An Introduction to Formal Argumentation Theory

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Research Agenda: Argumentation for Explainable Inference

- Formal Argumentation has its roots in Non Monotonic Reasoning (NMR)
- The idea is how to reason with "rules of thumb"
- Many formalisms for NMR can be captured by formal argumentation
- One of the aims of formal argumentation is to bridge the gap between human reasoning and automated inference

An Example [Prakken]

Paul: My car is very safe.
Olga: Why?
Paul: Since it has an airbag.
Olga: It is true that your car has an airbag, but I do not think that this makes your car safe, because airbags are unreliable: the newspapers had several reports on cases where airbags did not work.
Paul: I also read that report but a recent scientific study showed that cars with airbags are safer than cars without airbags, and scientific studies are more important than newspaper reports.

Arguments and attacks

Argument: expresses one or more reasons that lead to a proposition

$a, b, c \Rightarrow d$ or $a, b \Rightarrow c;\ c \Rightarrow d$

An argument can *attack* another argument

rebutting attack:

attack one of the *conclusions* of the other argument:

$e, f, g \Rightarrow \neg d$ against $a, b, c \Rightarrow d$

undercutting attack:

attack the *reasons* of the other argument

$e, f, g \Rightarrow [a, b, c \not\Rightarrow d]$ against $a, b, c \Rightarrow d$

Example

A: My car is very safe, since it has an airbag:

$$has\_airbag \Rightarrow safe$$

B: The newspapers say that airbags are not reliable, so having an airbag is not a good reason why your car is safe

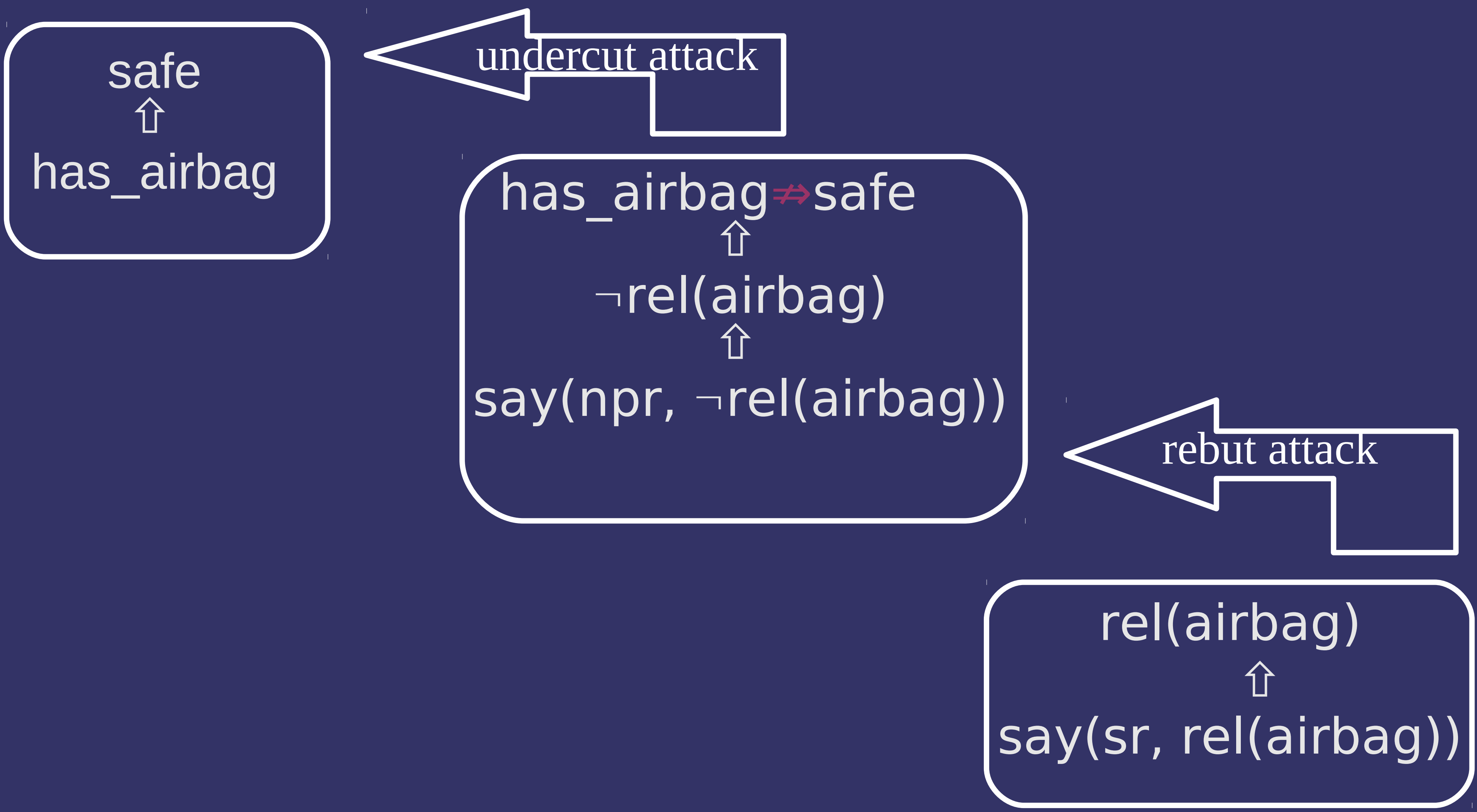
$$say(npr, \neg rel(airbag)) \Rightarrow \neg rel(airbag)$$

$$\neg rel(airbag) \Rightarrow [has\_airbag \not\Rightarrow safe]$$

C: Scientific reports say that airbags are reliable.

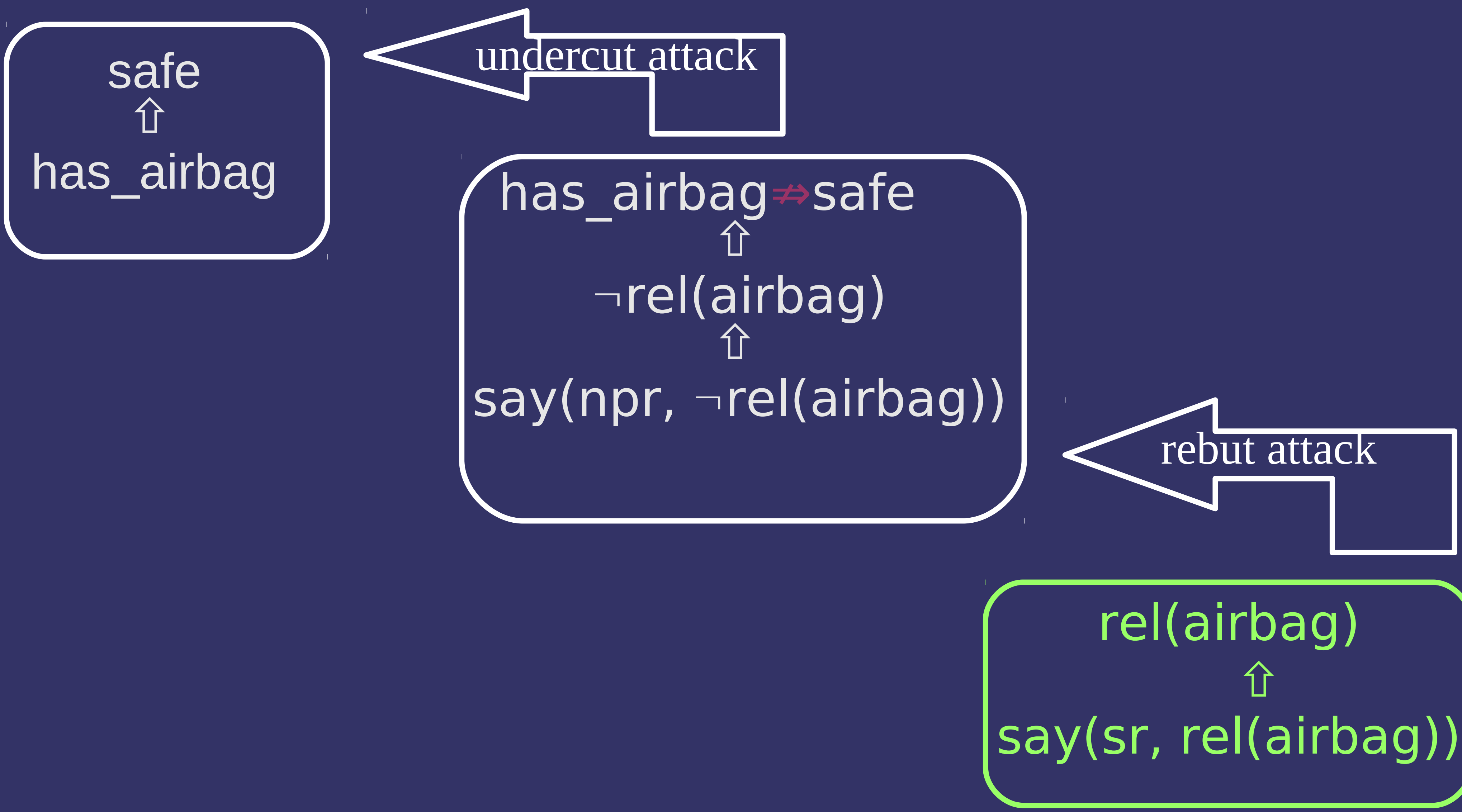
$$say(sr, rel(airbag)) \Rightarrow rel(airbag)$$

Example



safe
has_airbag
undercut attack
has_airbag ⇏ safe
¬rel(airbag)
say(npr, ¬rel(airbag))
rebut attack
rel(airbag)
say(sr, rel(airbag))

Example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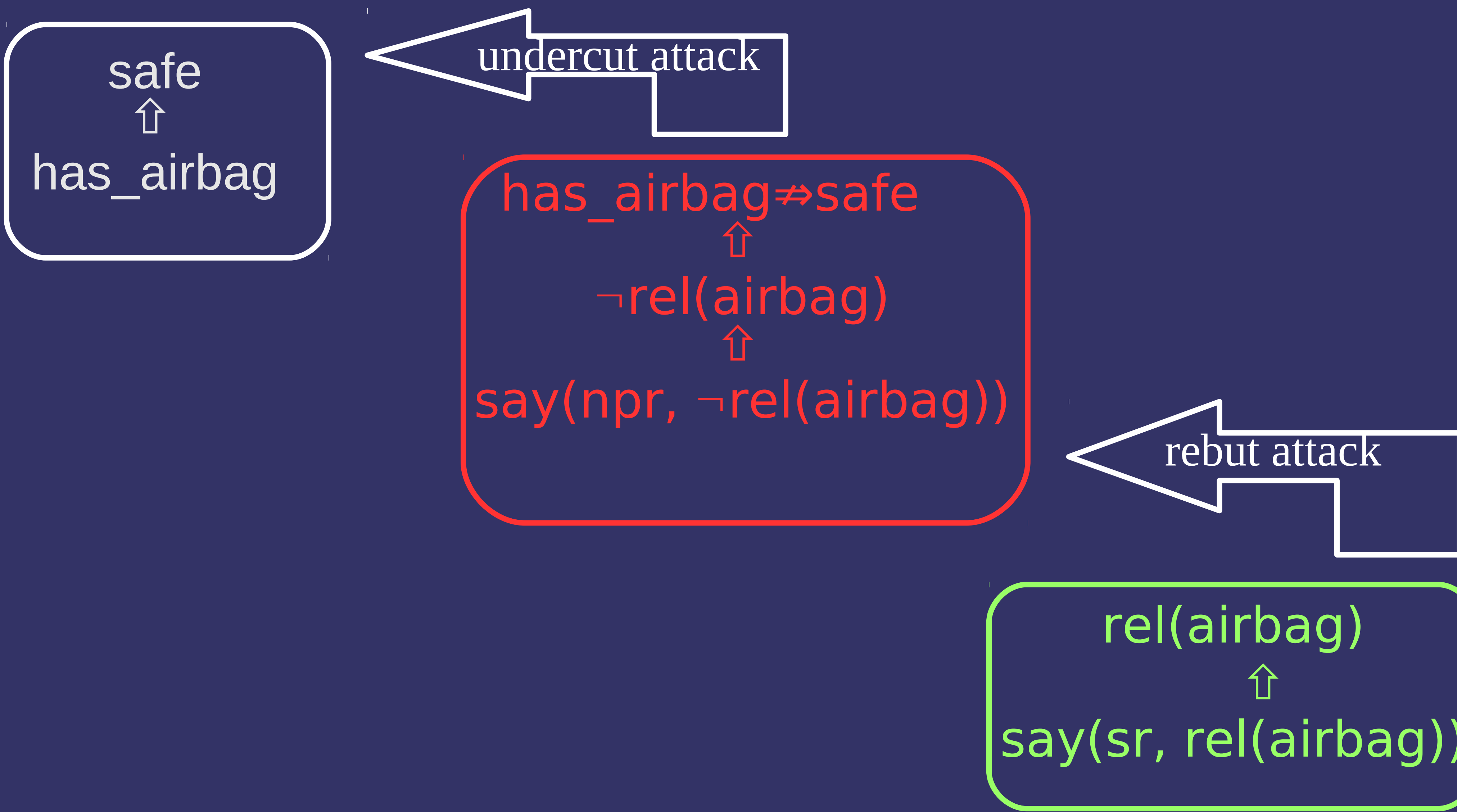
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Example

safe
$\Uparrow$
has_airbag

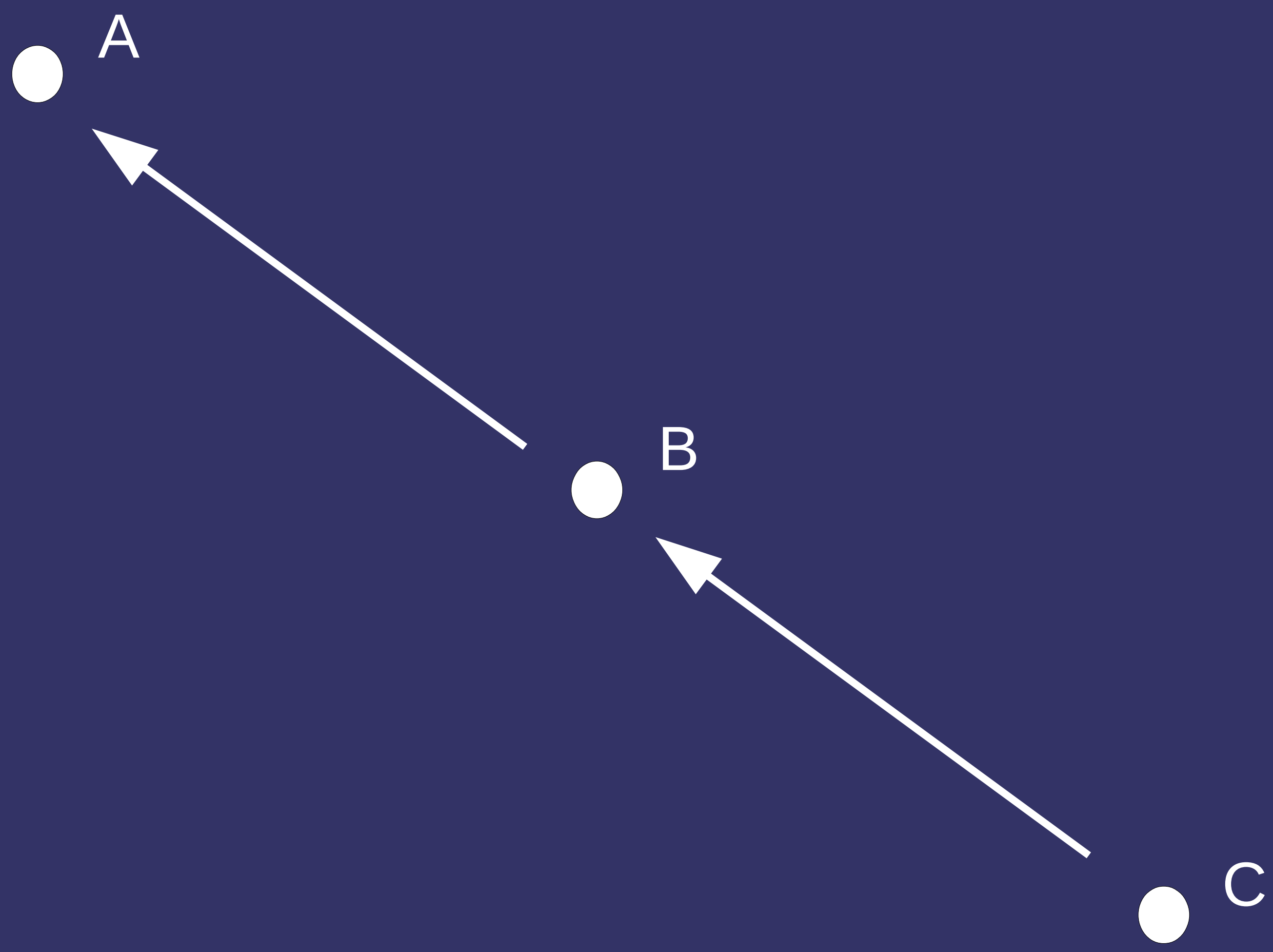
undercut attack

has_airbag$\not\Rightarrow$safe
$\Uparrow$
$\neg$rel(airbag)
$\Uparrow$
say(npr, $\neg$rel(airbag))

rebut attack

rel(airbag)
$\Uparrow$
say(sr, rel(airbag))

