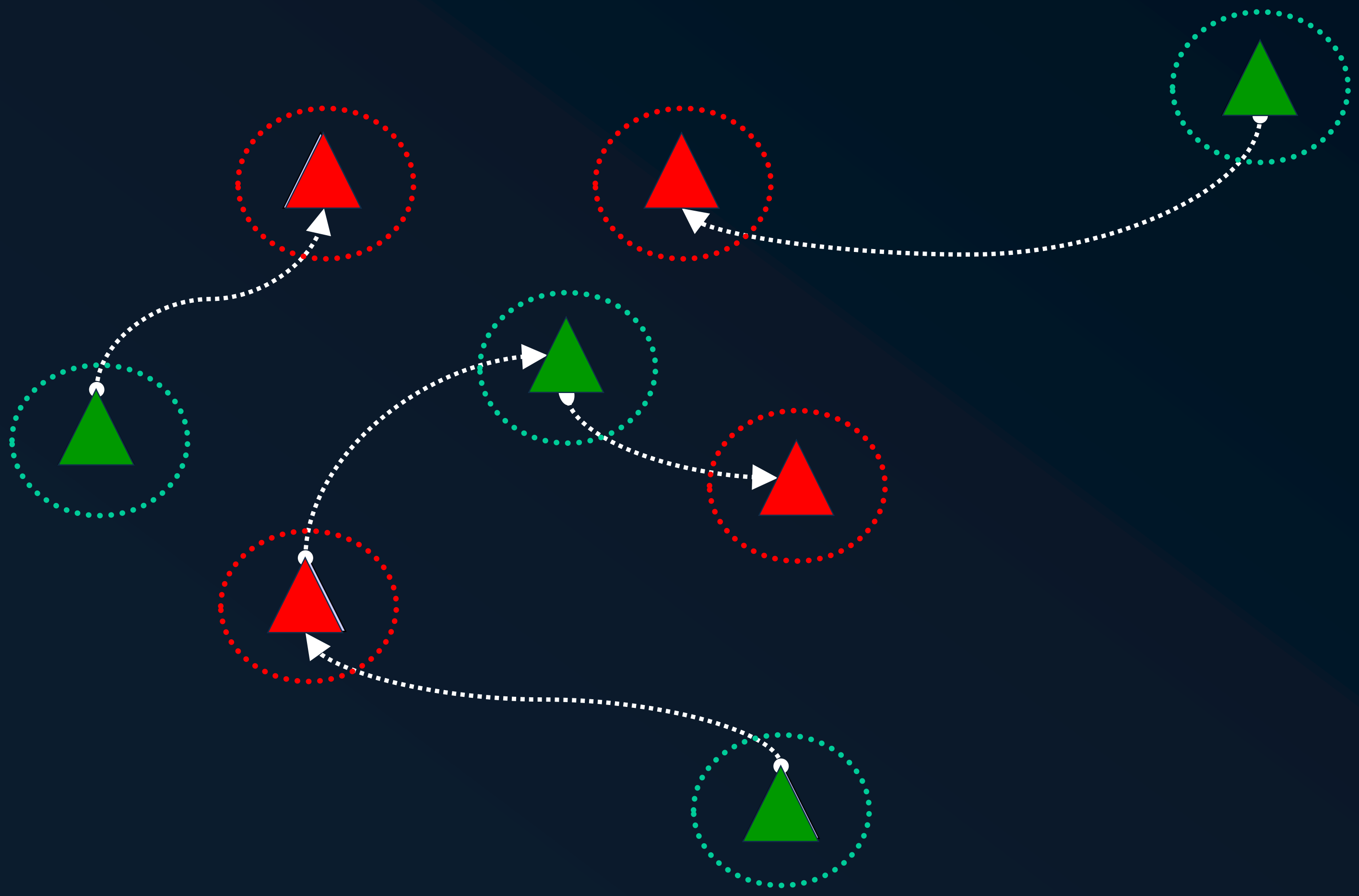

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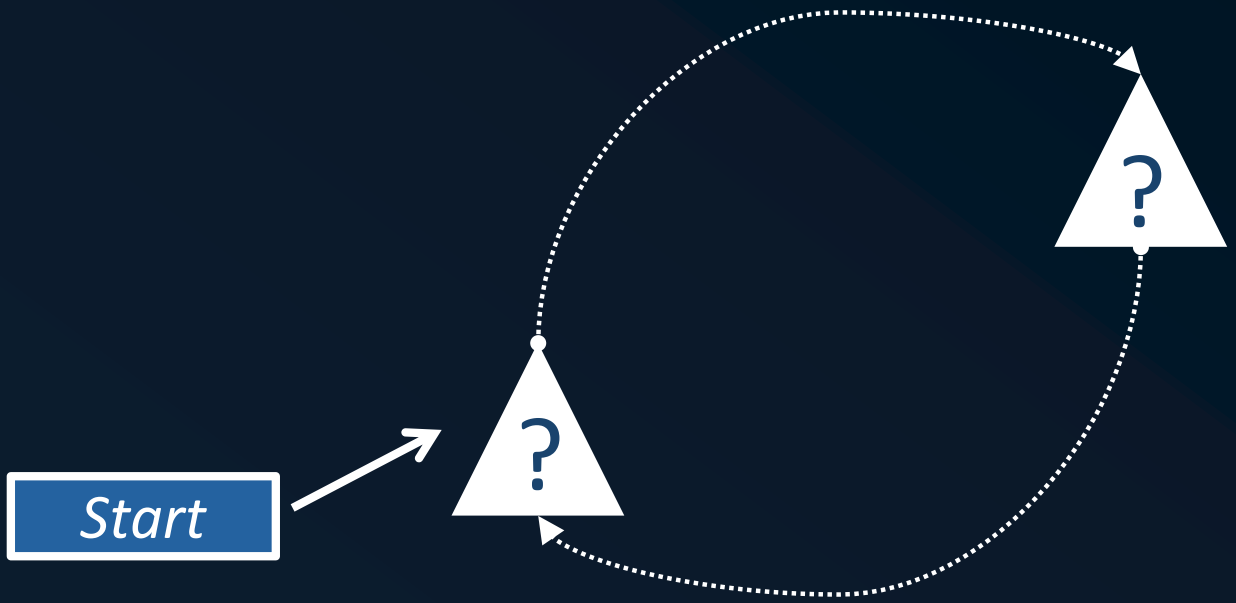

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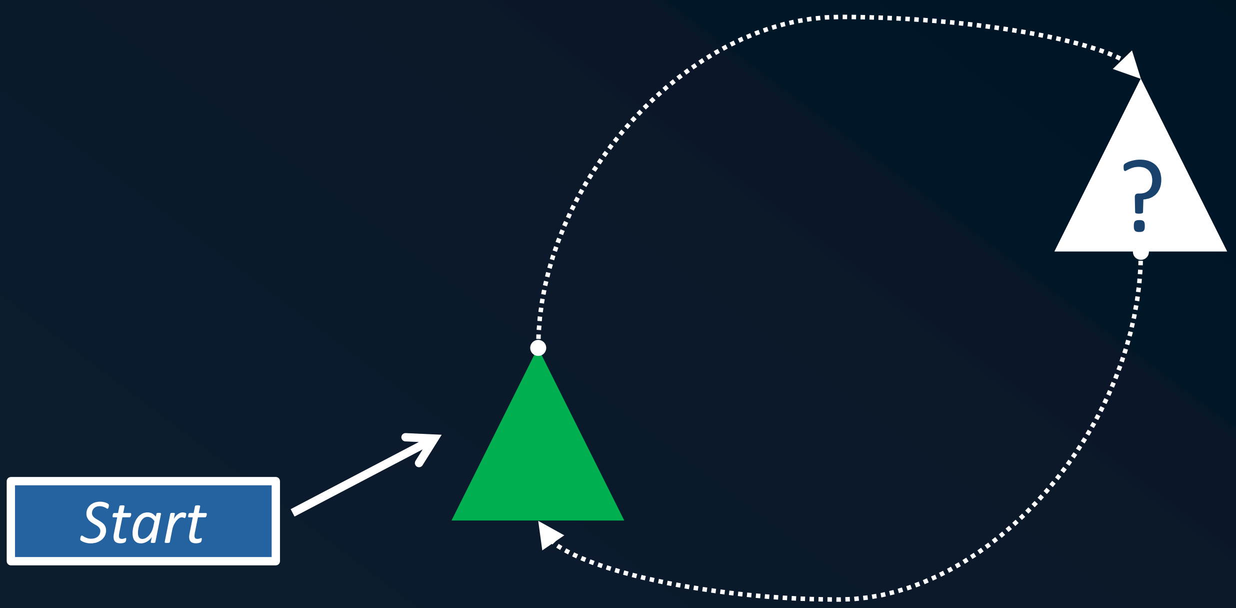

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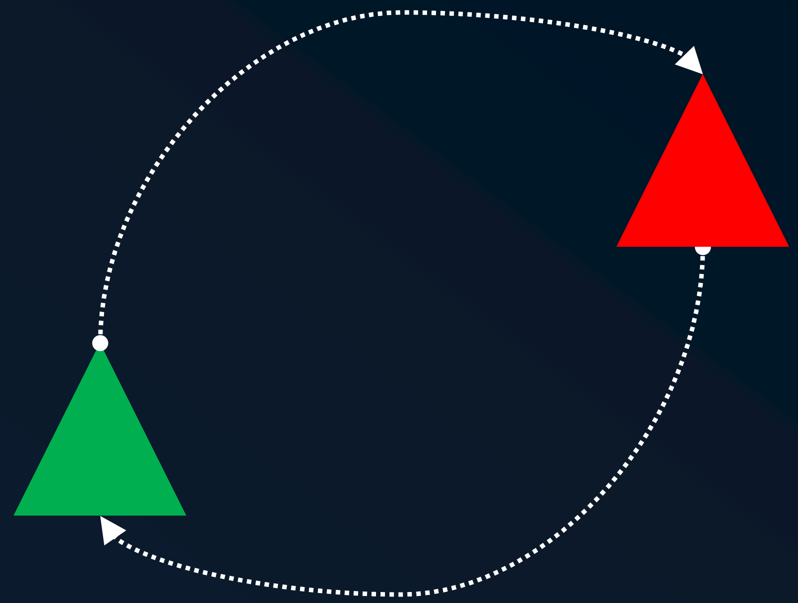

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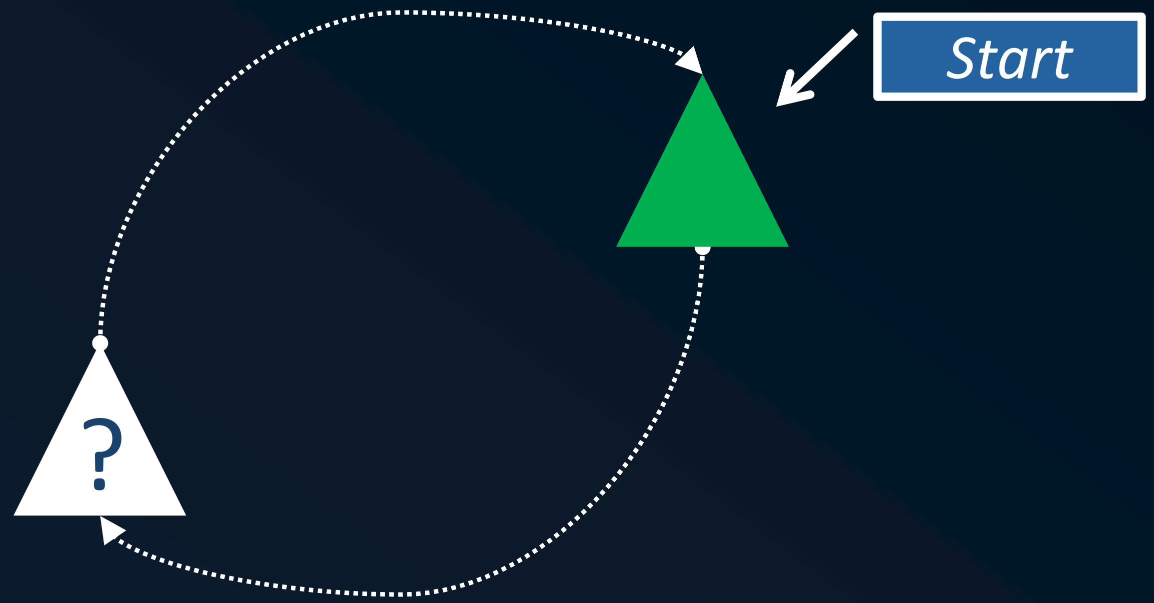