Abstraction



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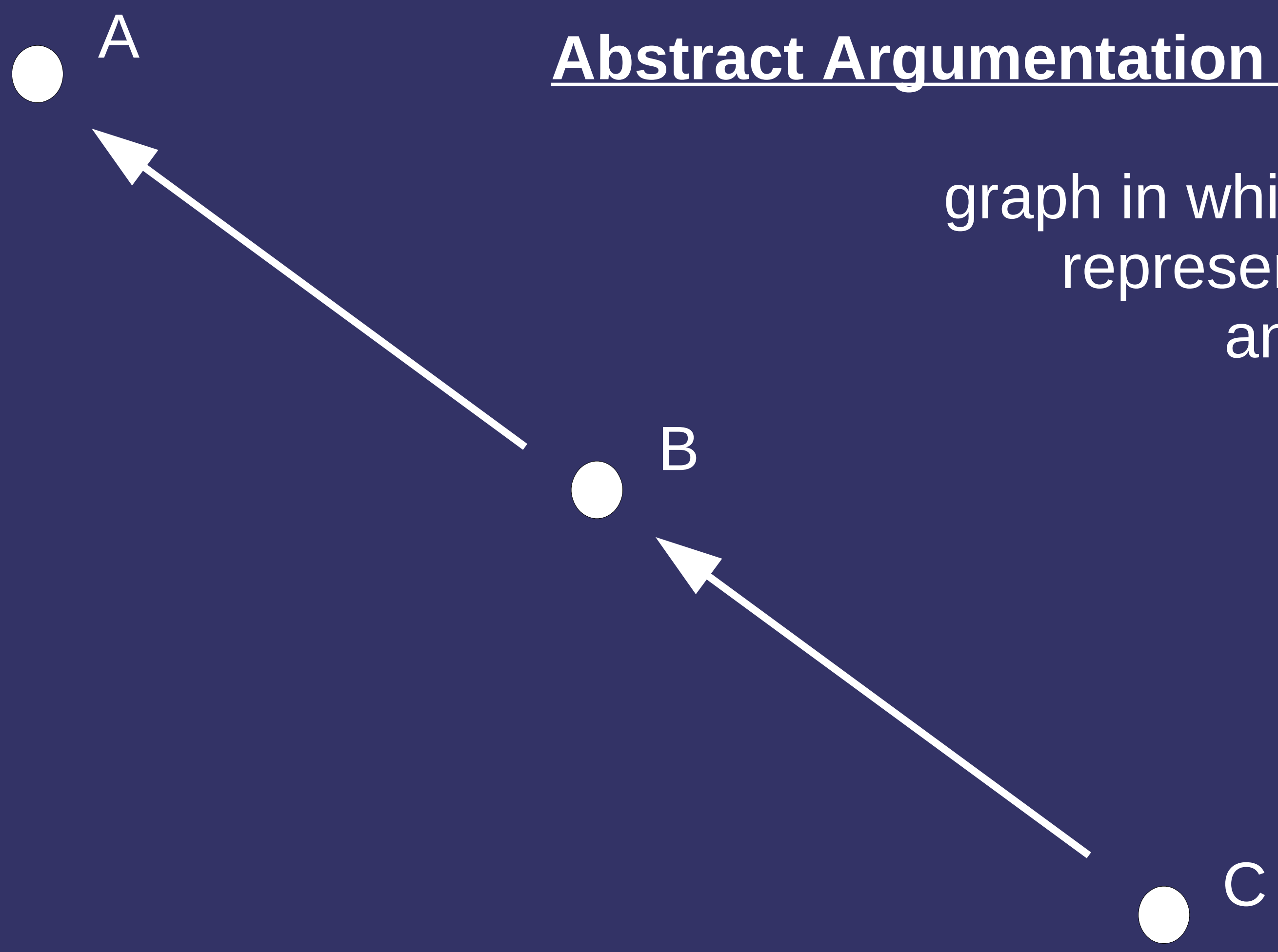

Abstract Argumentation Framework:

graph in which the nodes represent arguments and the arrows represent attacks

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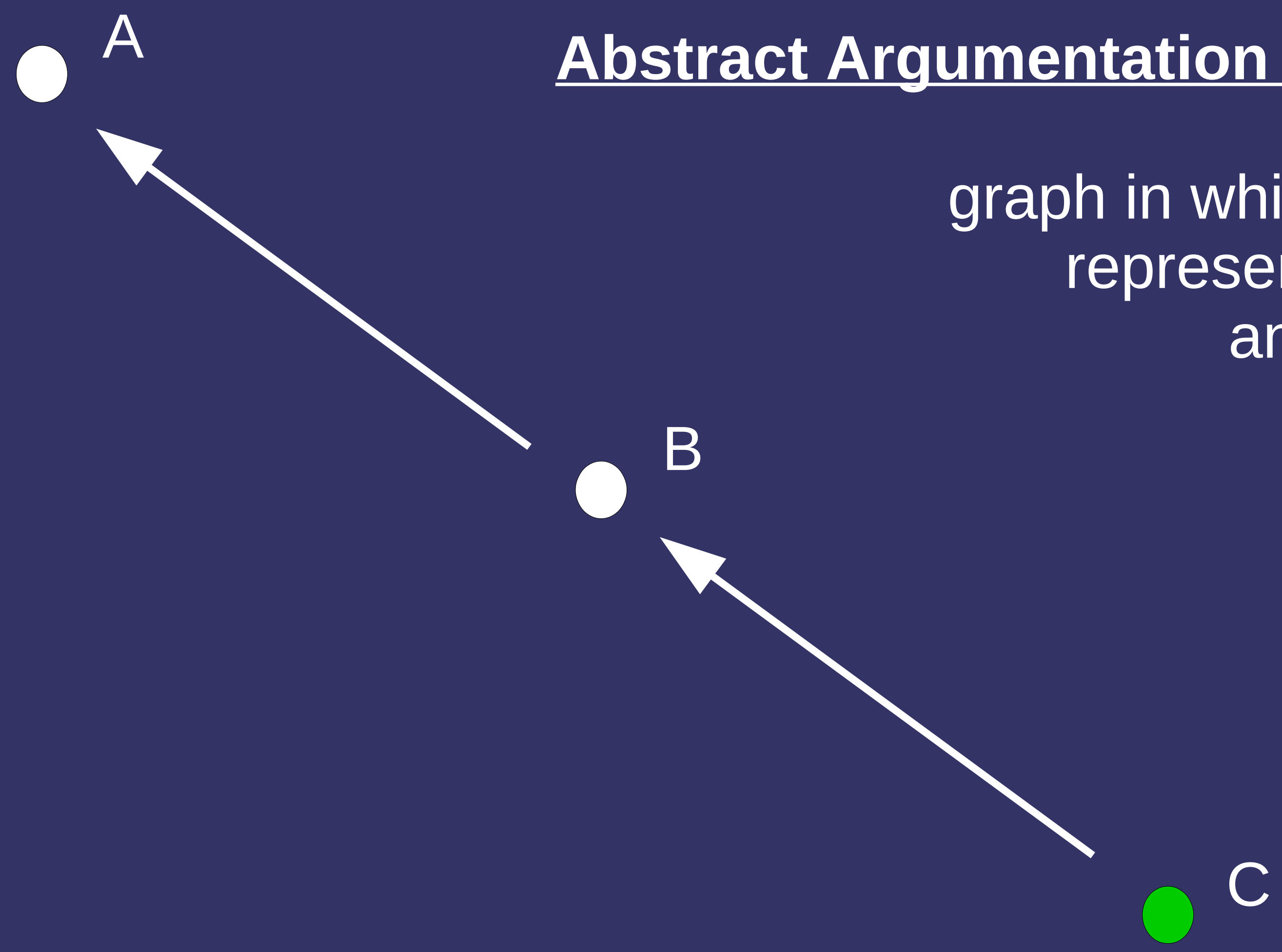

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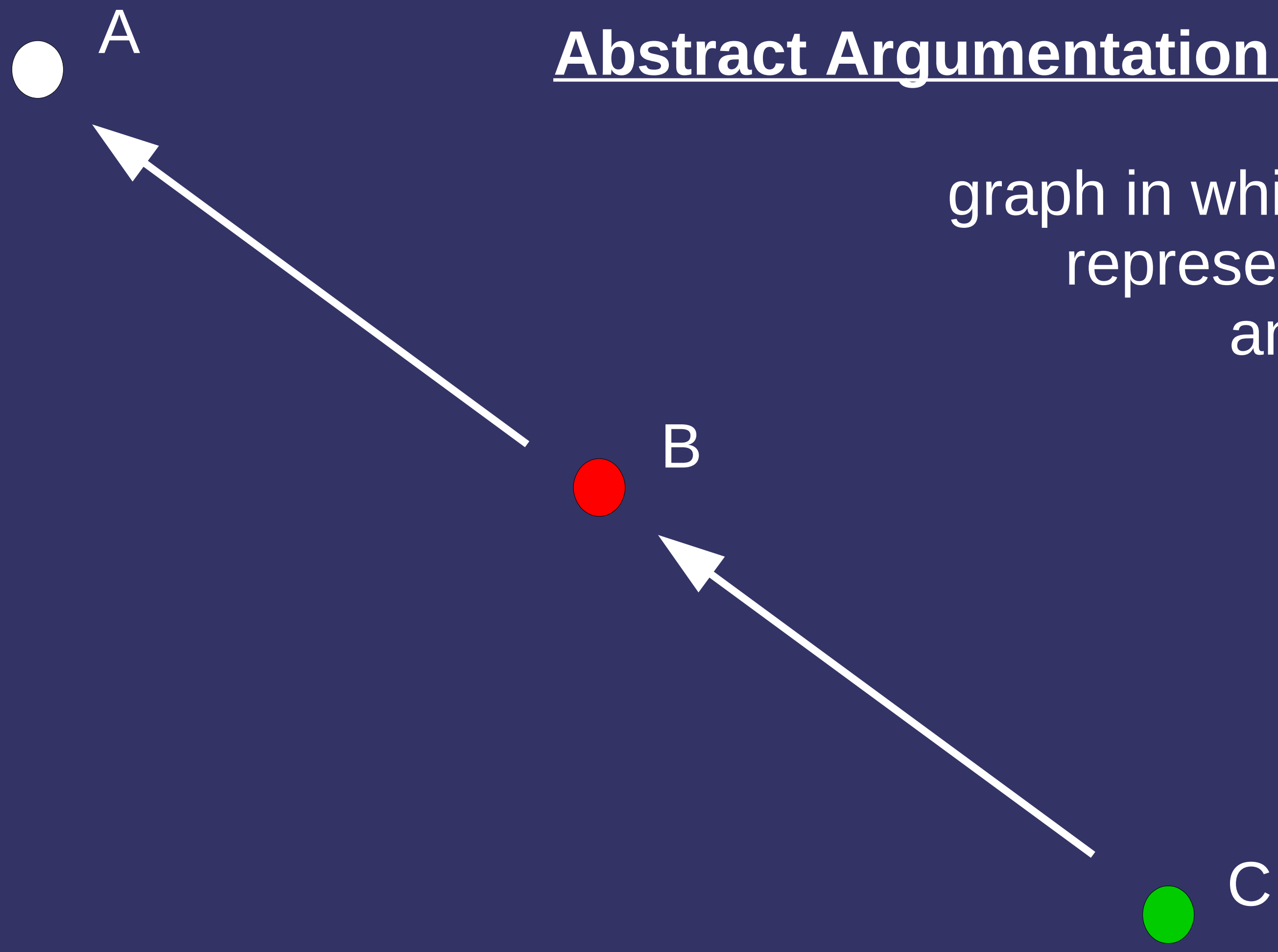

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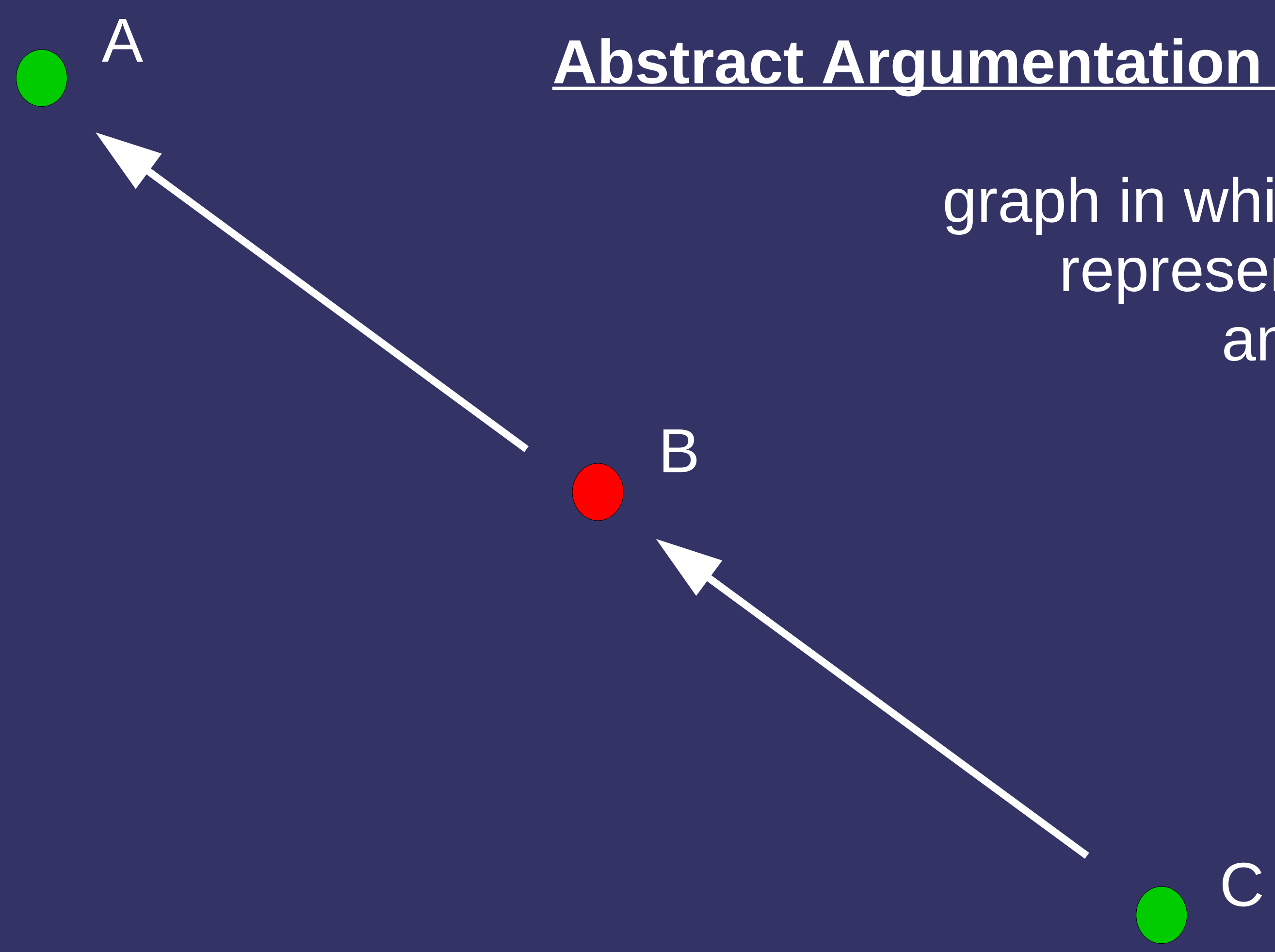


Abstract Argumentation Framework:

graph in which the nodes represent arguments and the arrows represent attacks

Next Topic

How do we evaluate an argumentation framework?