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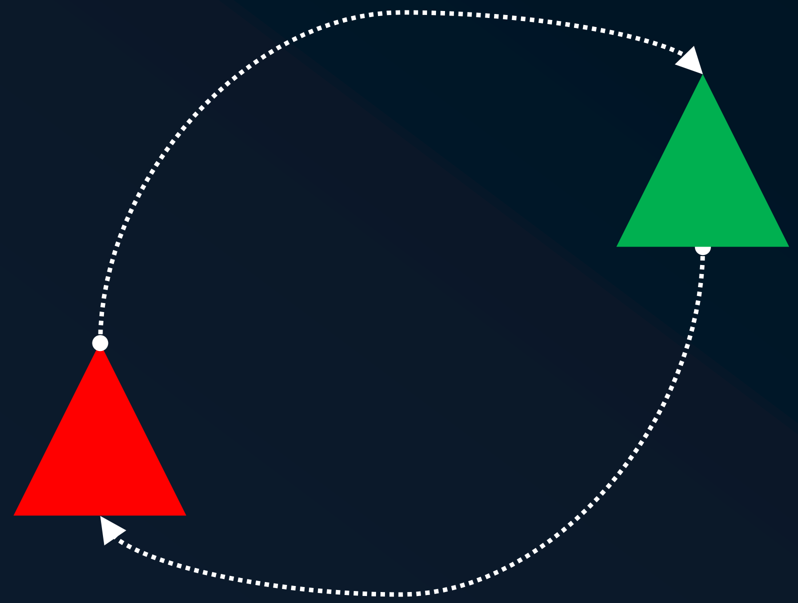
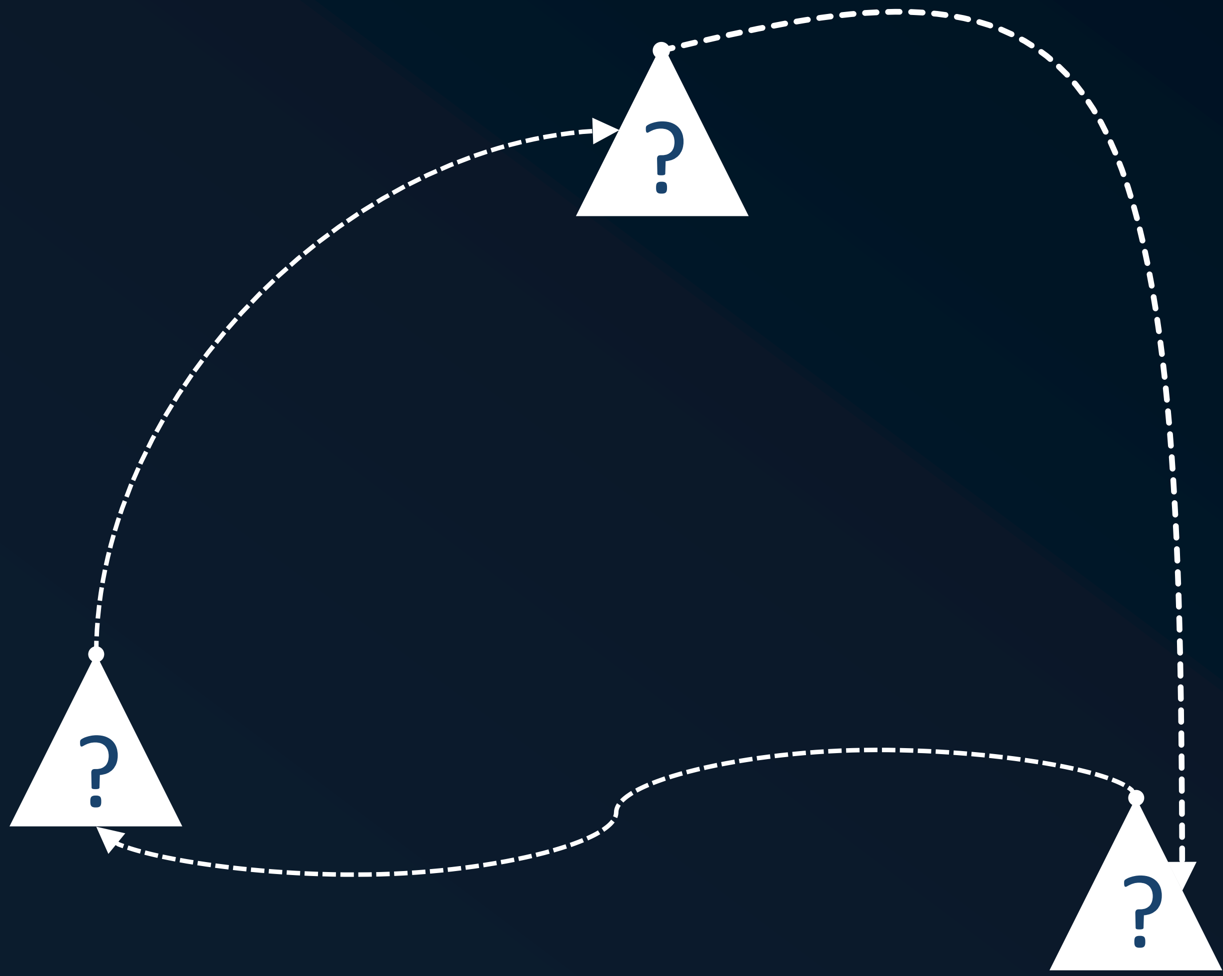


There are two choices

Abstract Argumentation



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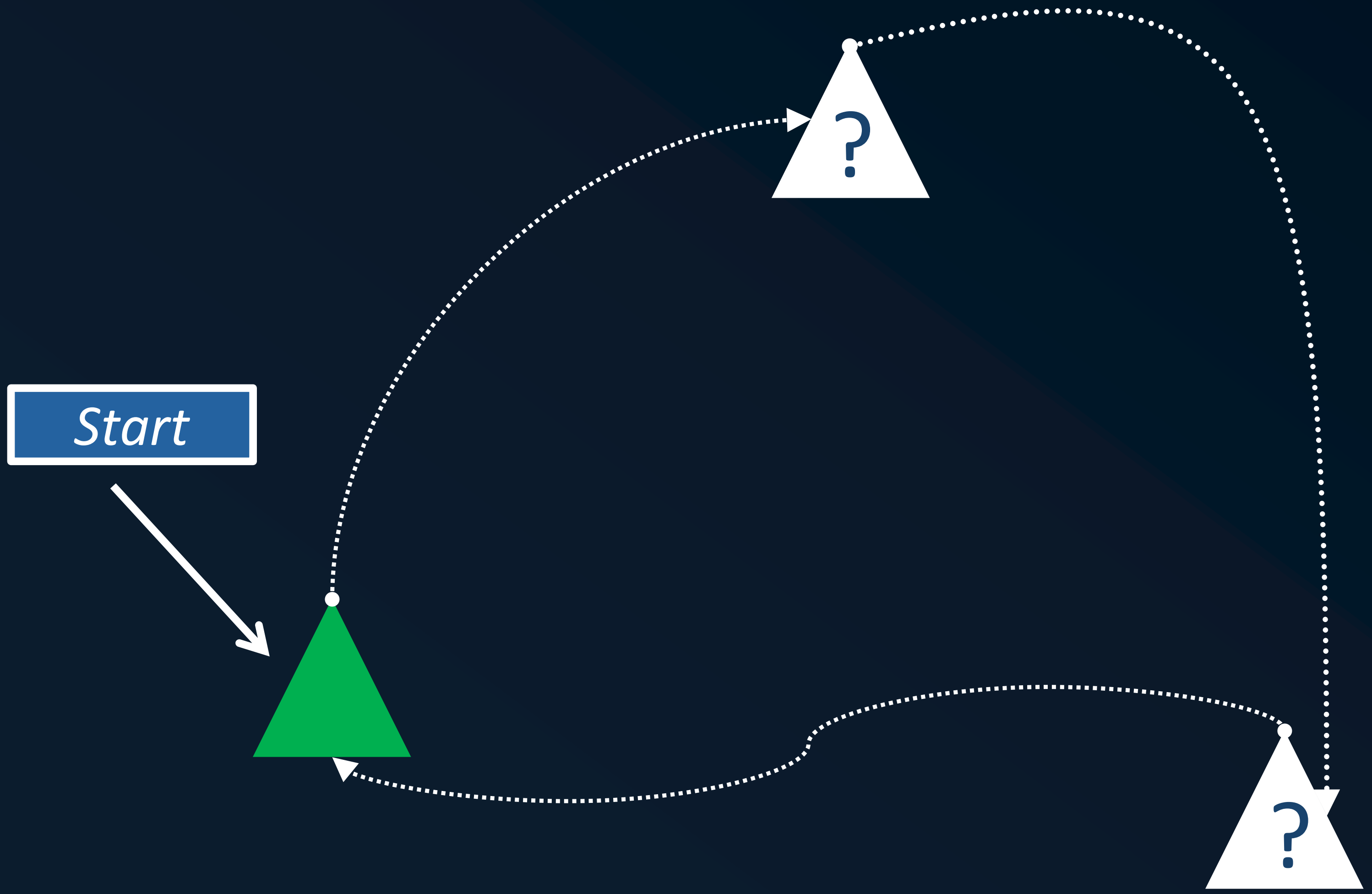

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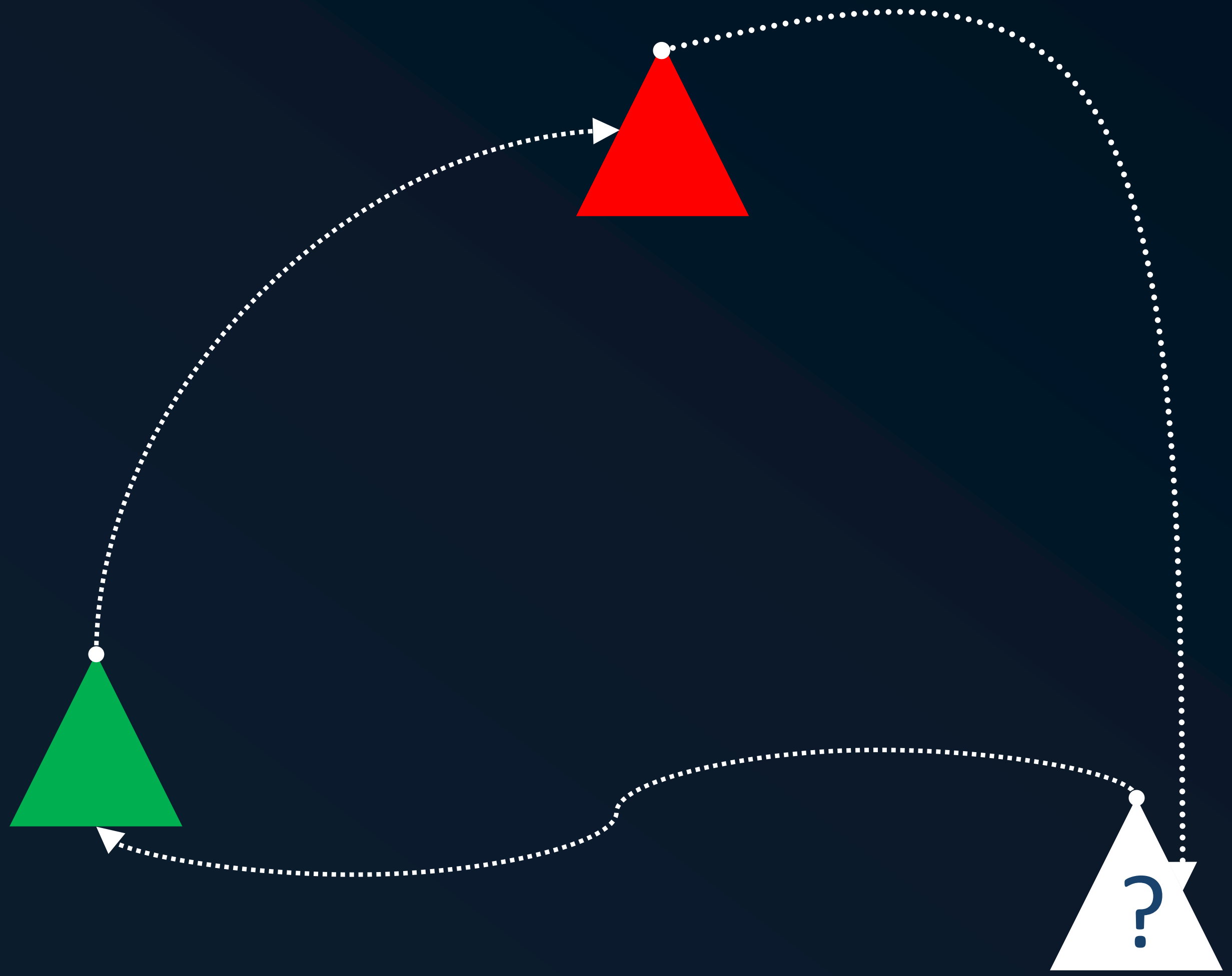

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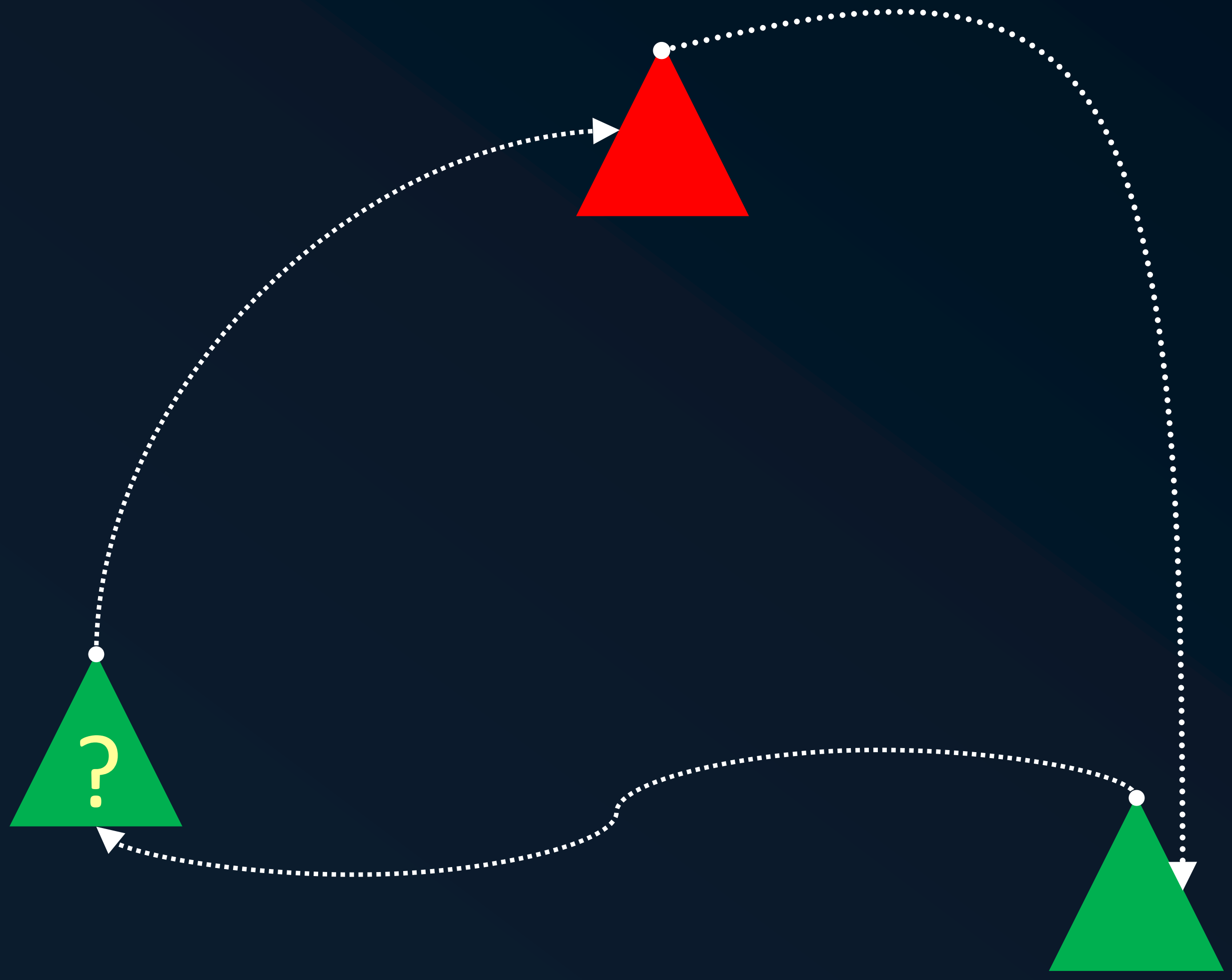

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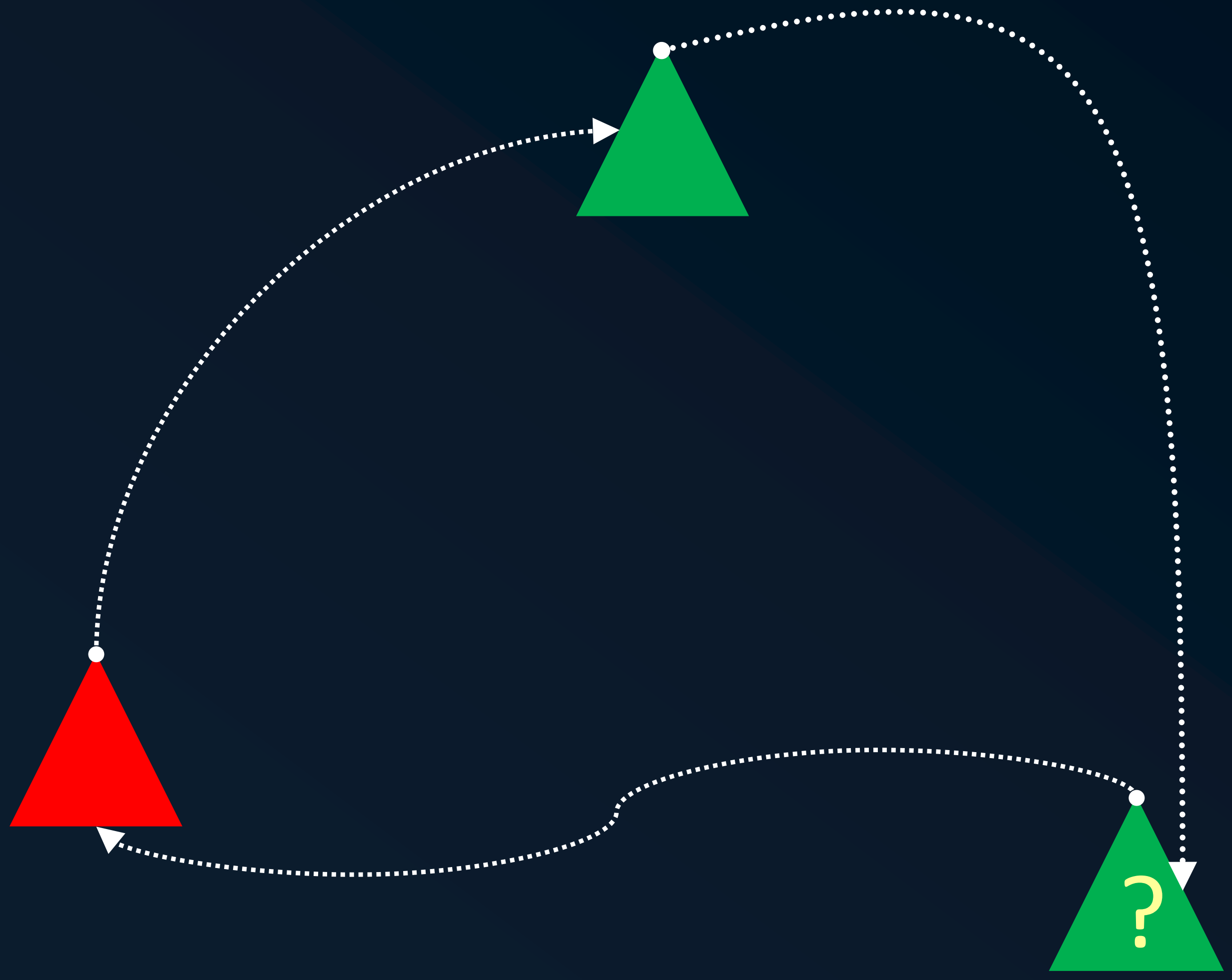