(“*argumentation semantics*”)

Argument Labellings

Each argument is labelled in, out or undec

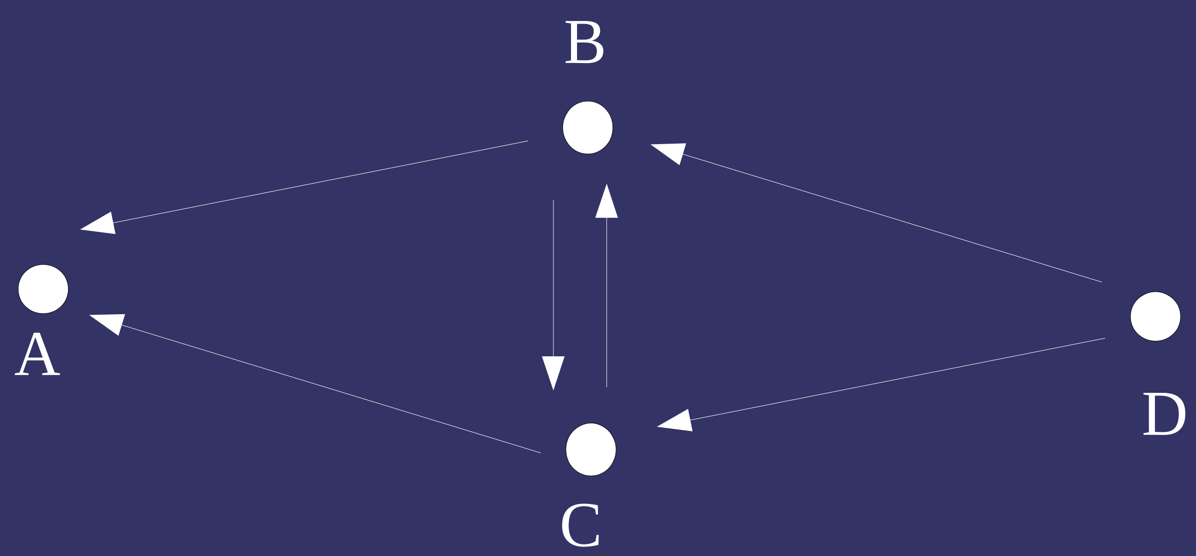
an argument is in ⇔
all its attackers are out

an argument is out ⇔
it has an attacker that is in

an argument is undec ⇔
<u>not</u> all its attackers are out
and it does <u>not</u> have an attacker that is in

Applying Argument Labellings (1/3)

in ⇔ all attackers are out
out ⇔ there is an attacker that is in
undec ⇔ not all attackers are out, and no attacker is in



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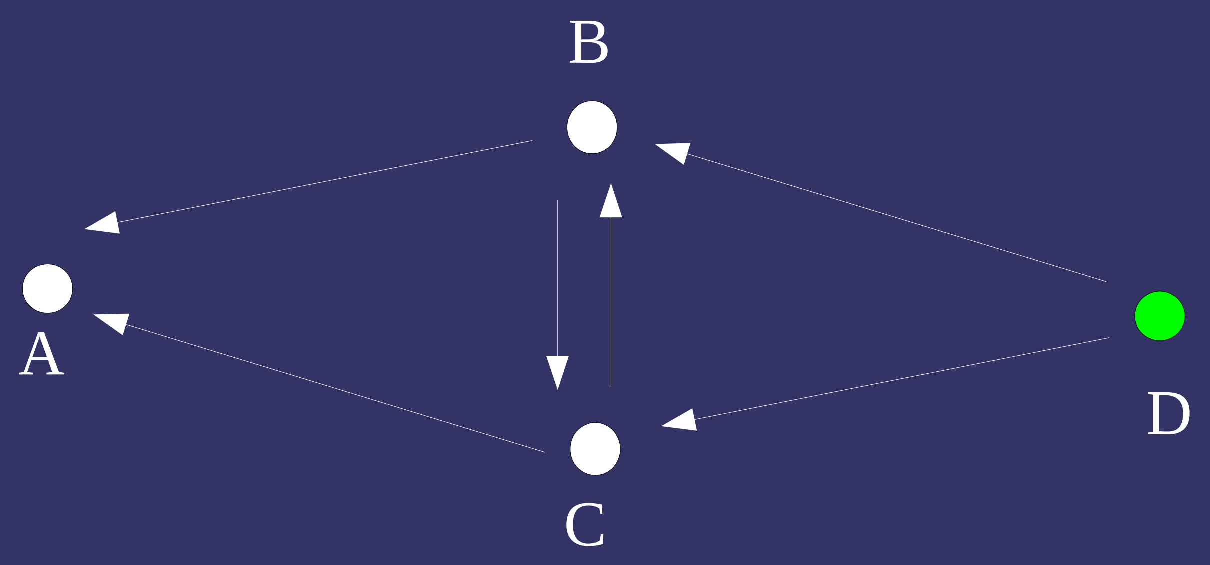

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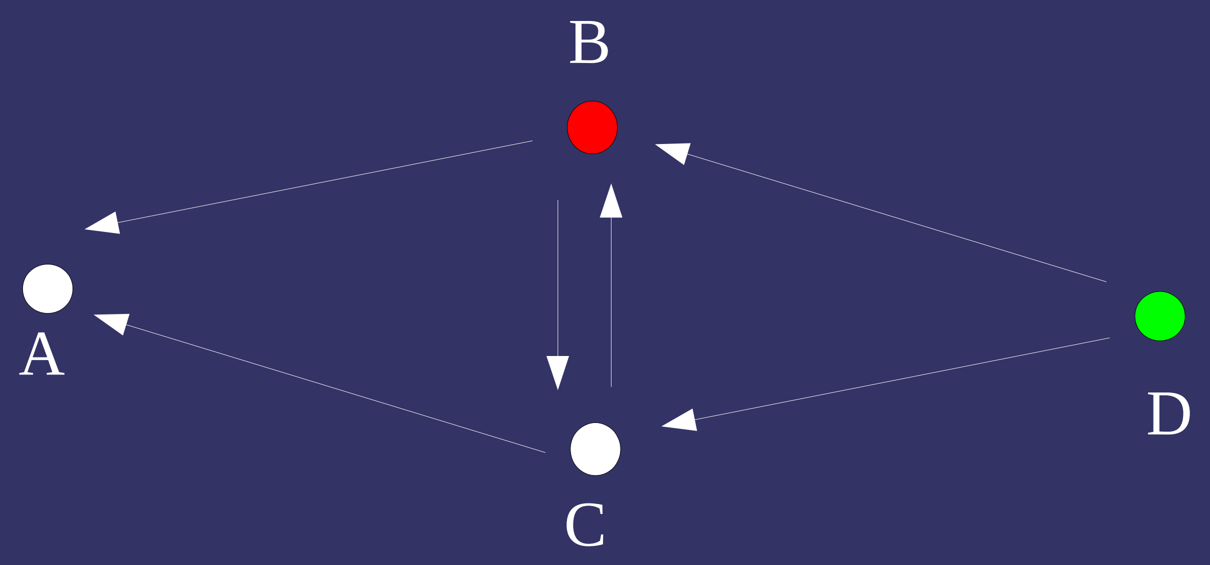

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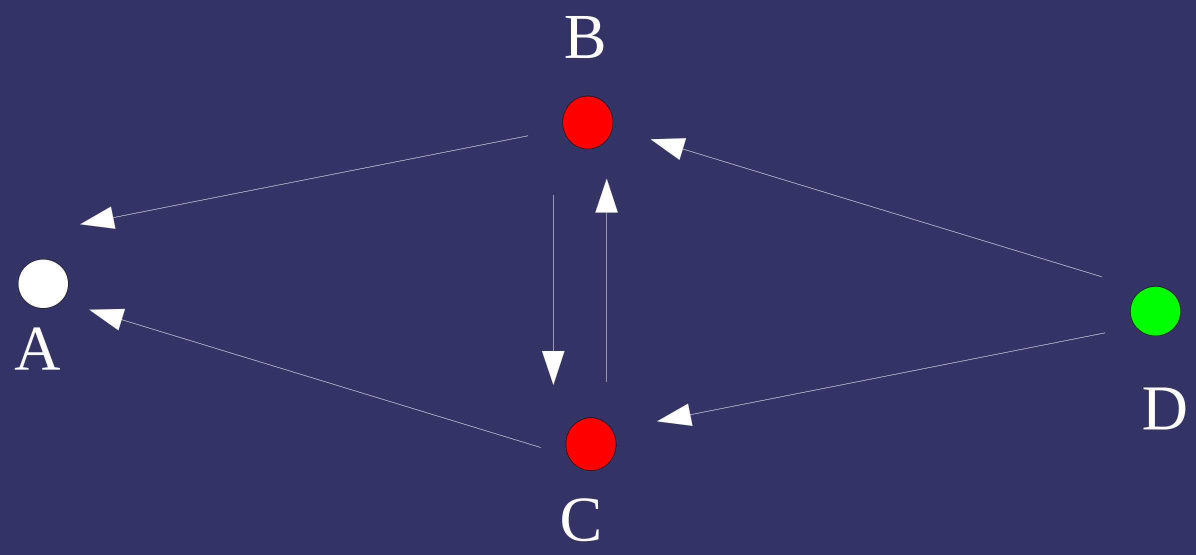

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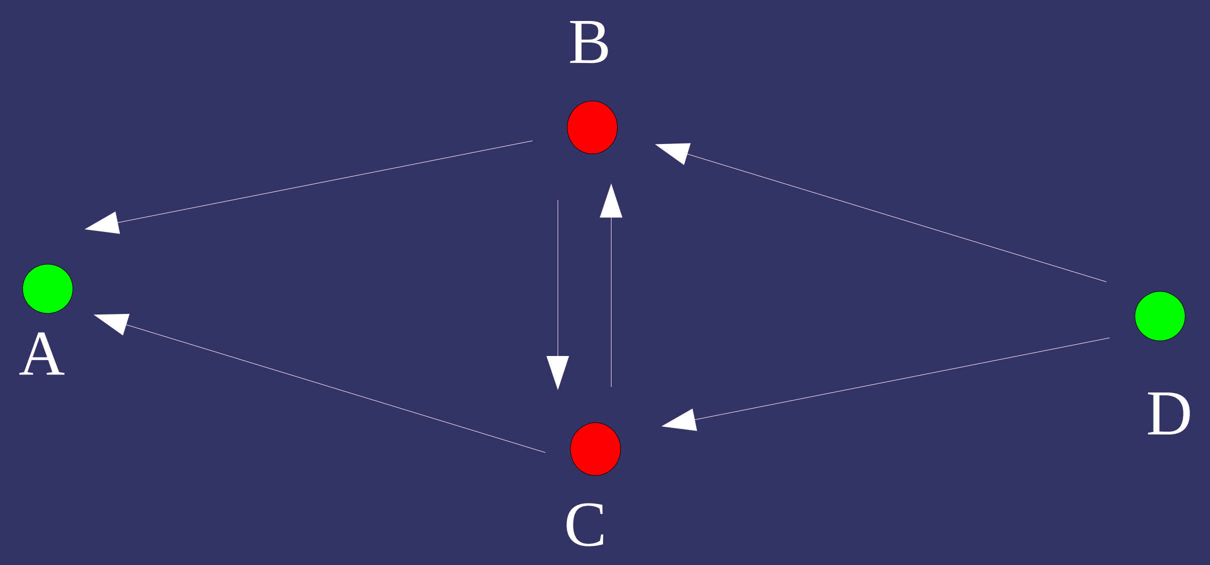
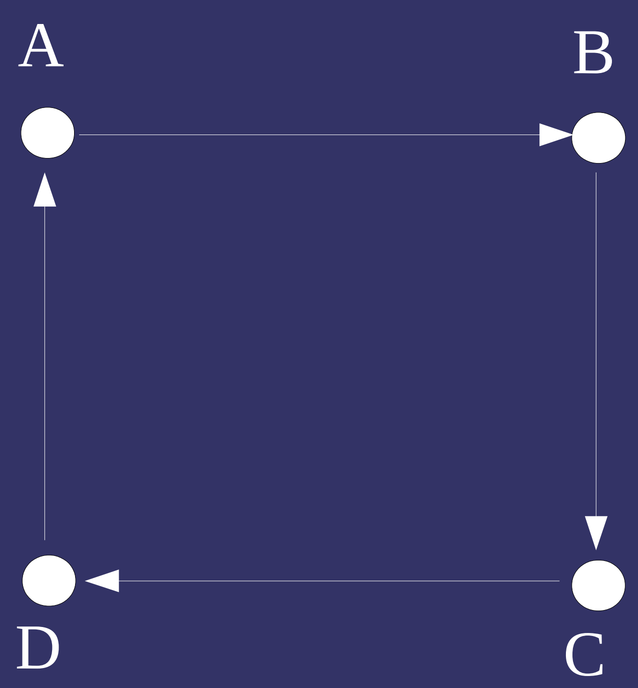


Applying Argument Labellings (2/3)



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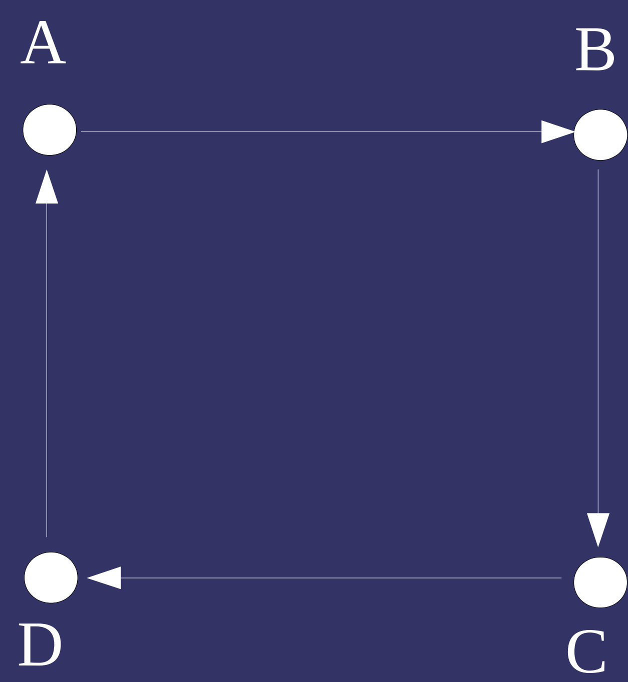