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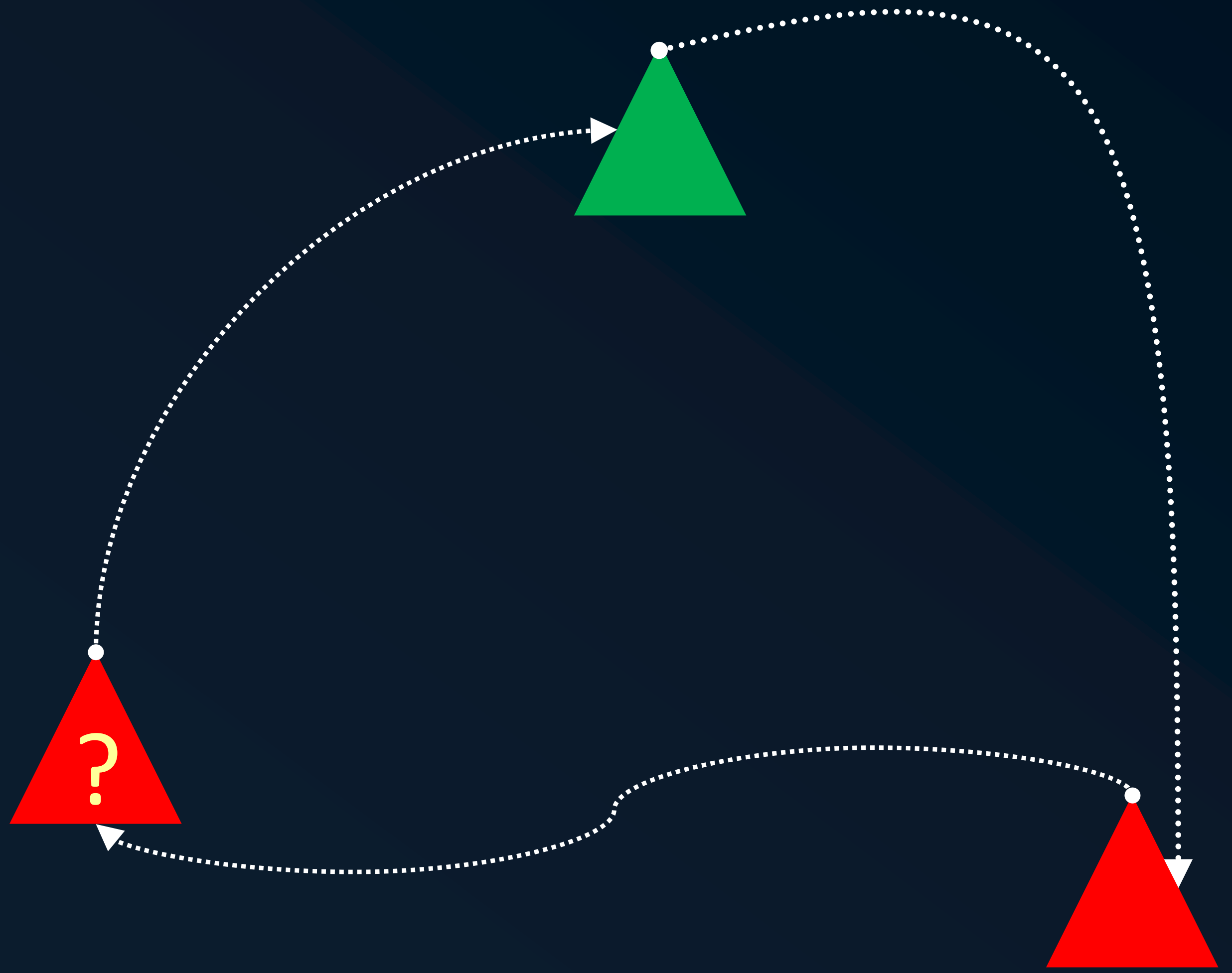

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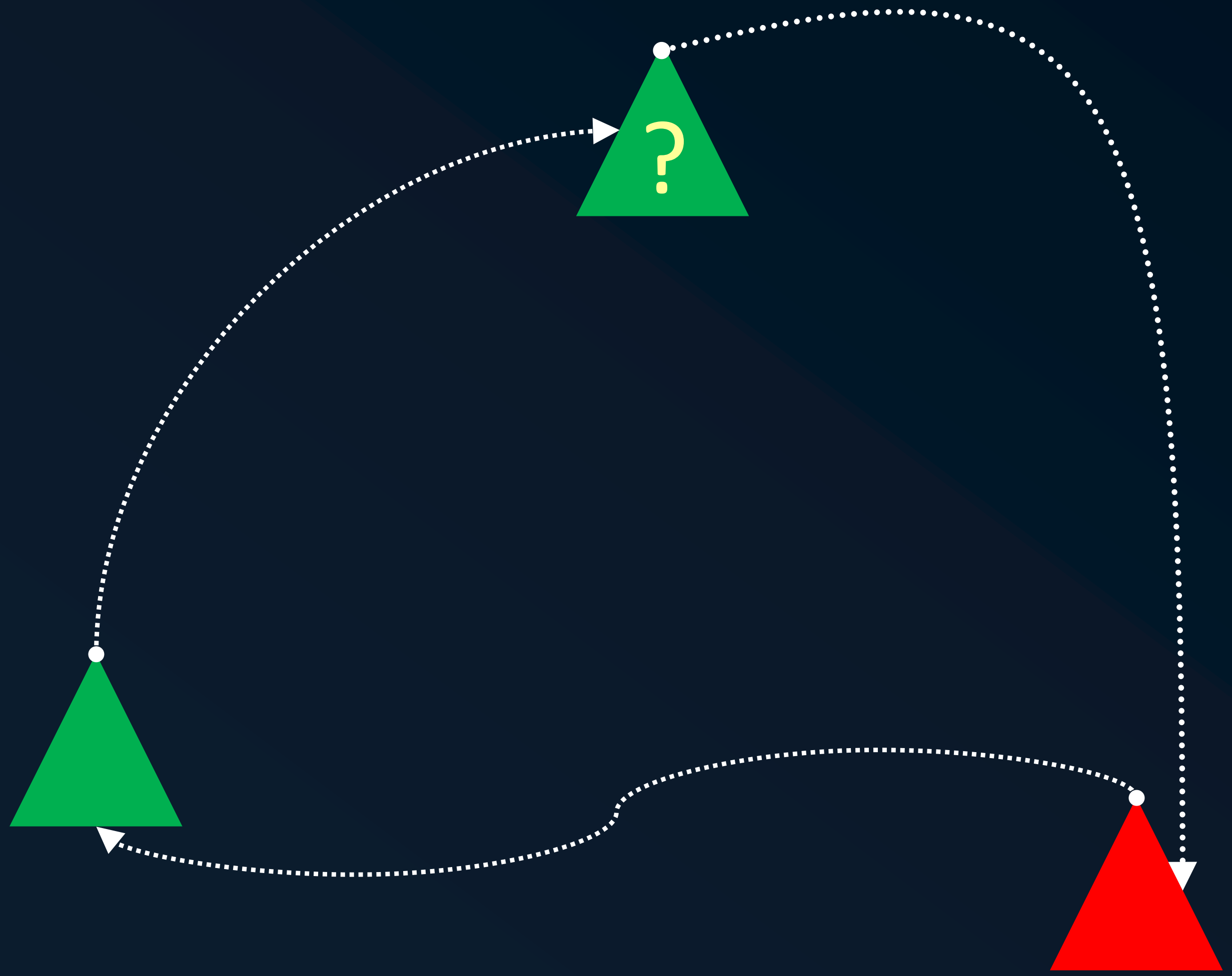

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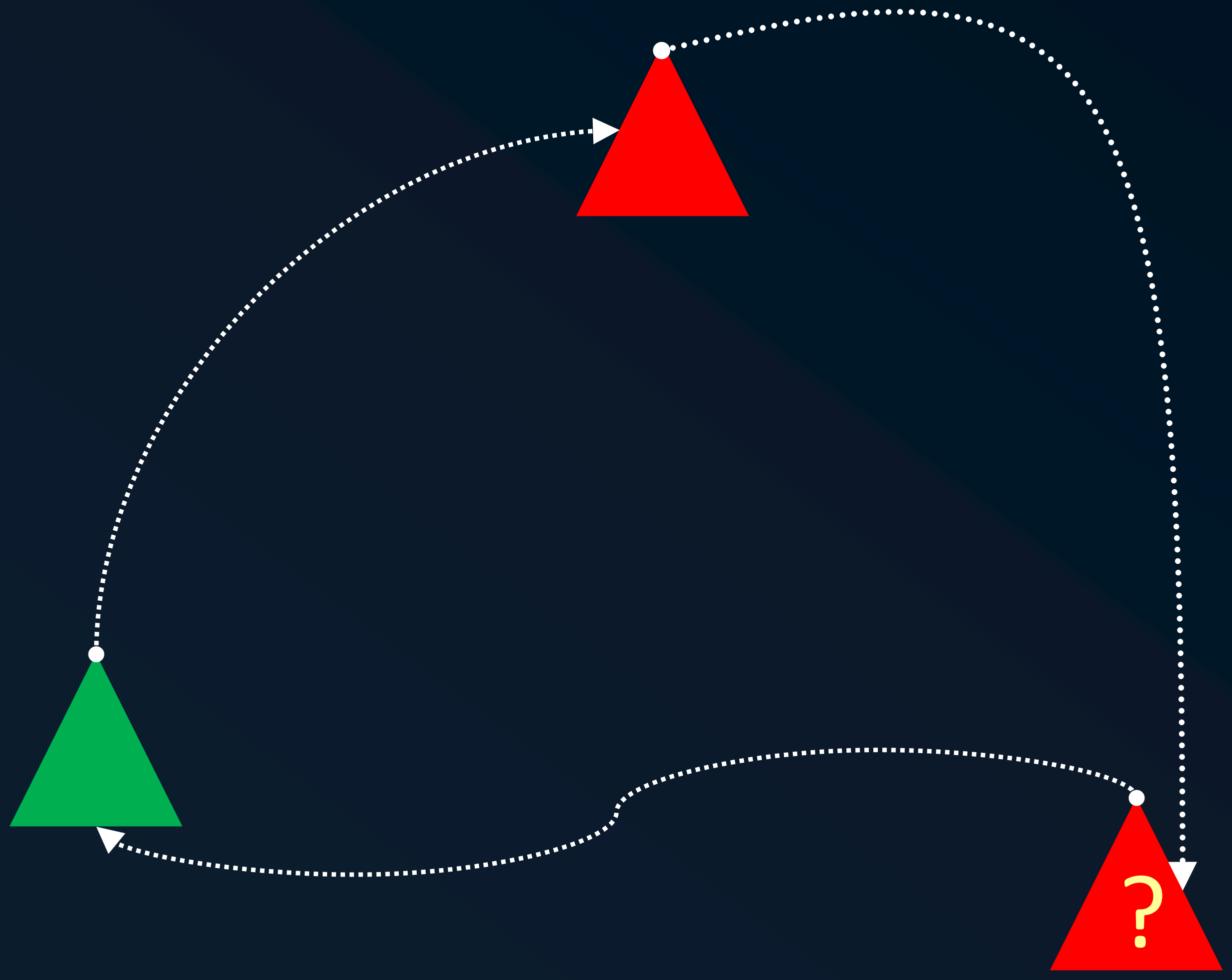


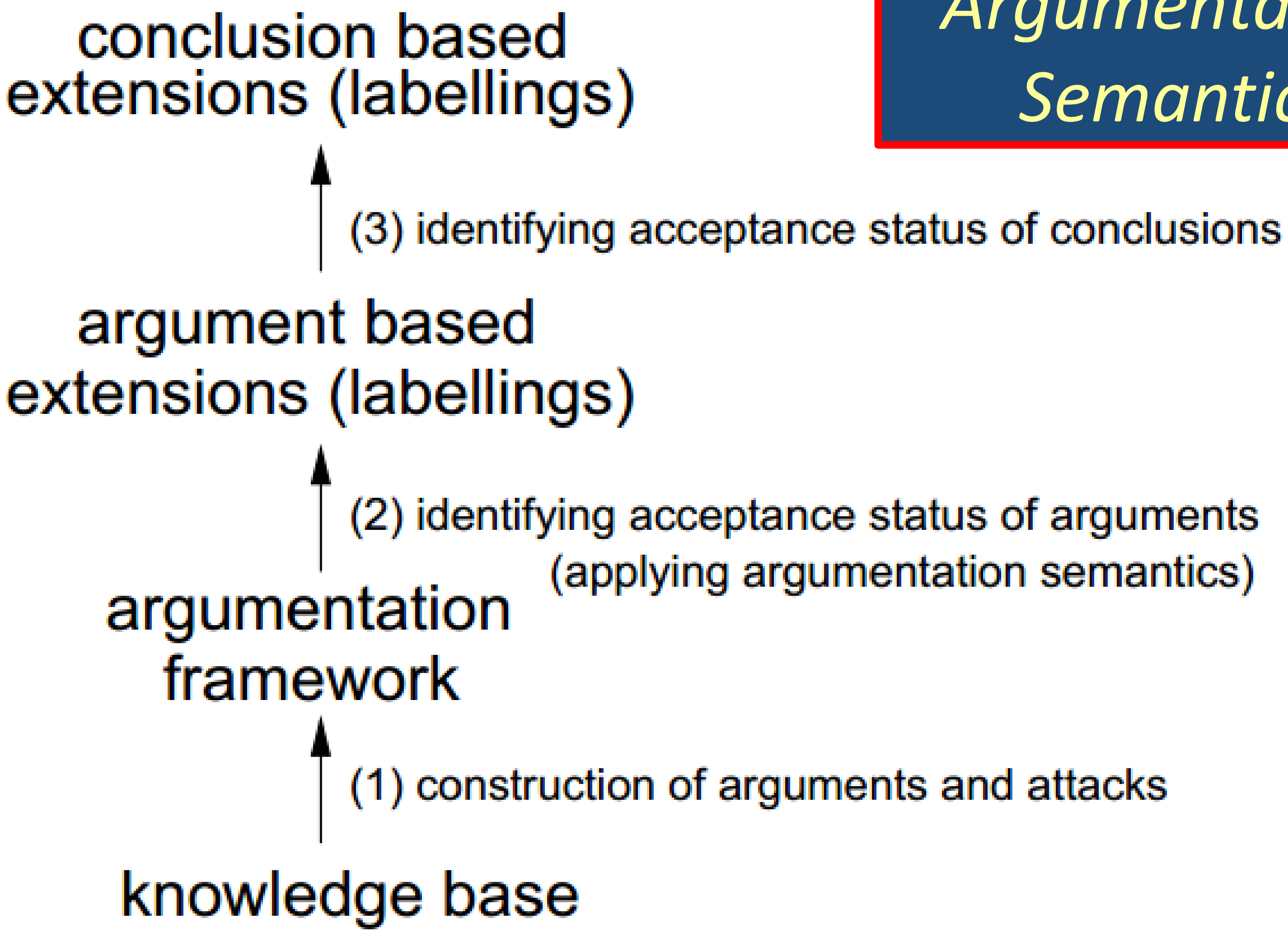
Semantics

Several argumentation semantics were developed

- *Complete, Grounded, Stable, and Preferred (Dung's 1995 paper)*
- *Stage, Semi-stable, Ideal, CF2, and Prudent*

An Introduction to Argumentation Semantics
P. Baroni, M. Caminada, and M. Giacomin
The Knowledge Engineering Review, 26(4): 365-410 (2011), CUP

Argumentation Semantics



From: An Introduction to Argumentation Semantics

P. Baroni, M. Caminada, and M. Giacomin

The Knowledge Engineering Review, 26(4): 365-410 (2011), Cambridge UP

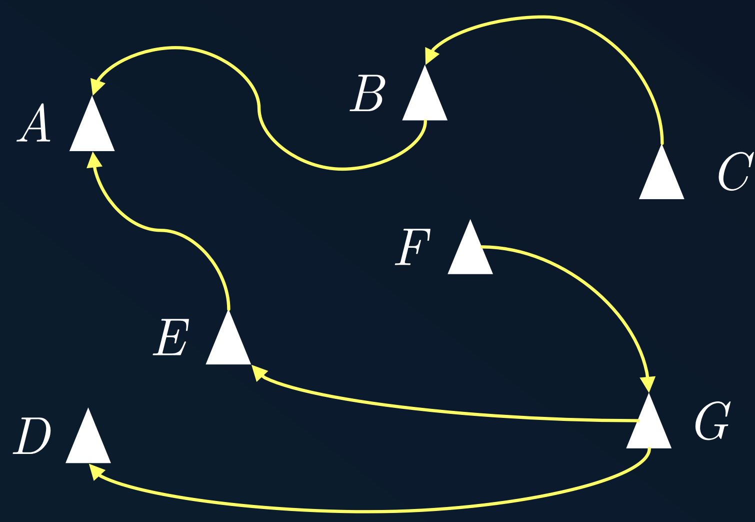
Abstract Argumentation Frameworks

The following is an example of an argumentation framework:

$\mathrm{AF} = < AR, \mathcal{R} >$ where

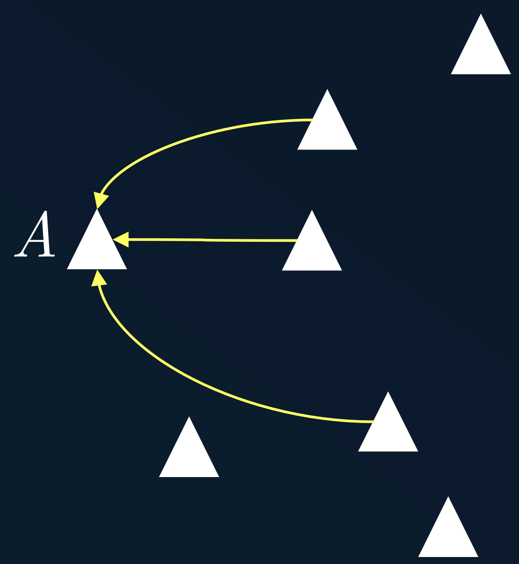
- $AR = \{ A, B, C, D, E, F, G \}$
- $\mathcal{R} = \{(B, A), (C, B), (E, A), (G, E), (F, G), (G,D)\}$

Below, AF *is visualized as a graph: the nodes are labeled by the arguments and the arcs represent the attack relation.*



Acceptability in a Framework

- Given an abstract framework $\mathrm{AF} = < AR, \mathcal{R} >$, a set $S \subseteq AR$ ***attacks*** an argument $A \in AR$ if some argument $B \in S$ attacks A.



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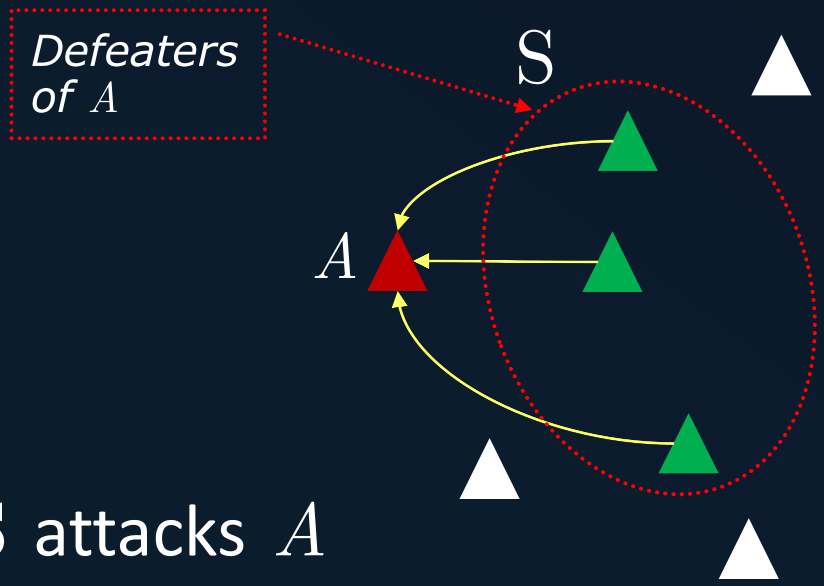
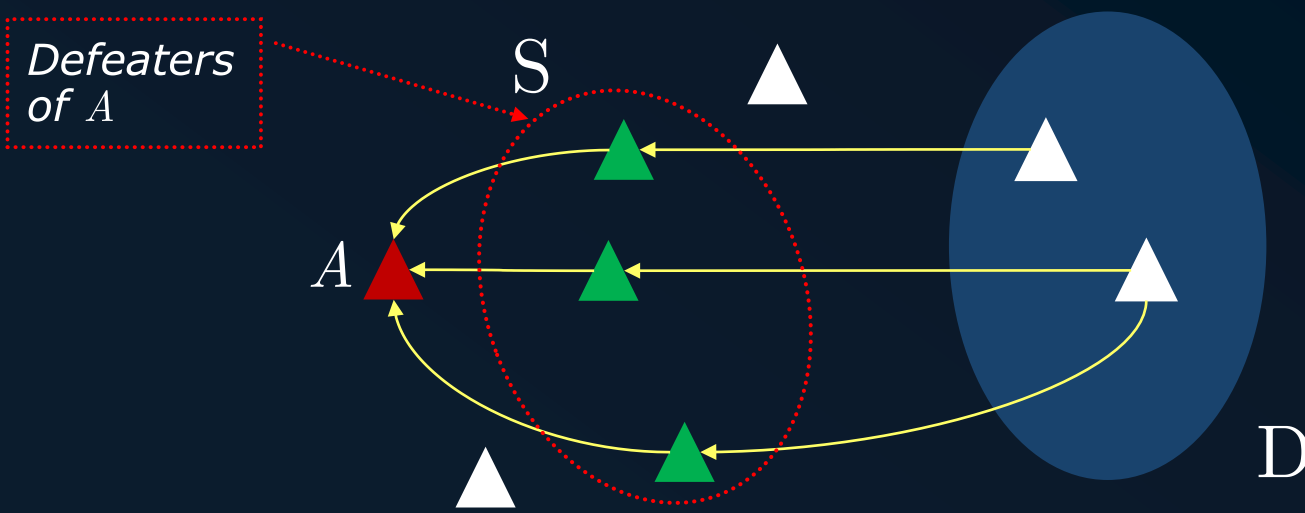


S attacks A

Acceptability in a Framework

- Given an abstract framework $\mathrm{AF} = < AR, \mathcal{R} >$, a set $S \subseteq AR$ ***attacks*** an argument $A \in AR$ if some argument $B \in S$ attacks A.
- An argument $A \in AR$ is ***acceptable with respect to a set*** $\mathrm{D} \subseteq AR$ iff for each argument $B \in AR$, if argument B attacks A then D attacks B.