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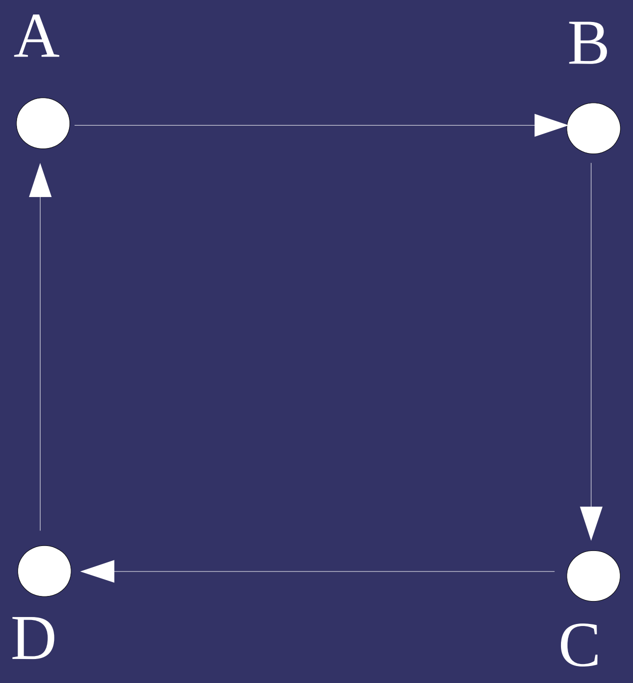

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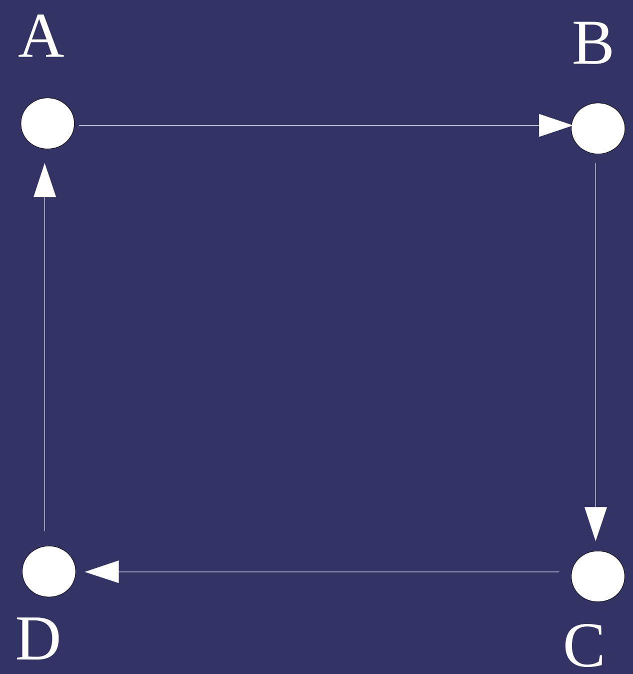

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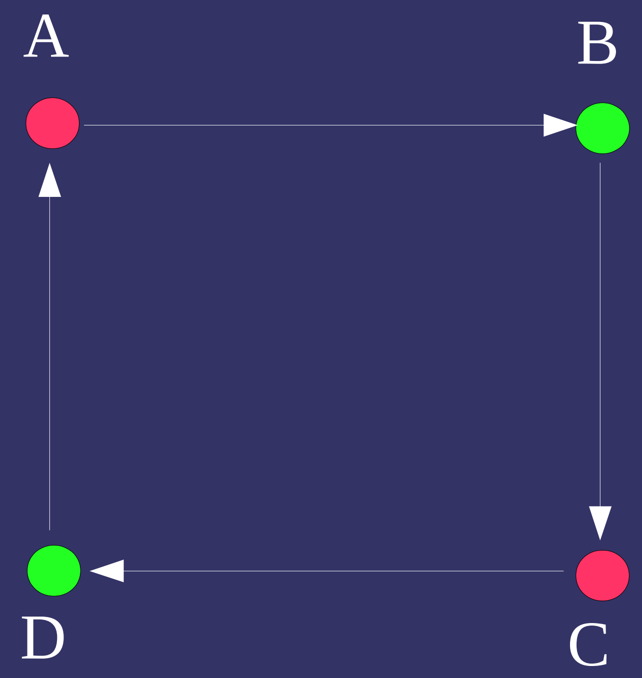

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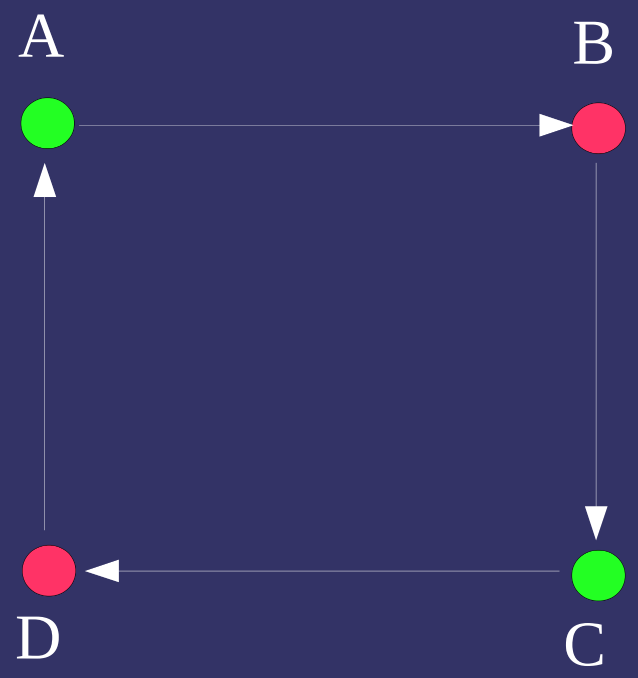

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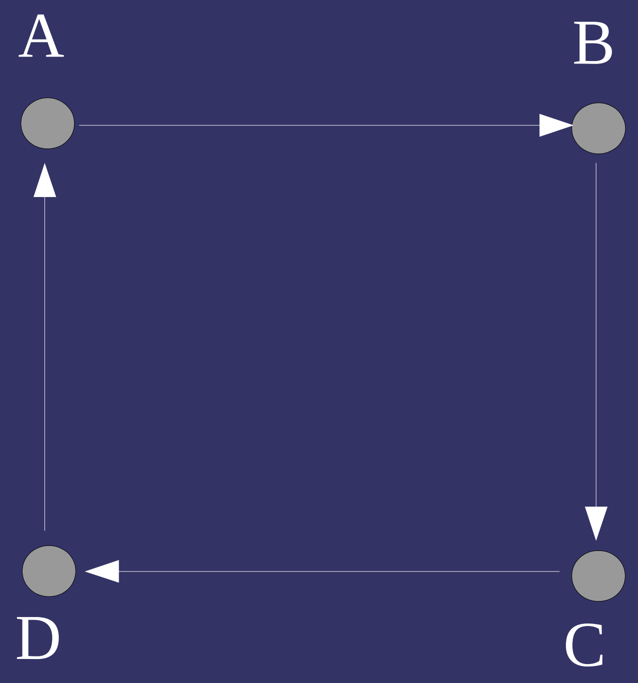

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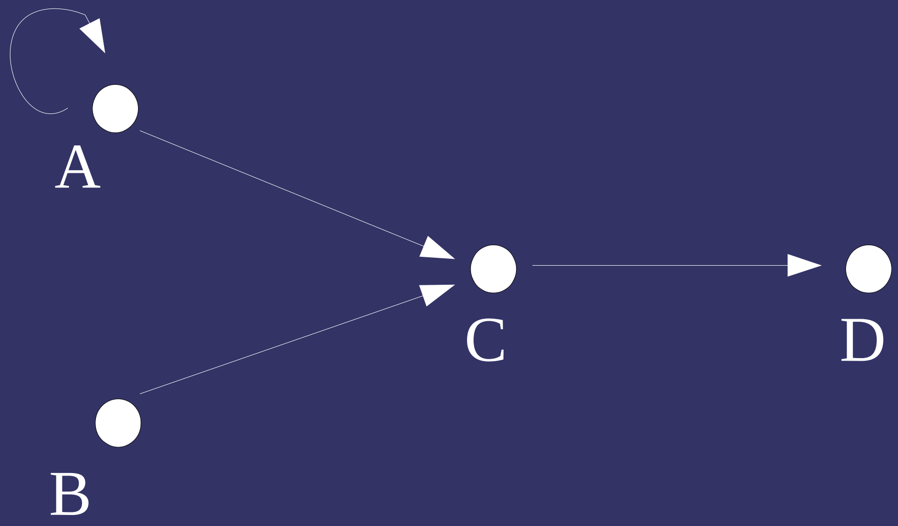

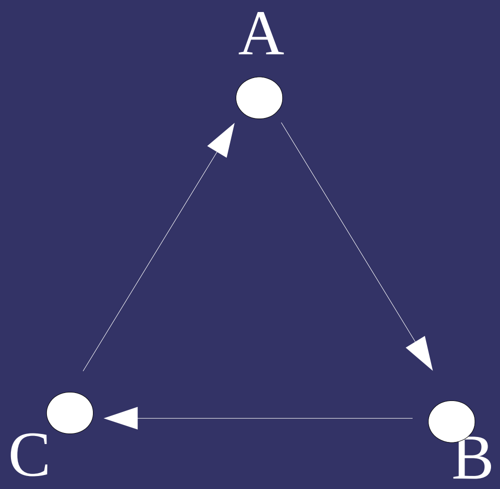

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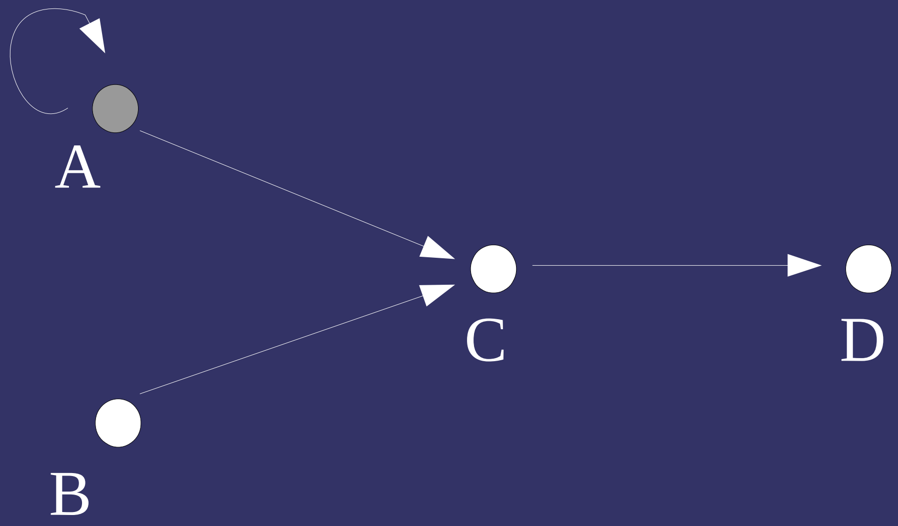

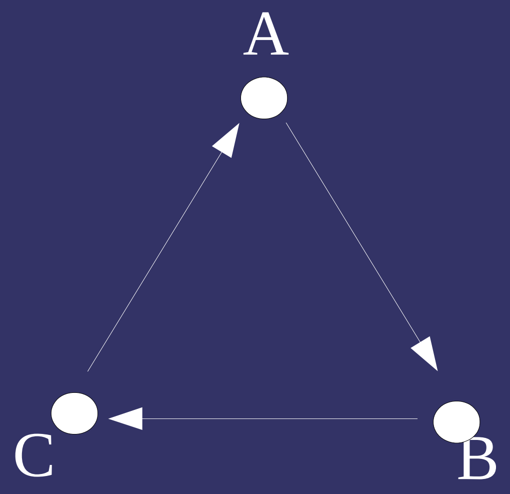

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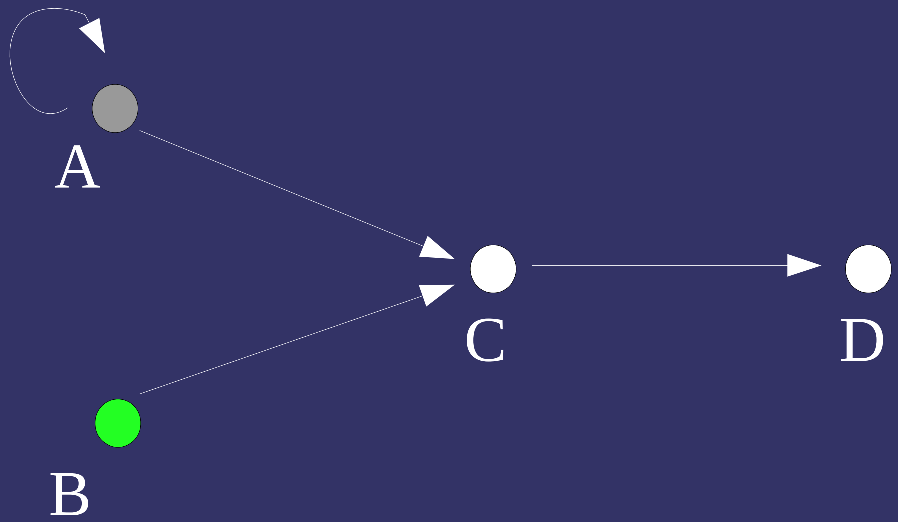

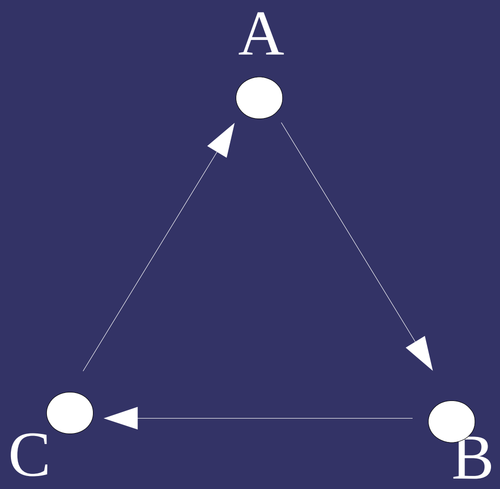

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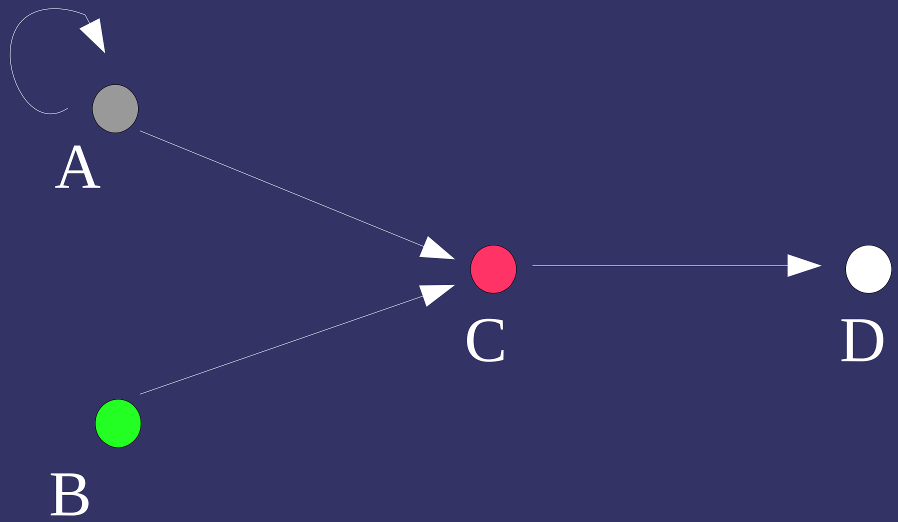