A is acceptable with respect to D

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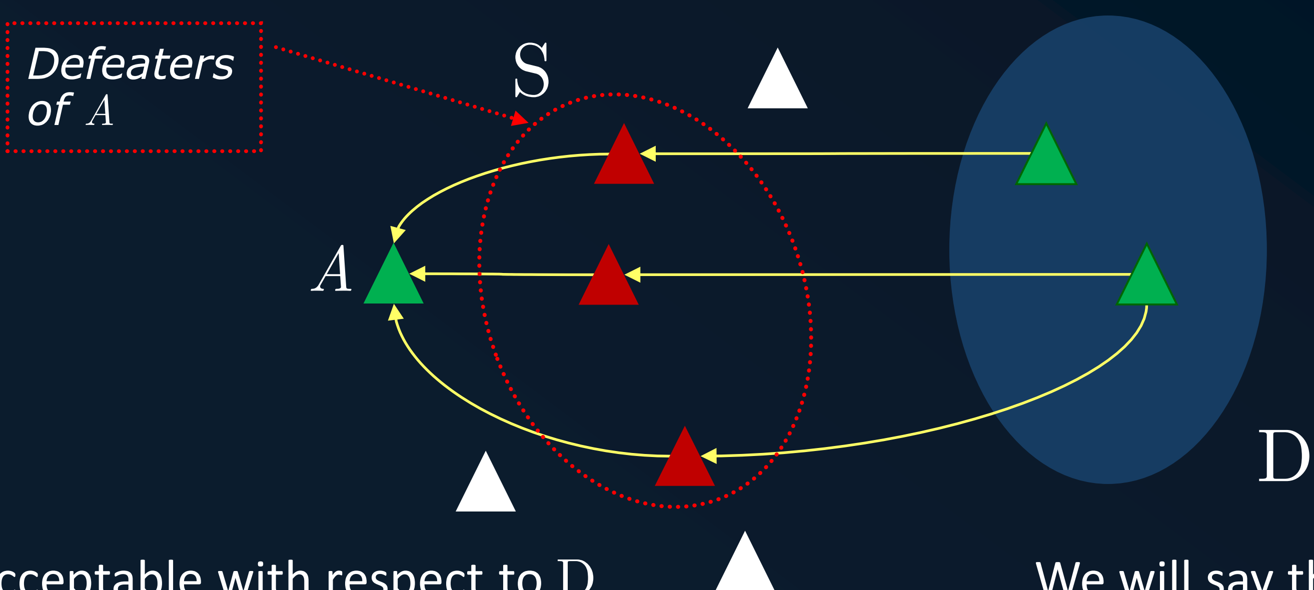
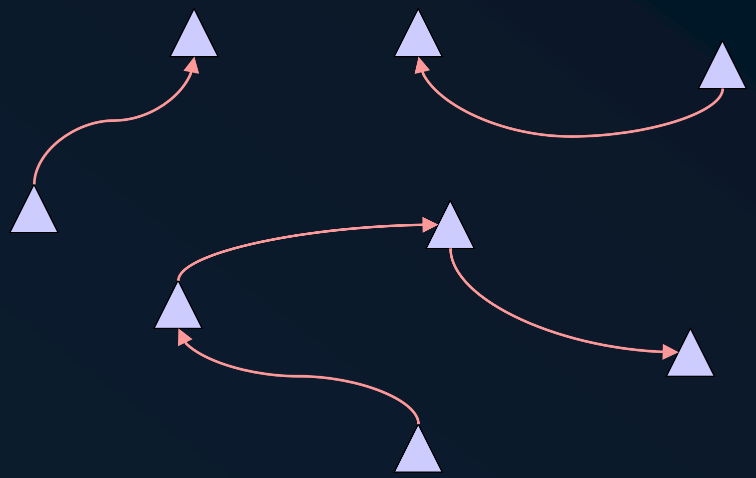


A is acceptable with respect to D

We will say that D defends A.

Acceptability in a Framework

Arguments are classified as justified if all their defeaters are arguments non-justified; they are classified as non-justified if at least one of their defeaters is a justified argument.



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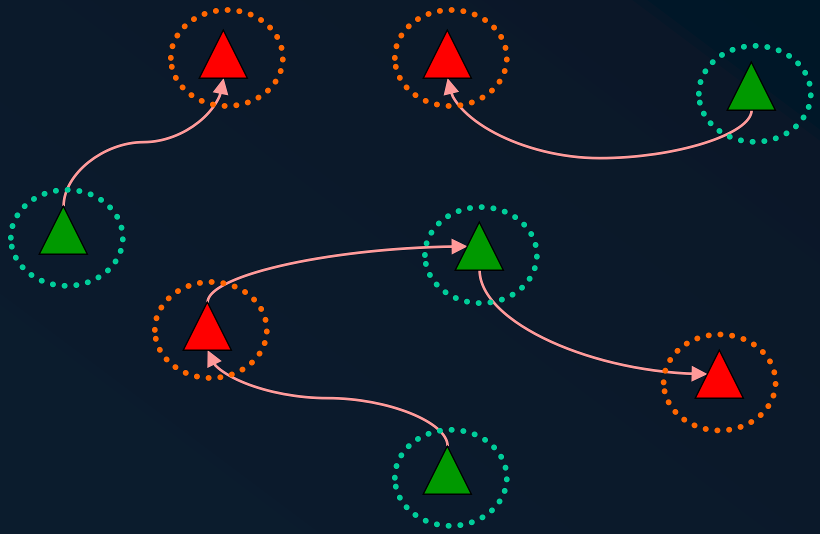

Acceptability in a Framework

- *A set $\mathrm{S} \subseteq AR$ is said to be conflict free iff there are no $A, B \in \mathrm{S}$ such that A attacks B.*
- *A set $\mathrm{S} \subseteq AR$ is said to be admissible iff S is conflict free and defends all its elements. Trivially, the set $\varnothing$ is always admissible.*

Let $\mathrm{AF} = < AR, \mathcal{R} >$ *where*

- $AR = \{\ A,\ B,\ C,\ D,\ E,\ F,\ G\ \}$
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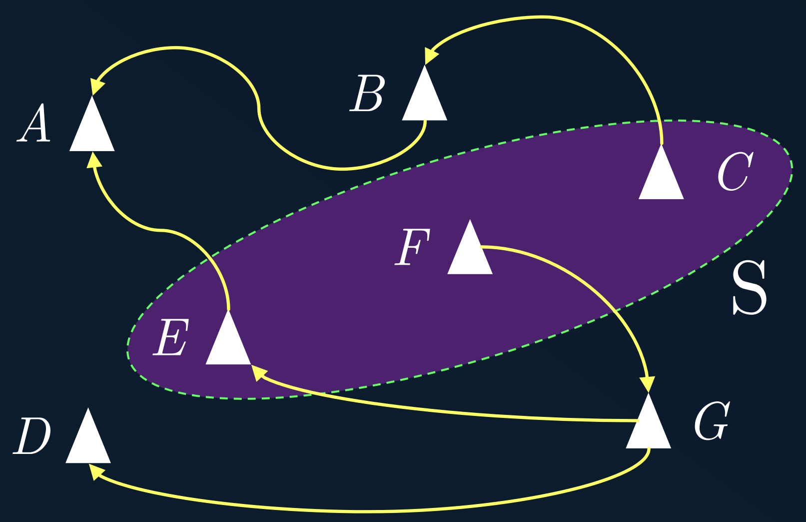

$\mathrm{S} = \{ C,\ E,\ F\ \}$ *is an admissible set.*

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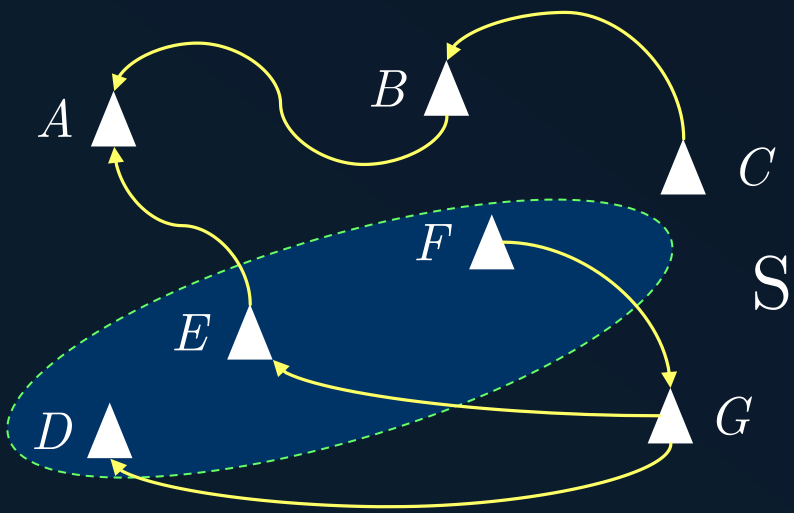

$S = \{D, E, F\}$ *is an admissible set.*

Acceptability in a Framework

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Let $\mathrm{AF} = < AR, \mathcal{R} >$ *where*

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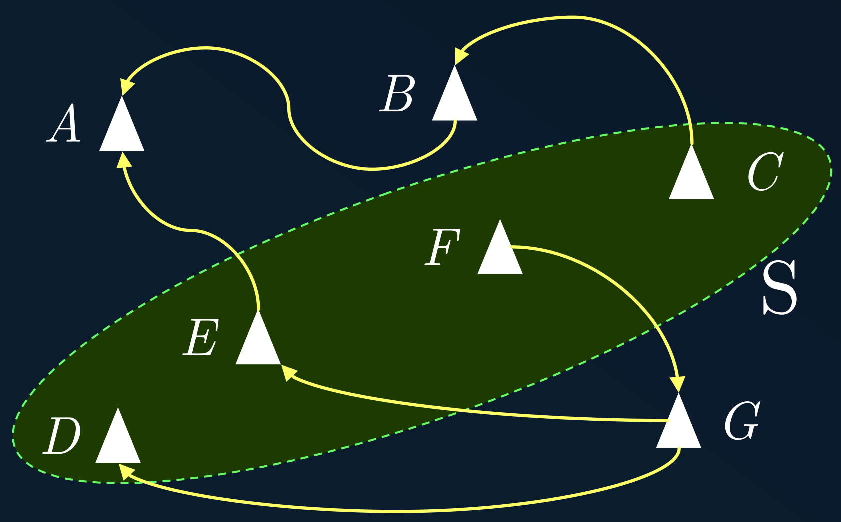

$\mathrm{S} = \{\ C,\ D,\ E,\ F\ \}$ *is an admissible set.*

Acceptability Semantics

- *A set* $\mathrm{S} \subseteq AR$ *is a complete extension iff* S *is an admissible set such that for each argument* $A \in AR$ *defended by* S, A *is in* S.
- *Clearly, every complete extension is an admisible set.*

Let $\mathrm{AF} = < AR, \mathcal{R} >$ *where*

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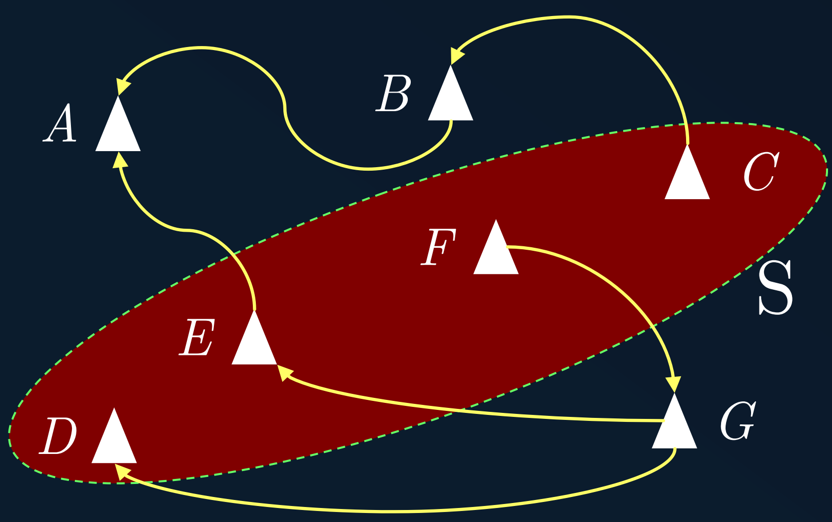

$\mathrm{S} = \{C,\ D,\ E,\ F\}$ *is an admissible set and contains all the arguments it defends, therefore* S *is a complete extension.*

Acceptability Semantics

- *A set* $\mathrm{S} \subseteq AR$ *is a preferred extension iff* S *is a* $\subseteq$*–maximal admissible set.*
- *Every preferred extension is a complete extension.*

Let $\mathrm{AF} = < AR, \mathcal{R} >$ *where*

- $AR = \{\ A,\ B,\ C,\ D,\ E,\ F,\ G\ \}$
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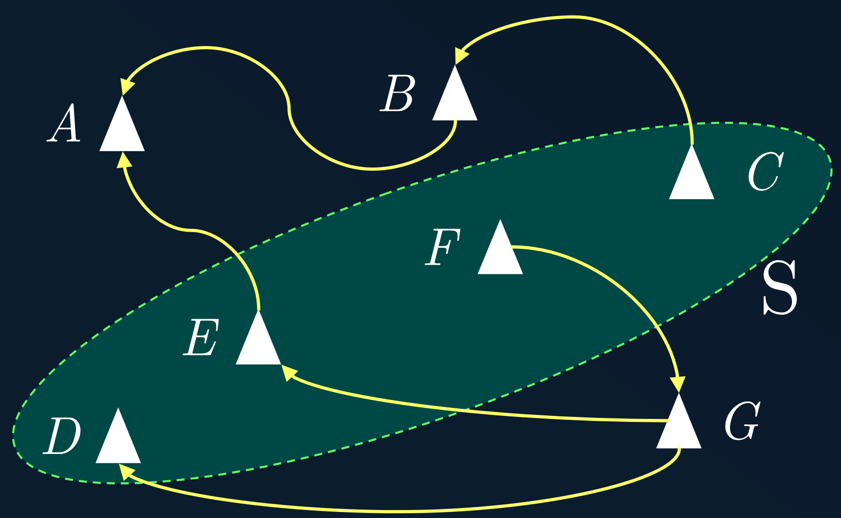

$\mathrm{S} = \{C,\ D,\ E,\ F\ \}$ *is a preferred extension.*

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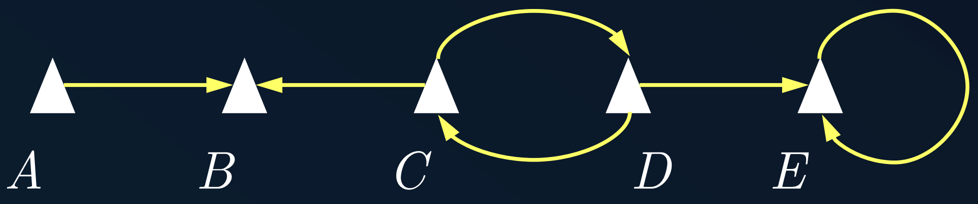

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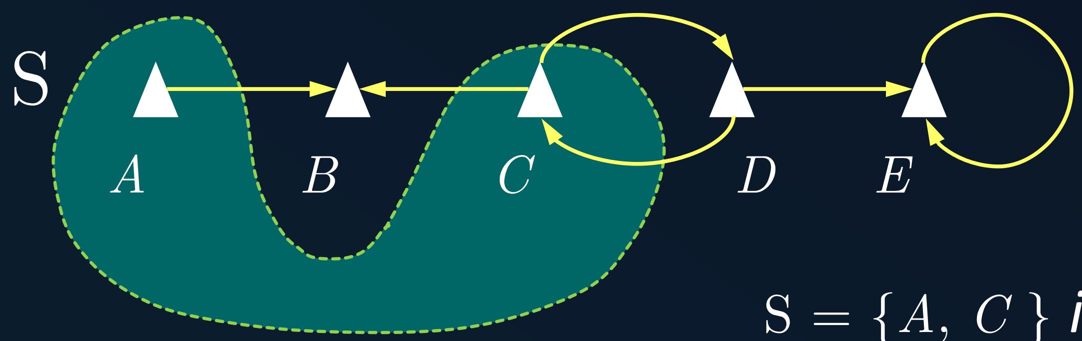

$\mathrm{S} = \{A,\ C\ \}$ *is a preferred extension.*

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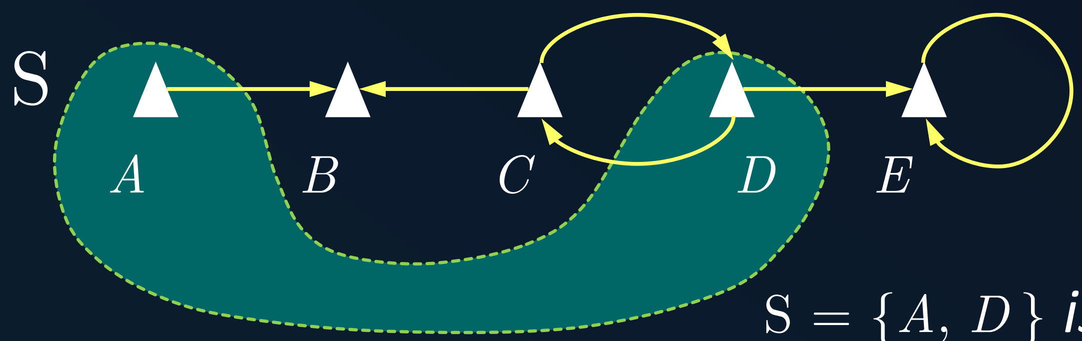


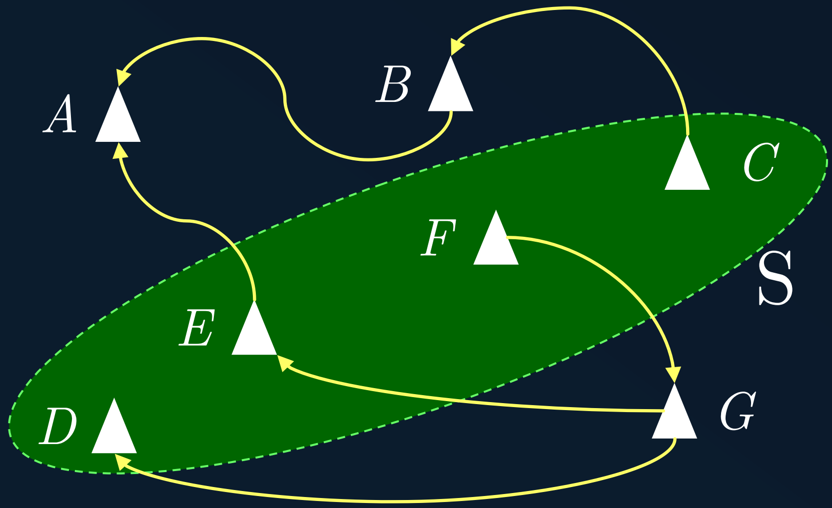
$\mathrm{S} = \{A,\ D\}$ *is a preferred extension.*

Acceptability Semantics

- *A set $\mathrm{S} \subseteq AR$ is a stable extension iff S is conflict-free and attacks every argument which is not in S.*

Let $\mathrm{AF} = < AR, \mathcal{R} >$ *where*

- $AR = \{\ A,\ B,\ C,\ D,\ E,\ F,\ G\ \}$
- $\mathcal{R} = \{(B,\ A),\ (C,\ B),\ (E,\ A),\ (G,\ E),\ (F,\ G),\ (G,D)\}$



$\mathrm{S} = \{C,\ D,\ E,\ F\ \}$ *is a stable extension.*

Acceptability Semantics

- *A set* $\mathrm{S} \subseteq AR$ *is a stable extension iff* S *is conflict-free and attacks every argument which is not in* S.

Let $\mathrm{AF} = < AR, \mathcal{R} >$ *where*

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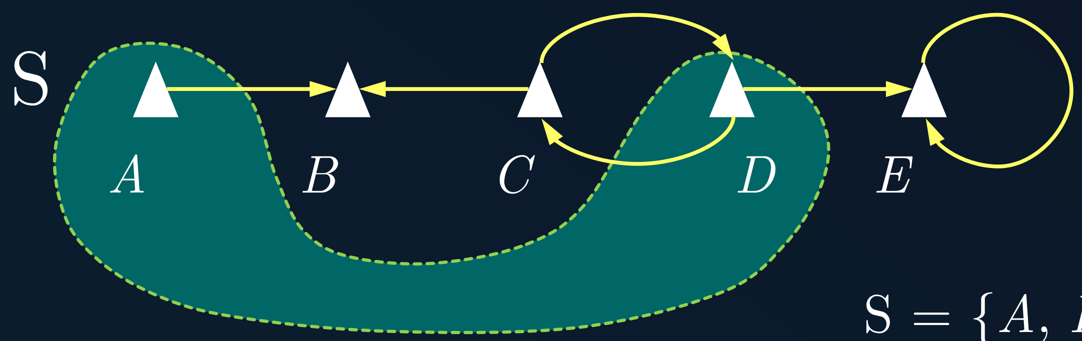

$\mathrm{S} = \{A,\ D\}$ *is a stable extension, and this is the only one.*

Acceptability Semantics

- *A set $\mathrm{S} \subseteq AR$ is a stable extension iff S is conflict-free and attacks every argument which is not in S.*

Let $\mathrm{AF} = < AR, \mathcal{R} >$ *where*

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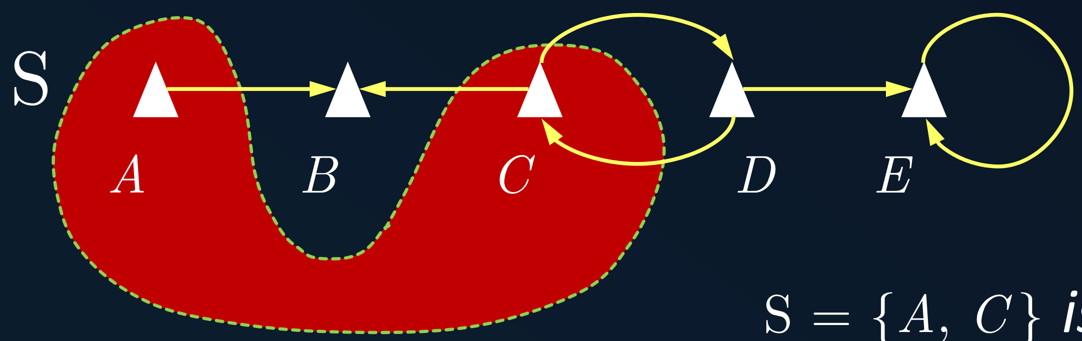

$\mathrm{S} = \{A,\ C\}$ *is not a stable extension because is not attacking argument* E.

Acceptability Semantics

- *A set* $\mathrm{S} \subseteq AR$ *is a stable extension iff* S *is conflict-free and attacks every argument which is not in* S*.*

Let $\mathrm{AF} = < AR, \mathcal{R} >$ *where*

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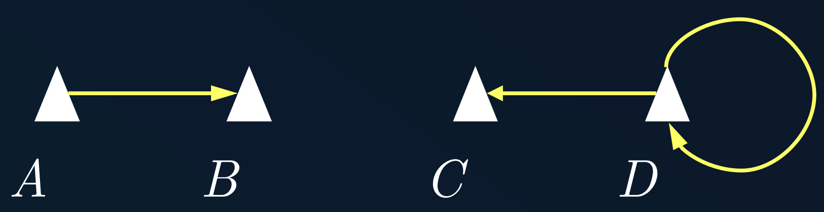


This framework has no estable extension.
But, $\{A\}$ *is complete and preferred.*

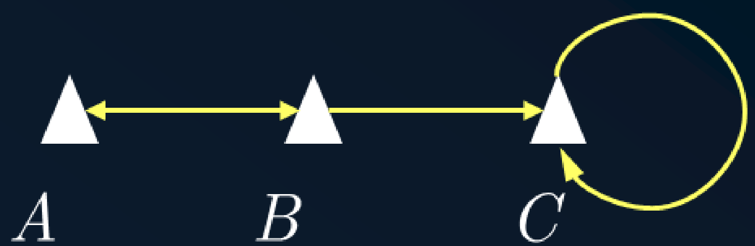
Acceptability Semantics

- *A set $\mathrm{S} \subseteq AR$ is a semi-stable extension iff S is a complete extension and for all complete extensions S' it holds that $\mathrm{S} \cup \mathrm{S}^{+} \subsetneq \mathrm{S}' \cup \mathrm{S}'^{+}$*

  (*where for* $\mathrm{X} \subseteq AR$, $\mathrm{X}^{+} = \{A \in AR \mid A$ *attacks* $\mathrm{X}\}$)

Let $\mathrm{AF} = < AR, \mathcal{R} >$ *where*

$AR = \{A, B, C\}, \mathcal{R} = \{(A, B), (B, A), (B, C), (C, C)\}$



The set $\{B\}$ is the only semi-stable extension, and it is also a stable extension.