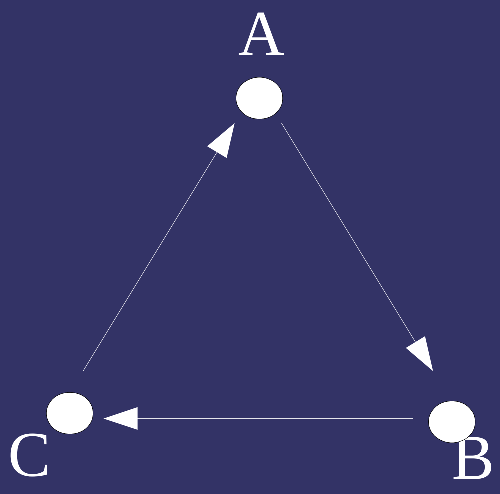

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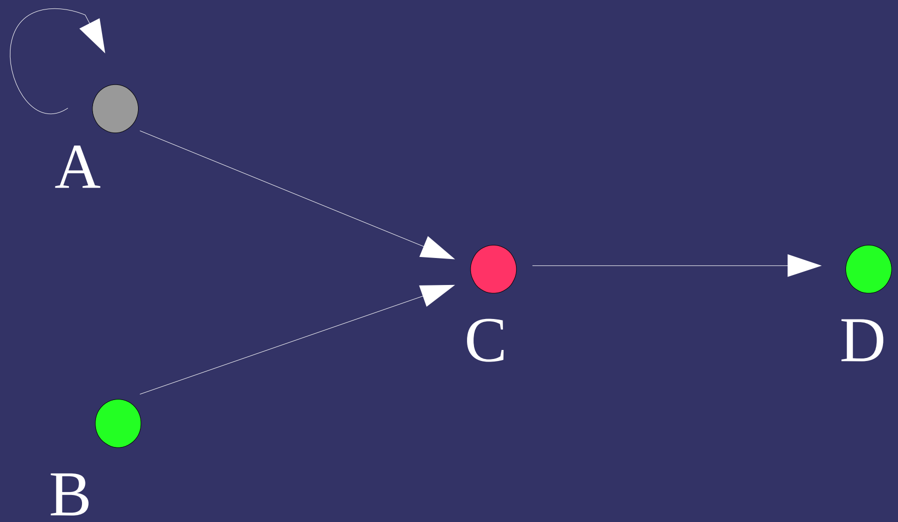

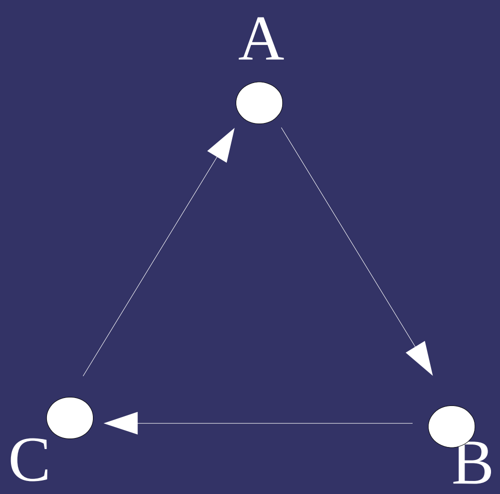

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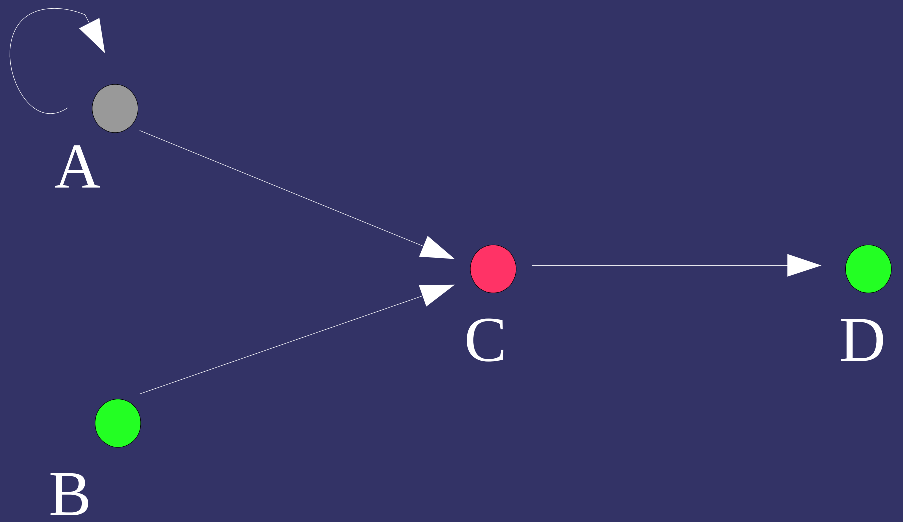

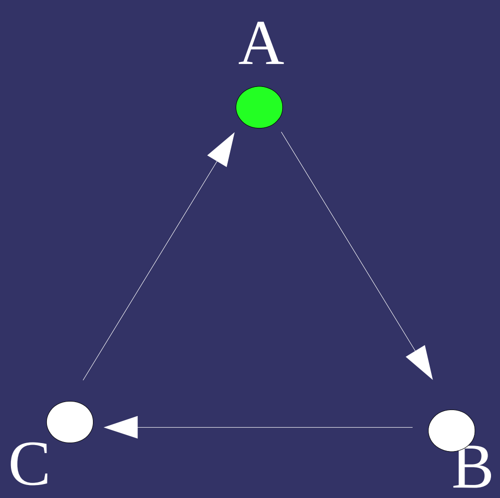

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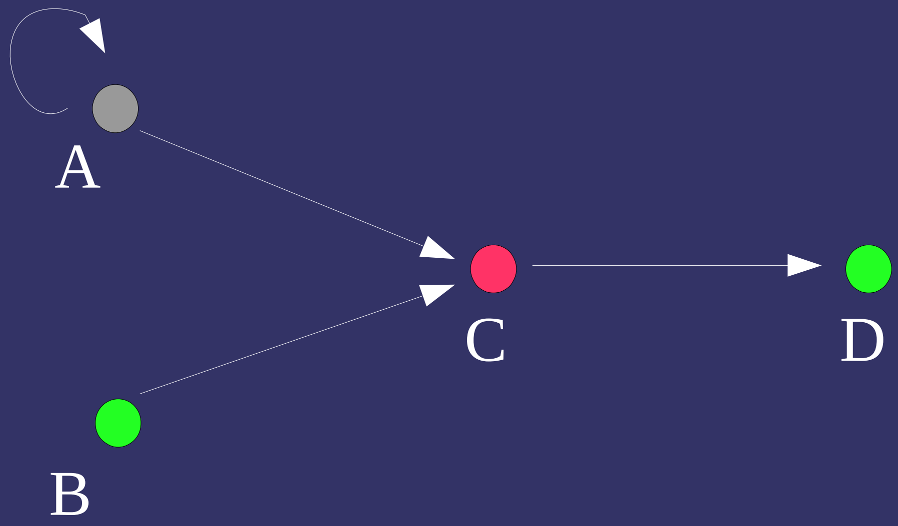

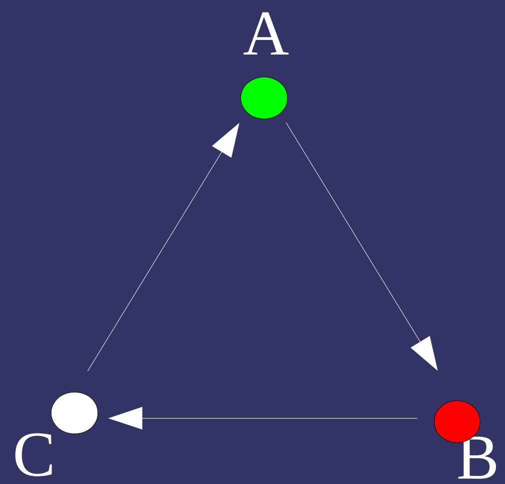

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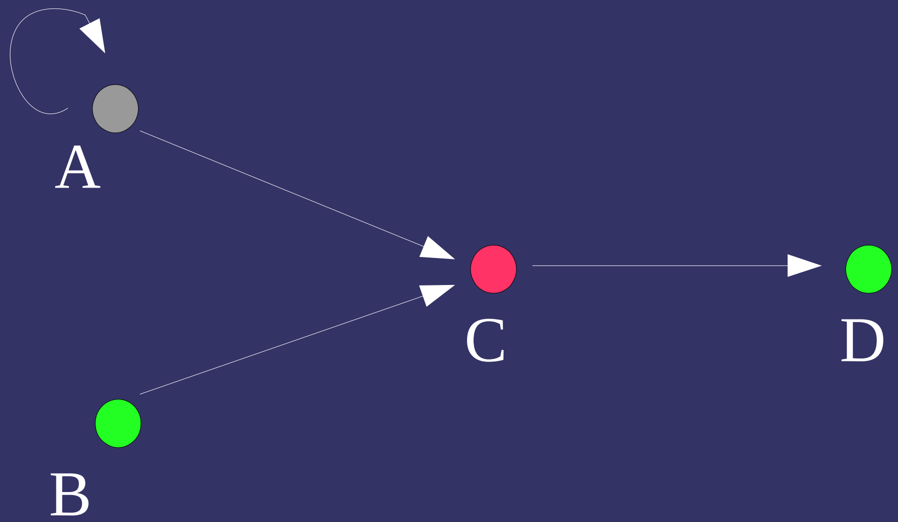

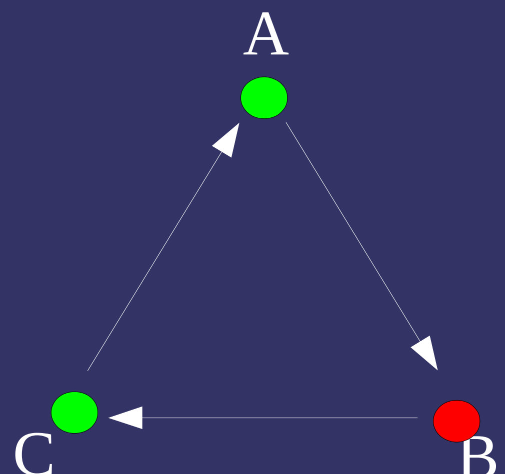

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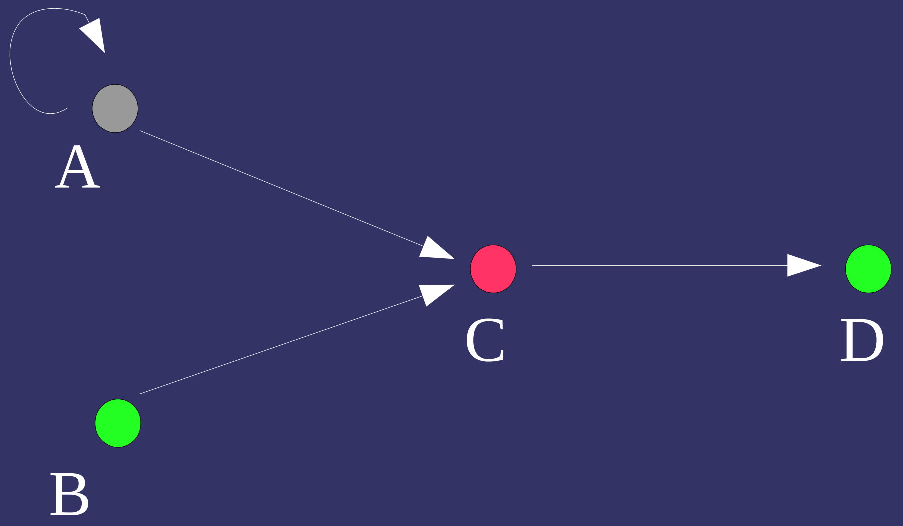

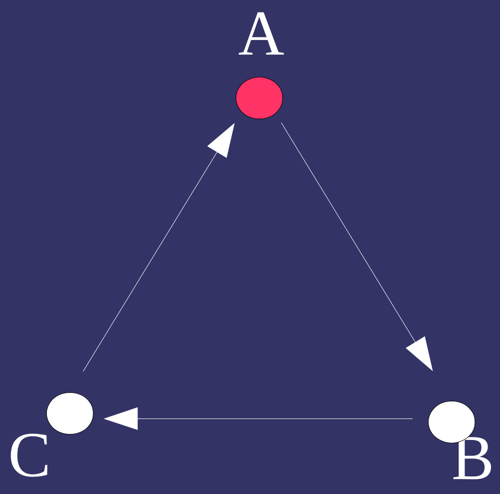

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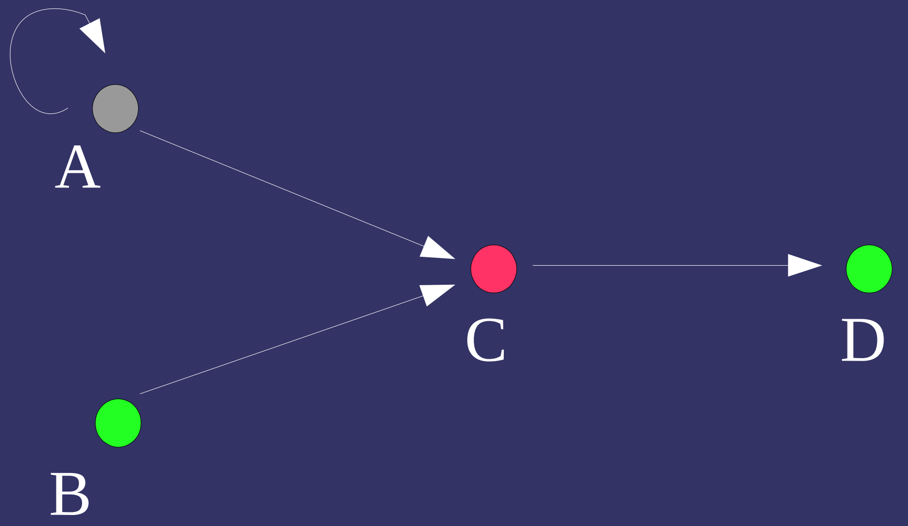

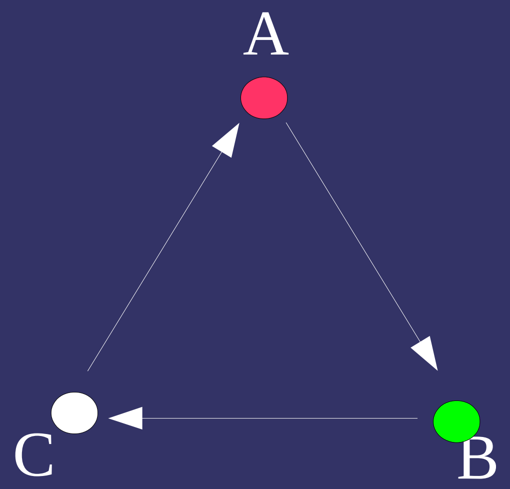

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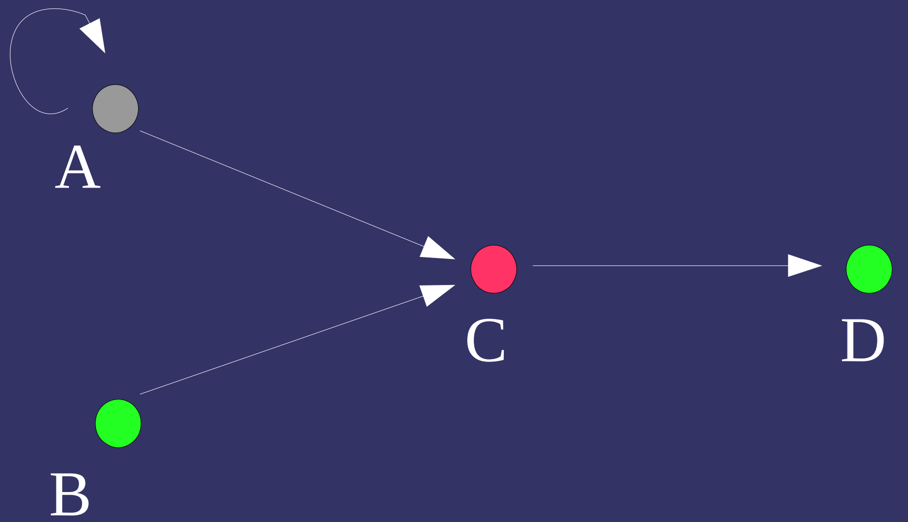

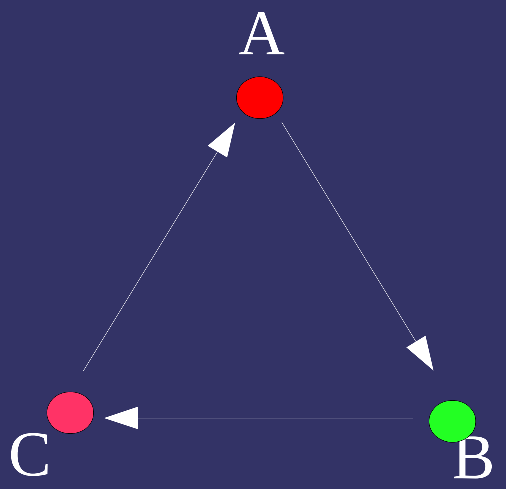

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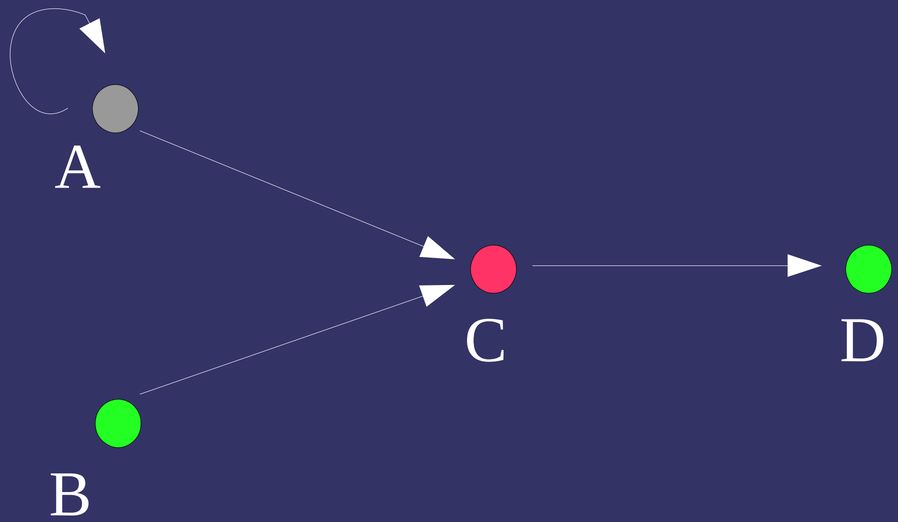
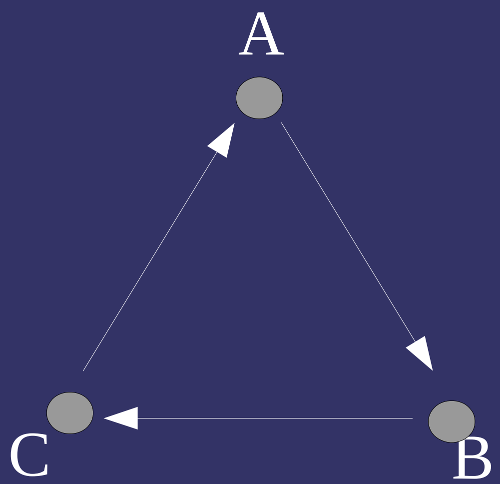
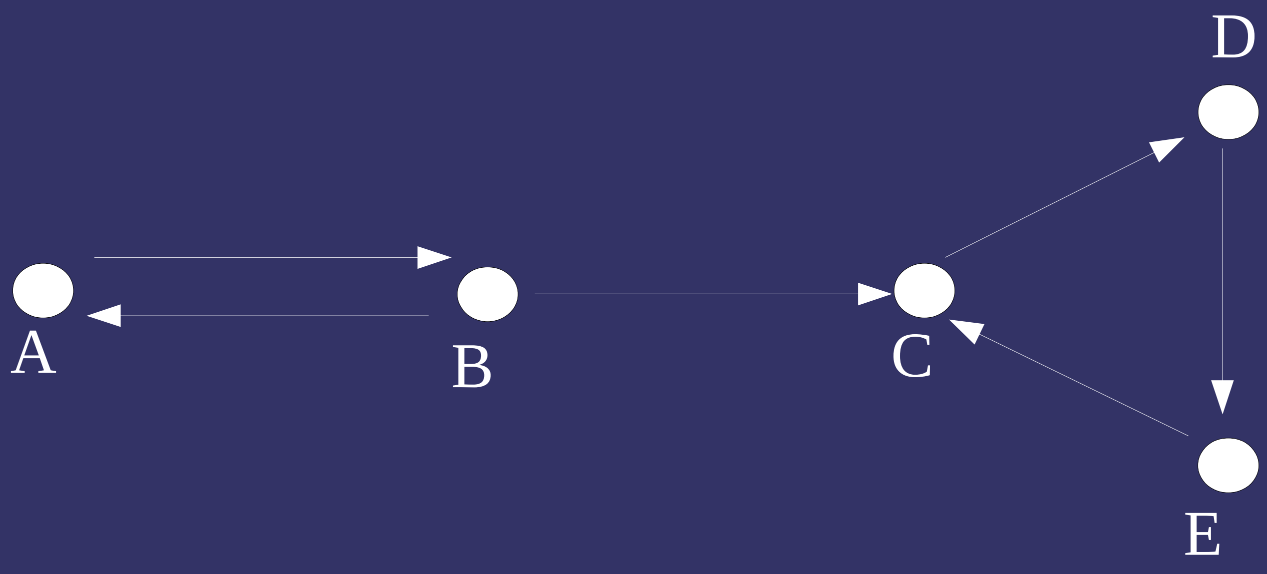




Exercise



Give the three labellings of this argumentation framework

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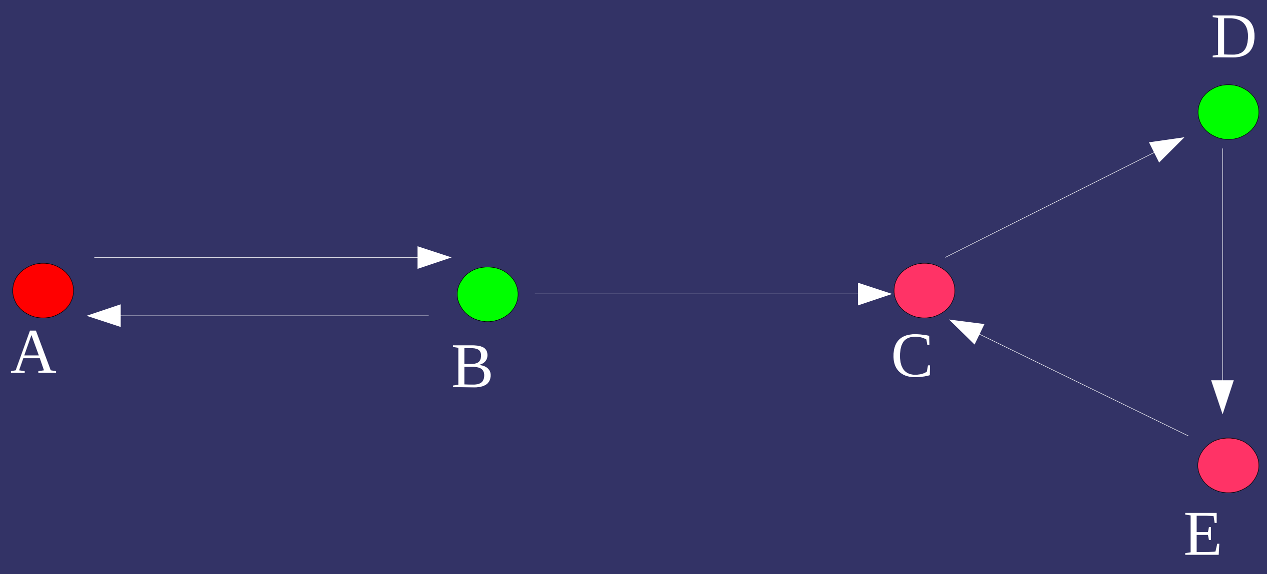

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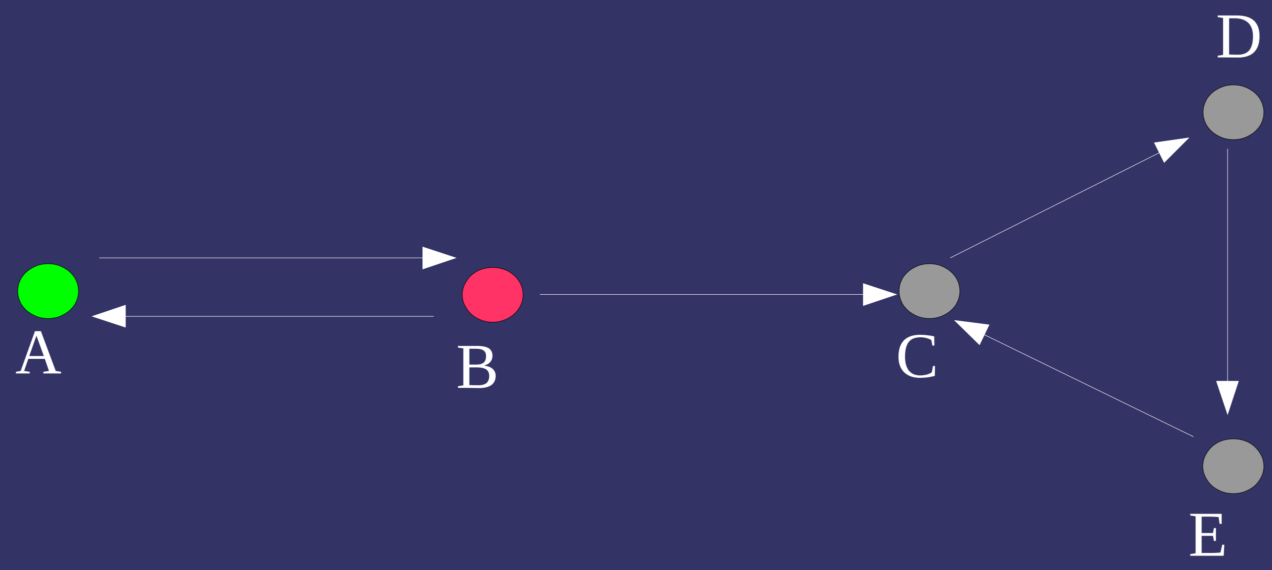

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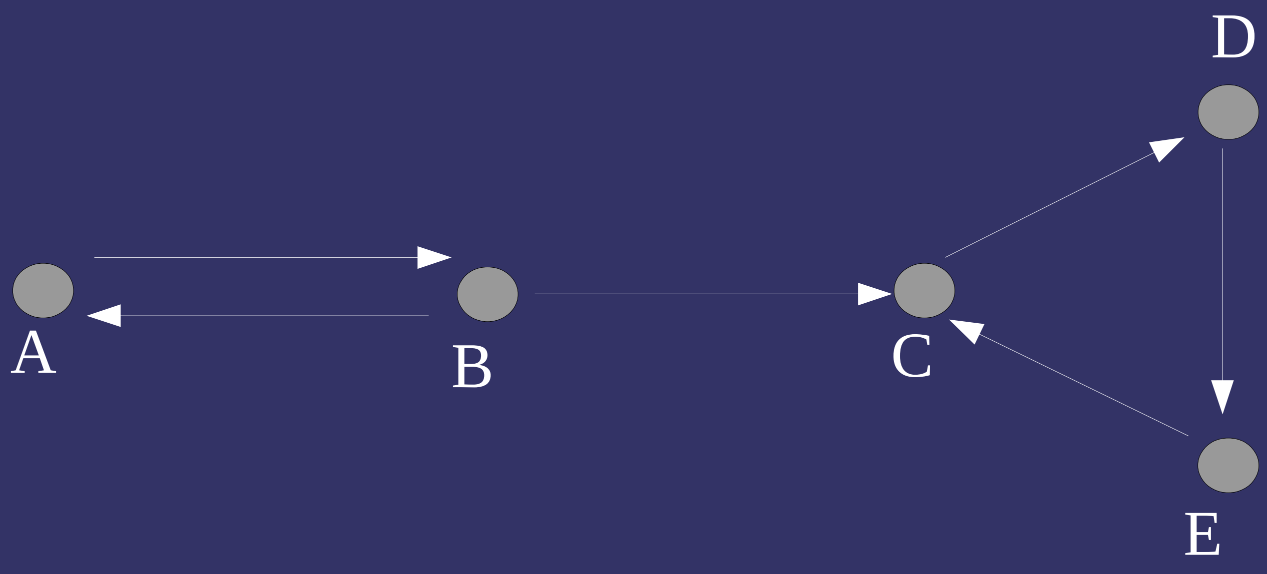

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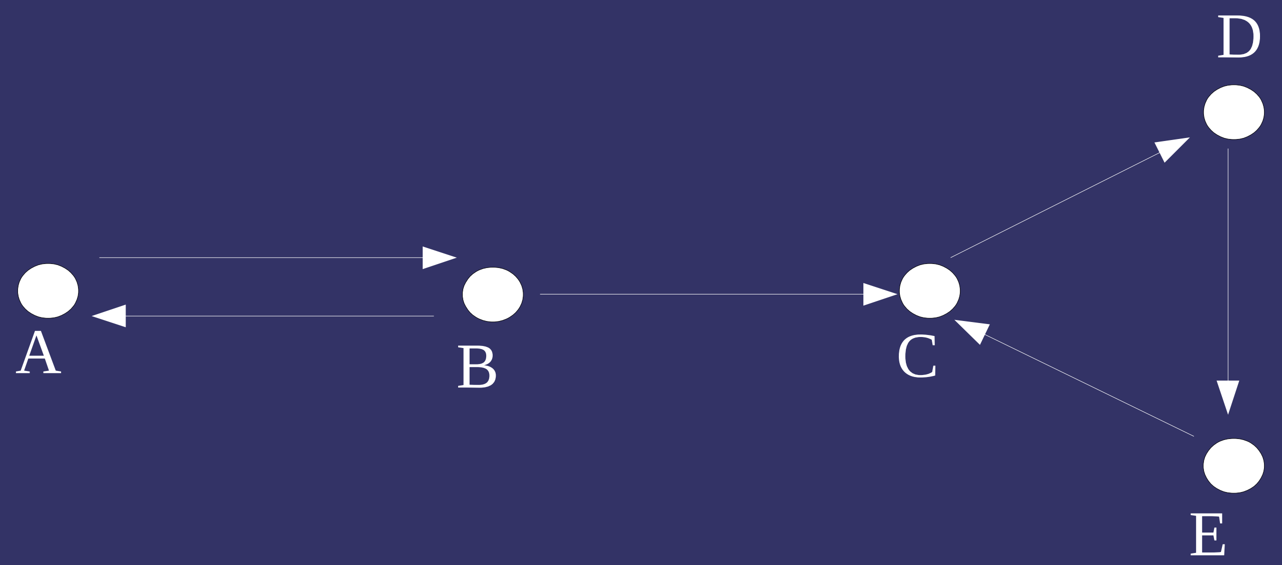
Maximisation / Minimisation