$\{A\}$ *is complete, but* $\{A\} \cup \{A\}^{+} = \{A\} \cup \{B\} = \{A, B\}$ *is a subset of* $\{B\} \cup \{B\}^{+} = \{B\} \cup \{A, C\} = \{A, B, C\}$

$\mathrm{S} \subseteq AR$ (*minimality and maximality are w.r.t.* $\subseteq$)

- *is an admissible extension iff* S *is conflict-free and defends all arguments* $A \in \mathrm{S}$.
- *is a complete extension iff* S *is conflict-free and contains all the arguments it defends.*
- *is a grounded extension iff* S *is a minimal complete extension.*
- *is a preferred extension iff* S *is a maximal complete extension.*

$\mathrm{S} \subseteq AR$ (*minimality and maximality are w.r.t.* $\subseteq$)

– *is a stable extension iff* S *is a complete argument extension and* $\mathrm{S} \bigcup \mathrm{S}^{+} = AR$*.*

– *is a semi-stable extension iff* S *is a complete extension and for all complete extensions* S', $\mathrm{S} \bigcup \mathrm{S}^{+} \subsetneq \mathrm{S}' \bigcup \mathrm{S}'^{+}$.

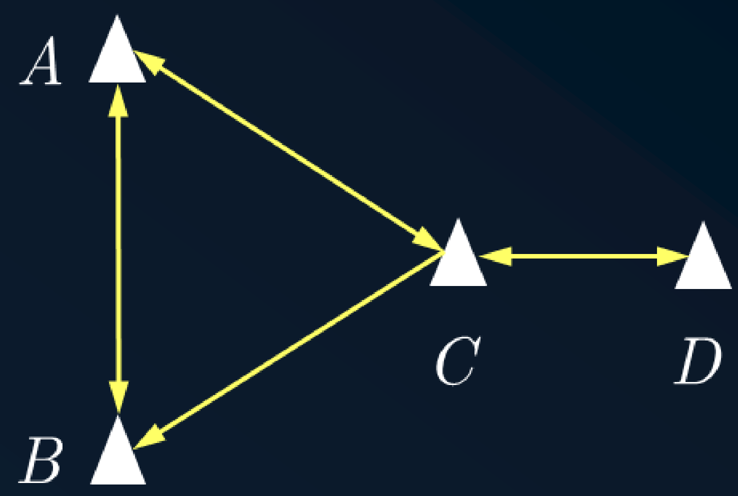
– *is an ideal extension iff* S *is a maximal admissible extension satisfying that for all preferred extensions* S', $\mathrm{S} \subseteq \mathrm{S}'$.

Acceptability Semantics

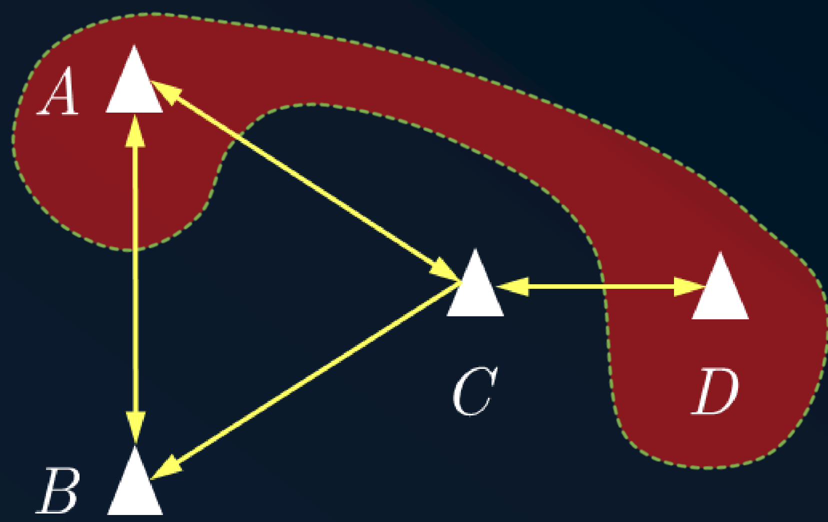
- *Ideal vs. Grounded extensions.*

Let $\mathrm{AF} = < AR, \mathcal{R} >$ *where*

- $AR = \{\ A,\ B,\ C,\ D\ \}$
- $\mathcal{R} = \{(A,\ B),\ (B,\ A),\ (A,\ C),\ (C,\ A),\ (B,\ C),\ (C,\ B),\ (C,\ D),\ (D,\ C)\}$



- *is a complete extension iff* S *is conflict-free and contains all the arguments it defends.*
- *is a grounded extension iff* S *is a minimal complete extension.*
- *is a preferred extension iff* S *is a maximal complete extension.*
- *is an ideal extension iff* S *is a maximal admissible extension satisfying that for all preferred extensions* S', $\mathrm{S} \subseteq \mathrm{S}'$.

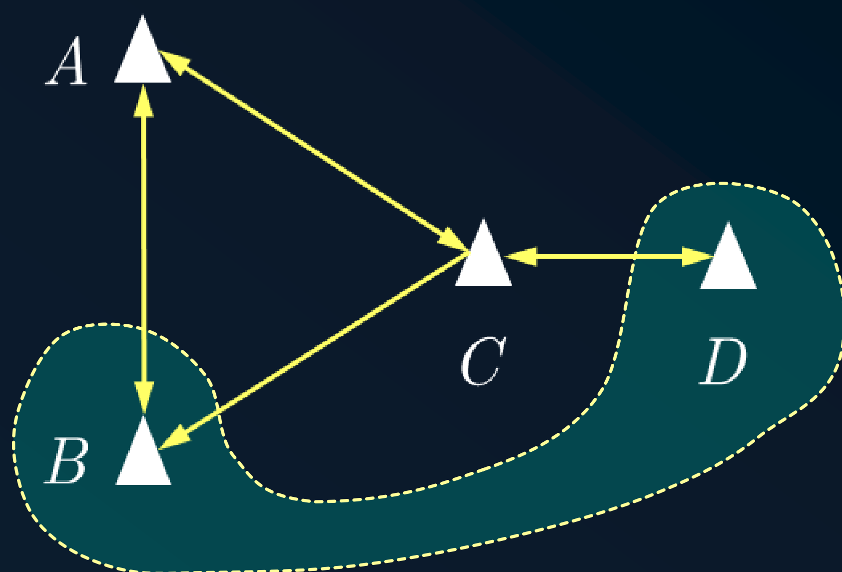


$\{A,\ D\}$ *and* $\{B,\ D\}$ *are preferred, thus* $\{D\}$ *is ideal.*
There is no grounded extension.

- is a *complete extension* iff S is conflict-free and contains all the arguments it defends.
- is a *grounded extension* iff S is a minimal complete extension.
- is a *preferred extension* iff S is a maximal complete extension.
- is an *ideal extension* iff S is a maximal admissible extension satisfying that for all preferred extensions S', $\mathrm{S} \subseteq \mathrm{S}'$.

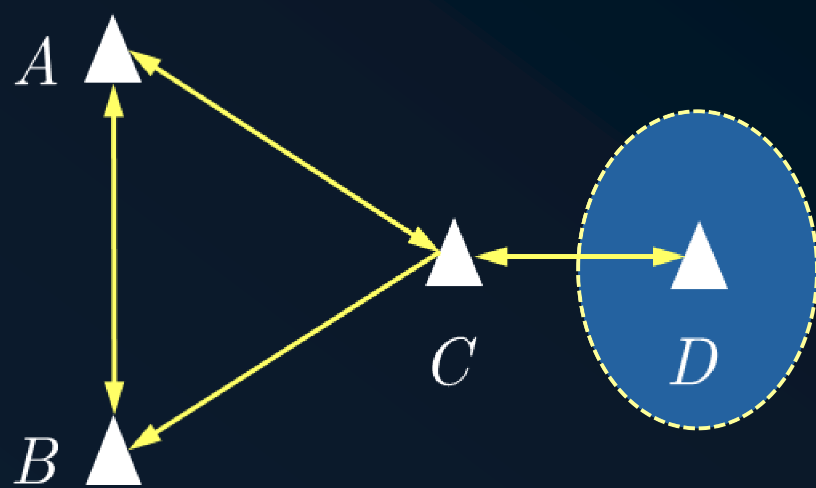
Le

- $R = \{(A, B), (B, A), (A, C), (C, A), (B, C), (C, B), (C, D), (D, C)\}$



$\{A,\ D\}$ and $\{B,\ D\}$ are preferred, thus $\{D\}$ is ideal.
There is no grounded extension.

- *is a* *complete extension* *iff* S *is conflict-free and contains all the arguments it defends.*
- *is a* *grounded extension* *iff* S *is a minimal complete extension.*
- *is a* *preferred extension* *iff* S *is a maximal complete extension.*
- *is an* *ideal extension* *iff* S *is a maximal admissible extension satisfying that for all preferred extensions* S', $\mathrm{S} \subseteq \mathrm{S}'$.



$\{A,\ D\}$ and $\{B,\ D\}$ are preferred, thus $\{D\}$ is ideal.
There is no grounded extension.

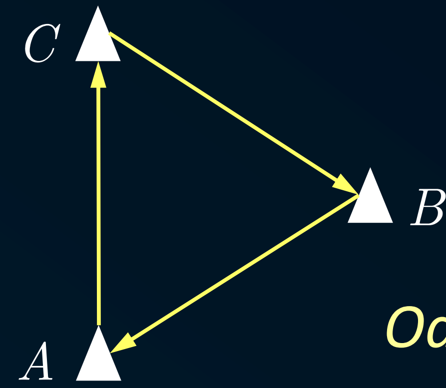
Cycles

- *Cycles in a graph can be even or odd.*

AF_1

Even Cycle

AF_2



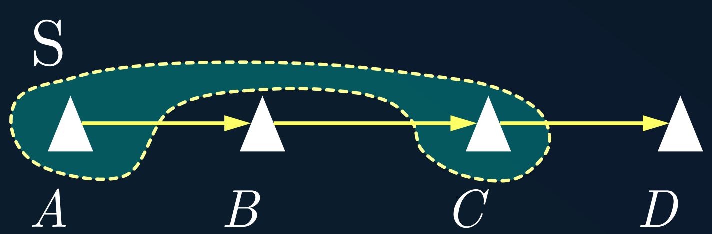
Odd Cycle

Framework AF_1 has two preferred extensions $\mathrm{S}_1=\{A\}$ and $\mathrm{S}_2=\{B\}$

Framework AF_2 has one preferred extension $\mathrm{S}=\{\ \}$

Finite frameworks without cycles have a single extension and this extension is complete, preferred, and stable.

AF_3



Framework AF_3 has one extension $\mathrm{S} = \{A,\ C\}$

Remarks

- *Abstract argumentation frameworks represent a formalism that has been intensely studied.*
- *Several different connections with logic programming have been investigated.*
- *There are other semantics not mentioned here: CF2, Prudent, Stage, etc.*

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Thank you!

Questions?