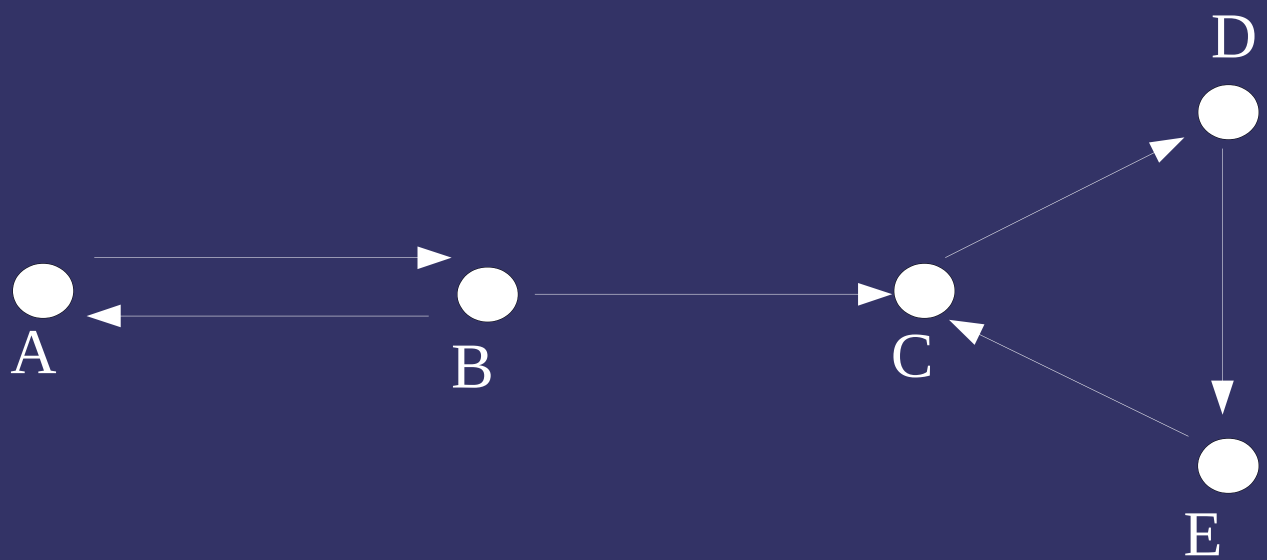
A B C D E

A B C D E

A B C D E

Maximisation / Minimisation

“maximal”: there is no other that has the same plus something
“minimal”: there is no other that has the same minus something



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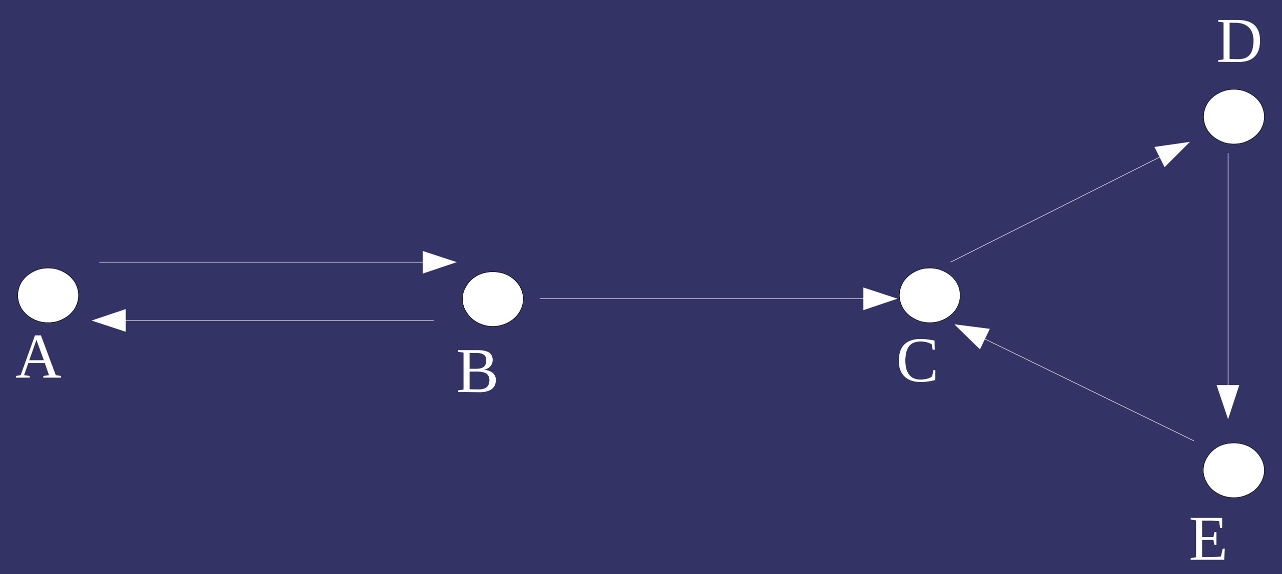

A B C D E   max in, max out, min undec

A B C D E

A B C D E

Maximisation / Minimisation

“maximal”: there is no other that has the same plus something
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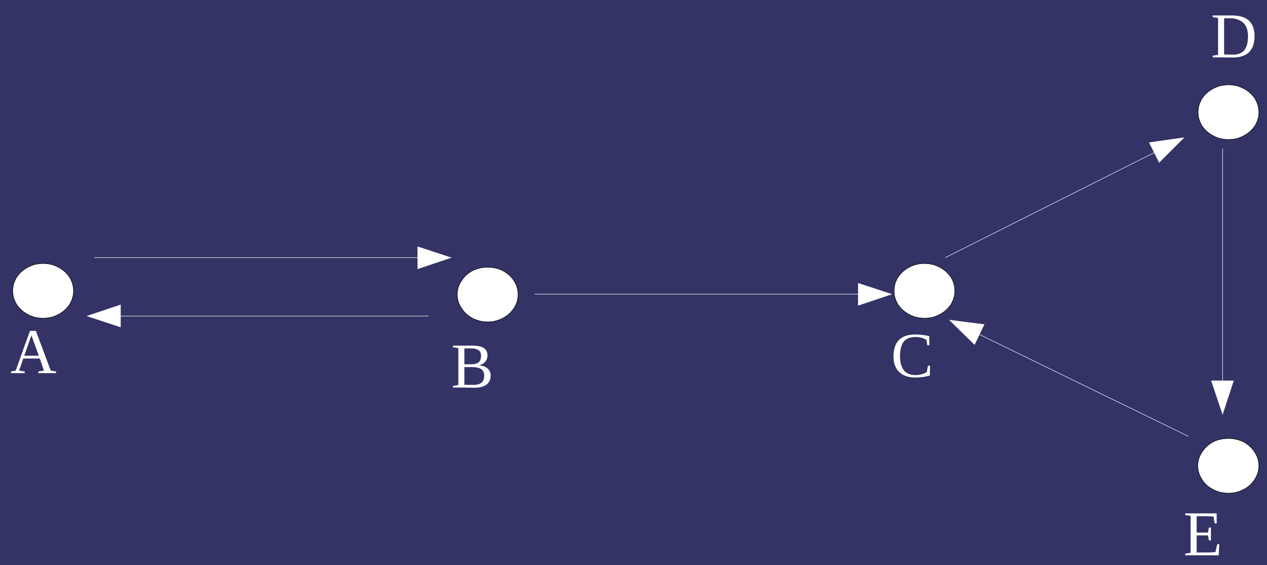

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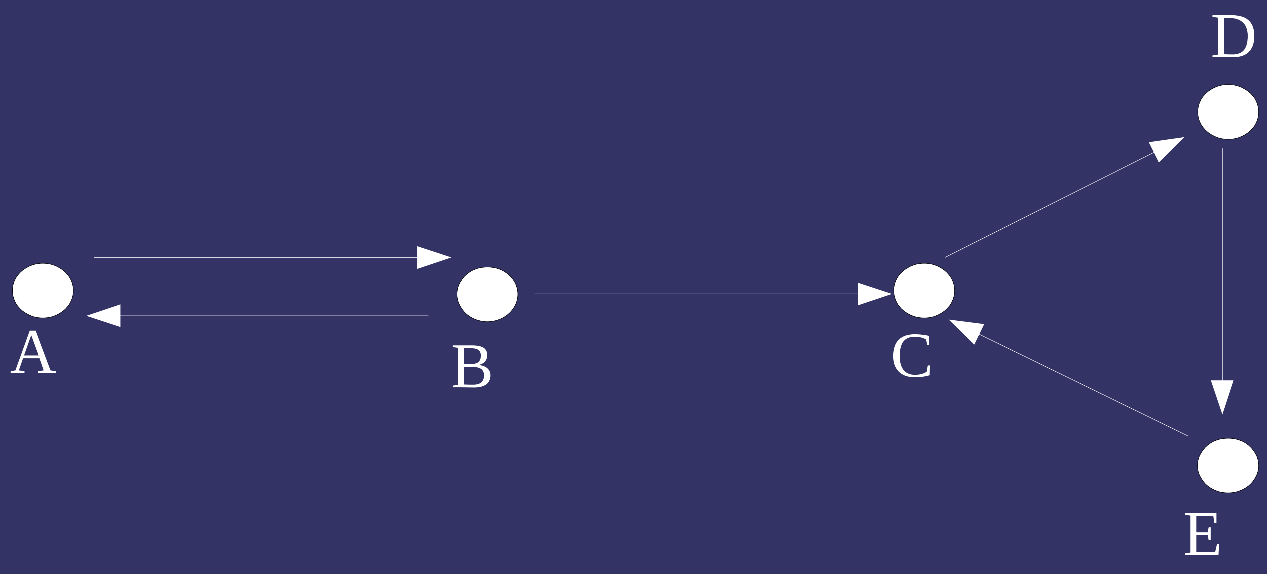


A B C D E	max in, max out, min undec
A B C D E	max in, max out
A B C D E	min in, min out, max undec

Complete, Stable, Preferred, Grounded and Semi-Stable Labellings

in ⇔ *all attackers are out*
out ⇔ *there is an attacker that is in*
undec ⇔ *not all attackers are out, and no attacker is in*

restriction on compl. labeling	***Dung-style semantics***
no further restrictions	complete semantics
empty undec	stable semantics
maximal in	preferred semantics
maximal out	preferred semantics
maximal undec	grounded semantics
minimal in	grounded semantics
minimal out	grounded semantics
minimal undec	semi-stable semantics

Complete Labellings and Admissible Labellings

complete labelling:

in ⬄ *all attackers are out*

out ⬄ *there is an attacker that is in*

undec ⬄ *not all attackers are out, and no attacker is in*

Complete Labellings and Admissible Labellings

complete labelling:

in ⇨ *all attackers are out*

out ⇨ *there is an attacker that is in*

undec ⇨ *not all attackers are out, and no attacker is in*

Complete Labellings and Admissible Labellings

admissible labelling:

in ⇨ *all attackers are out*

out ⇨ *there is an attacker that is in*

Roundup Labelling-Based Argumentation Semantics

admissible labelling:

in ⇨ *all attackers are out*

out ⇨ *there is an attacker that is in*

complete labelling:

in ⇨/⇔ *all attackers are out*

out ⇨/⇔ *there is an attacker that is in*

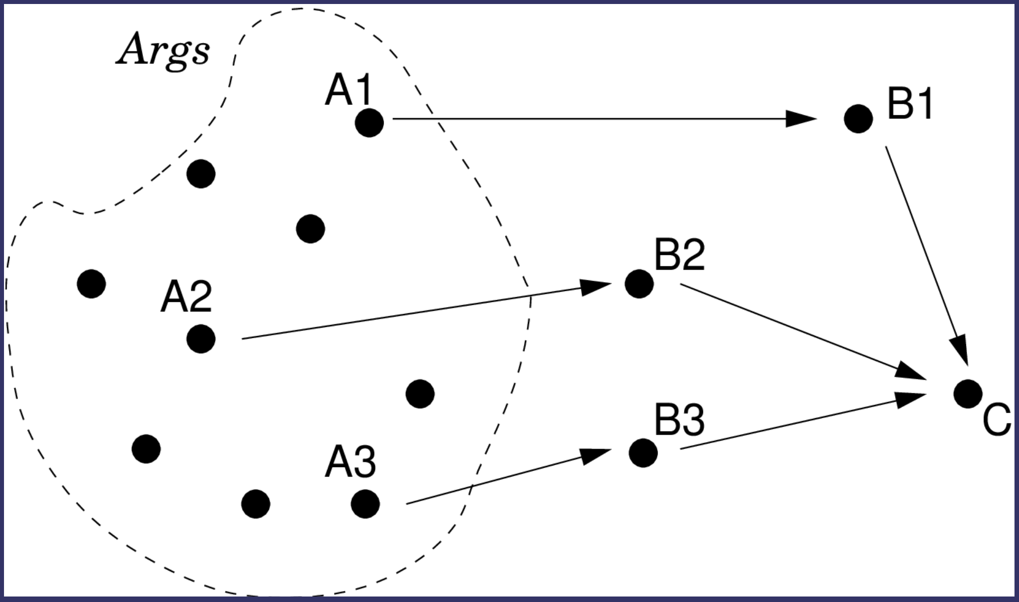
undec ⇨/⇔ *not all attackers are out, and no attacker is in*

grounded lab.: complete with min in / min out / max undec
preferred lab.: complete with max in / max out
semi-stable lab.: complete with min undec
stable lab.: complete with no undec

Extension-Based Argumentation Semantics (1/2)

- Args is <u>conflict-free</u> iff
  Args does not contain A,B such that A attacks B

- Args <u>defends</u> an argument C iff
  for each argument B that attacks C,
  Args contains an argument (A) that attacks B



Extension-Based Argumentation Semantics (1/2)

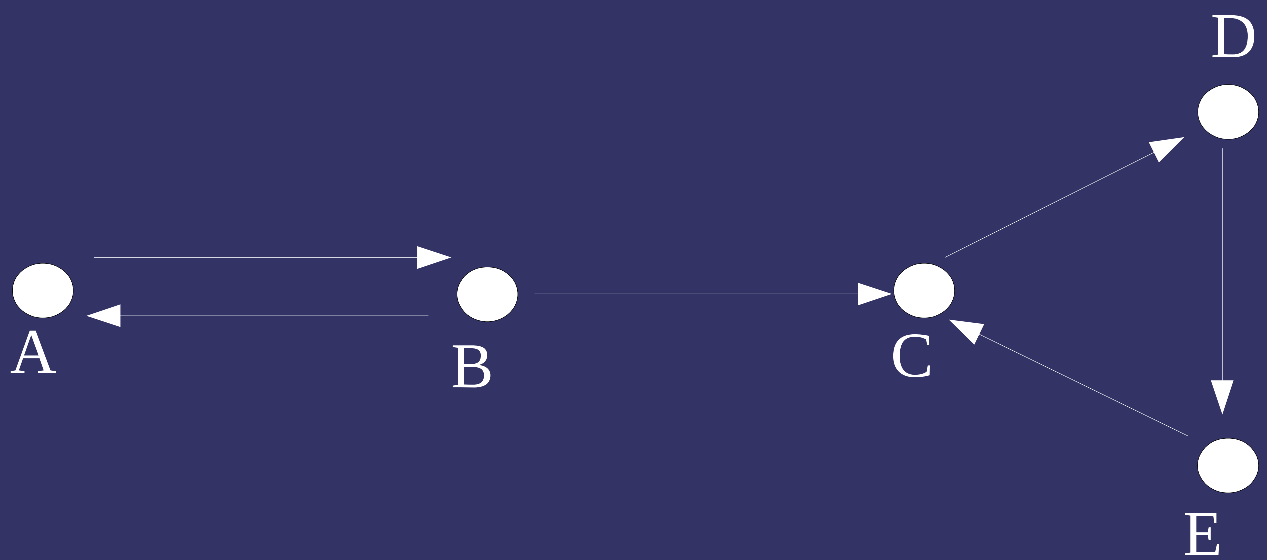
- Args is <u>conflict-free</u> iff
  $\nexists$ A,B $\in$ Args: A attacks B

- Args <u>defends</u> an argument C iff
  $\forall$ B that attacks C:
  $\exists$ A$\in$Args: A attacks B

- F(Args) = all arguments defended by Args

- $Args^{+}$ = { A | $\exists$ B $\in$ Args: B attacks A }

Exercise



What are $\{B\}^+$ and $F(\{B\})$

answer: $\{A,C\}$ and $\{B,D\}$

Extension-Based Argumentation Semantics (2/2)

A set of arguments Args is called:

- admissible iff
  Args is conflict-free and Args $\subseteq$ F(Args)
- a complete extension iff
  Args is conflict-free and Args = F(Args)
- a grounded extension iff
  Args is the minimal complete extension
- a preferred extension iff
  Args is a maximal admissible set
- a stable extension iff Args is a conflict-free set that attacks everything not in it
- a semi-stable extension iff Args is an admissible set with Args $\cup$ Args$^+$ maximal

Extension-Based Argumentation Semantics (2/2)

A set of arguments Args is called:

- admissible iff
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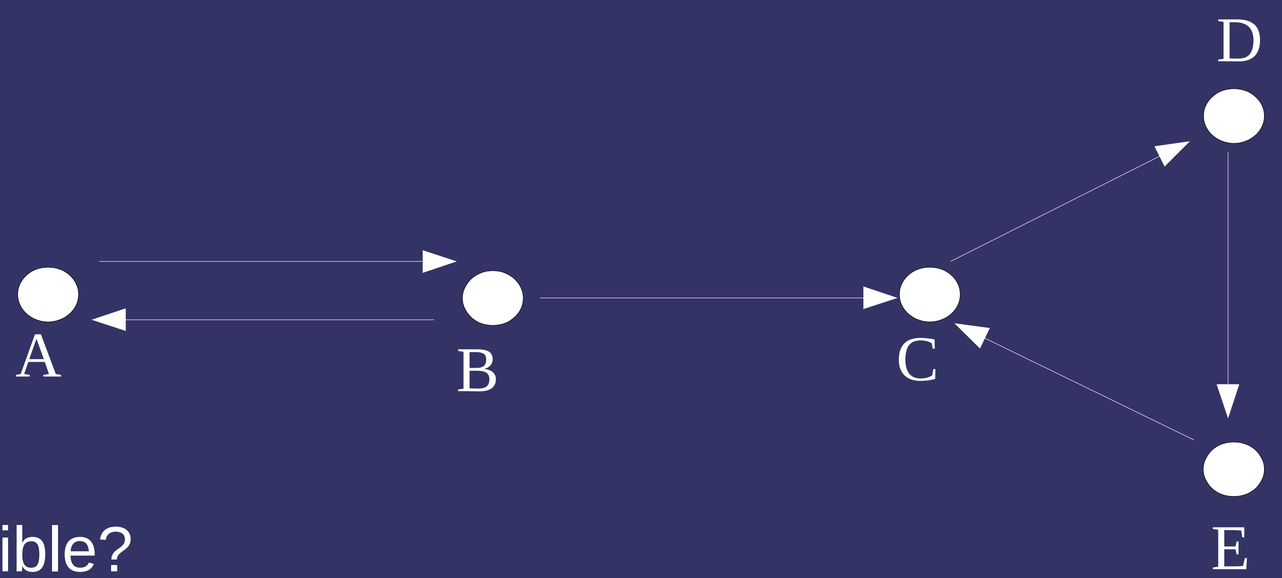
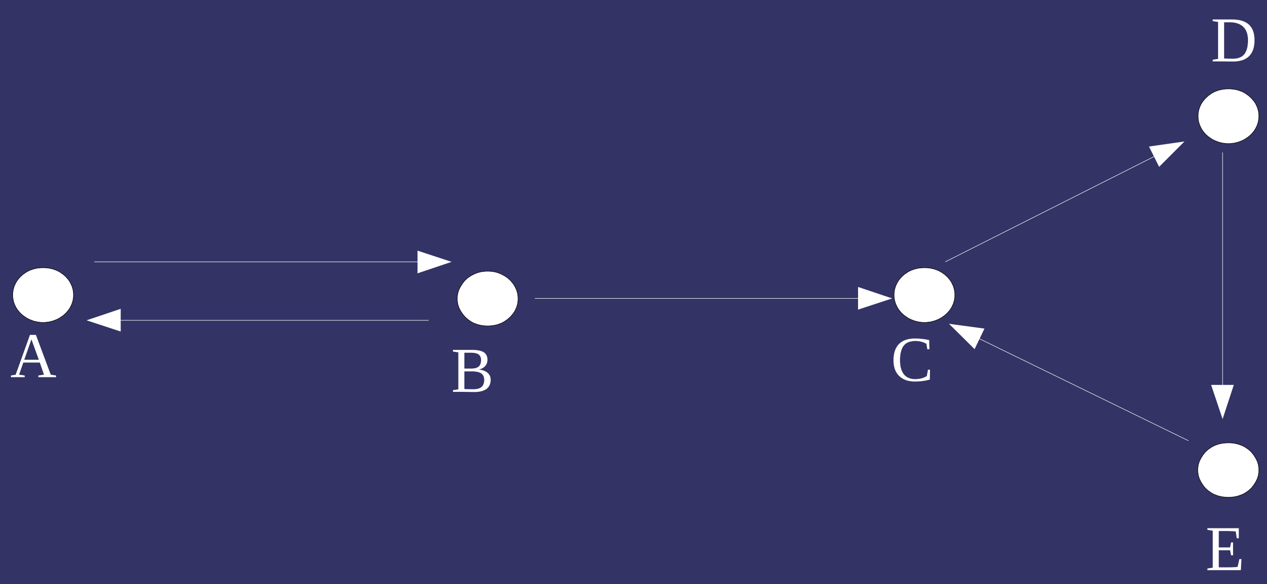
Exercise



Admissible?

- ∅ ☑
- {A} ☑
- {B} ☑
- {C} ☒
- {D} ☒
- {B,D} ☑
- {A,B} ☒

Exercise



Complete Extensions:	Grounded Extension:	Preferred Extensions:	Stable Extensions:	Semi-Stable Extensions:
∅	∅			
{A}		{A}		
{B,D}		{B,D}	{B,D}	{B,D}

Extension-Based semantics vs. Labelling-Based Semantics

Let Lab = (in(Lab), out(Lab), undec(Lab))
Let Args be a conflict-free set of arguments.

We define:
- Lab2Ext(Lab) = in(Lab)
- Ext2Lab(Args) = (Args, $Args^+$, Ar \ (Args ∪ $Args^+$))

It holds that:
- If Lab is a complete labelling,
  then Lab2Ext(Lab) is a complete extension
- If Args is a complete extension,
  then Ext2Lab(Args) is a complete labelling
- For complete labellings/extensions
  Lab2Ext and Ext2Lab are each other's inverse functions

Extension-Based semantics vs. Labelling-Based Semantics

complete labelling	$\equiv$	complete extension
grounded labelling	$\equiv$	grounded extension
preferred labelling	$\equiv$	preferred extension
semi-stable labelling	$\equiv$	semi-stable extension
stable labelling	$\equiv$	stable extension

(equivalence through Lab2Ext and Ext2Lab)

<u>take home message:</u>
An extension is
the in-labelled part of a labelling

Next Topic

What is the relation between argumentation semantics and discussion?

Grounded Discussion Game
Preferred Discussion Game

Next Topic

The Grounded Discussion Game

A Discussion Game for Grounded Semantics (1/3)

A Discussion Game for Grounded Semantics (1/3)

two players:

- proponent (P)
- opponent (O)

A Discussion Game for Grounded Semantics (1/3)

two players:

- proponent (P)
- opponent (O)

four moves ($A, B \in Ar$)

(1) P: HTB(A)
“A has to be the case”

(2) O: CB(B)
“B can be the case”

(3) O: CONCEDE(A)
“I now agree that A”

(4) O: RETRACT(B)
“I no longer hold that B can be the case”

A Discussion Game for Grounded Semantics (1/3)

two players:

- proponent (P)
- opponent (O)

four moves ($A,B \in Ar$)

(1) P: HTB(A)
"A is labelled in by every complete"

(2) O: CB(B)
"B can be the case"

(3) O: CONCEDE(A)
"I now agree that A"

(4) O: RETRACT(B)
"I no longer hold that B can be the case"

A Discussion Game for Grounded Semantics (1/3)

two players:

- proponent (P)
- opponent (O)

four moves ($A,B \in Ar$)

(1) P: HTB(A)
"A is labelled in by every complete"

(2) O: CB(B)
"Perhaps B isn't labelled out by every complete"

(3) O: CONCEDE(A)
"I now agree that A"

(4) O: RETRACT(B)
"I no longer hold that B can be the case"

A Discussion Game for Grounded Semantics (1/3)

two players:

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“I now agree that A is labelled in by every complete”

(4) O: RETRACT(B)
“I no longer hold that B isn't labelled out by every comple

A Discussion Game for Grounded Semantics (1/3)

two players:

- proponent (P)
- opponent (O)

four moves (A,B $\in$ Ar)

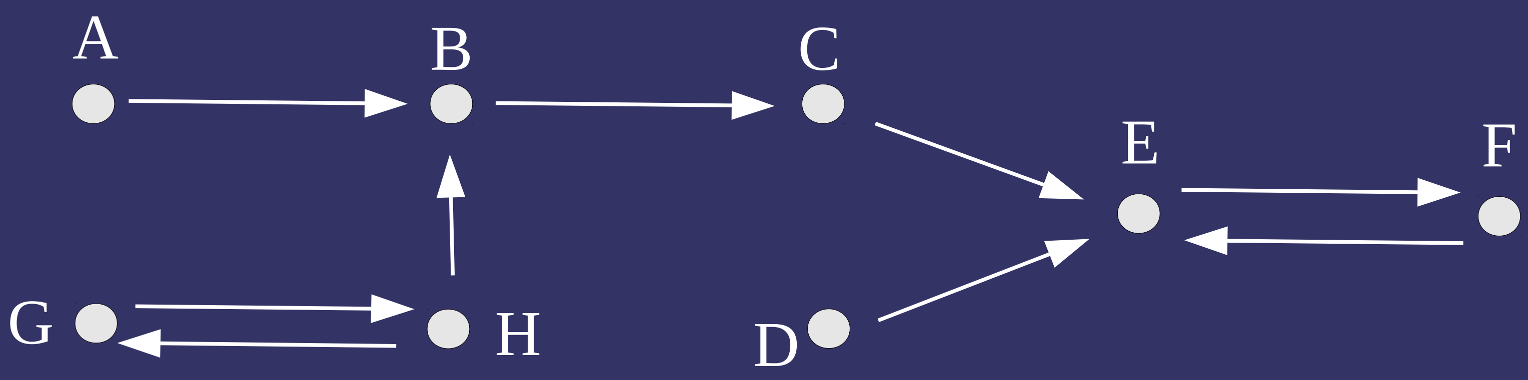
(1) P: HTB(A)
“A is labelled in by every complete”

(2) O: CB(B)
“Perhaps B isn't labelled out by every complete”

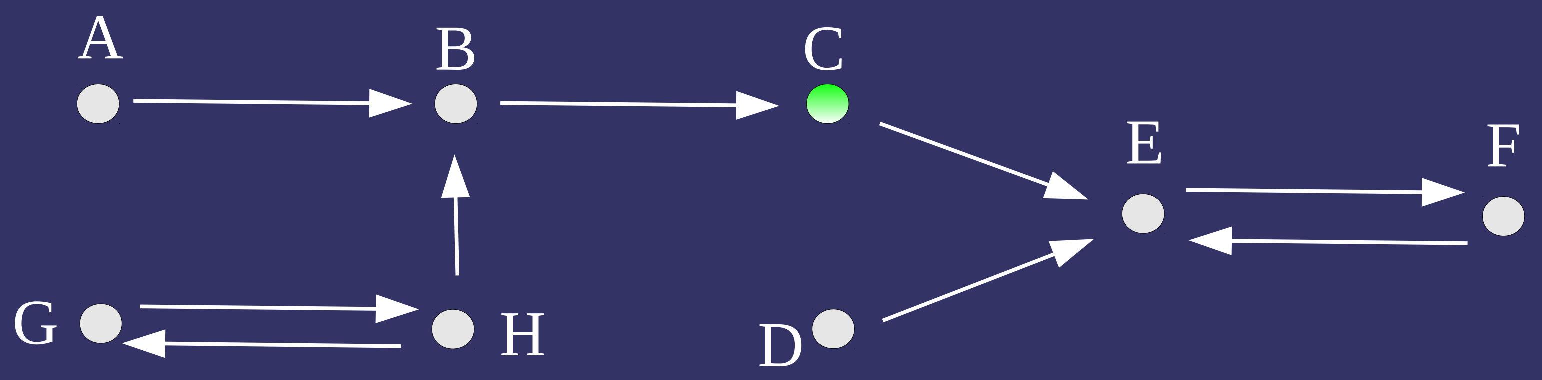
(3) O: CONCEDE(A)
“I now agree that A is labelled in by every complete”

(4) O: RETRACT(B)
“I now think that B is labelled out by every complete”

Example

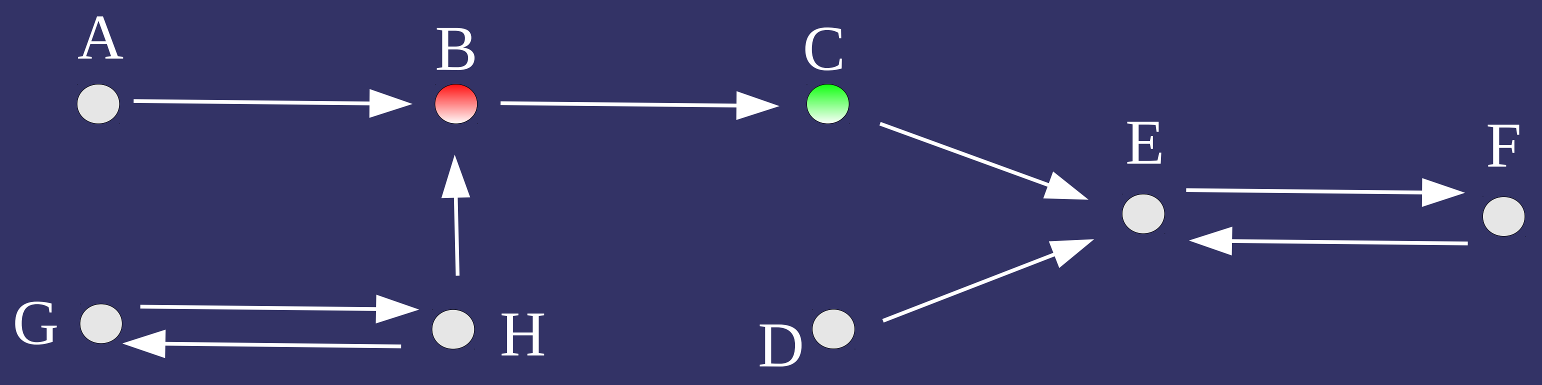


Example



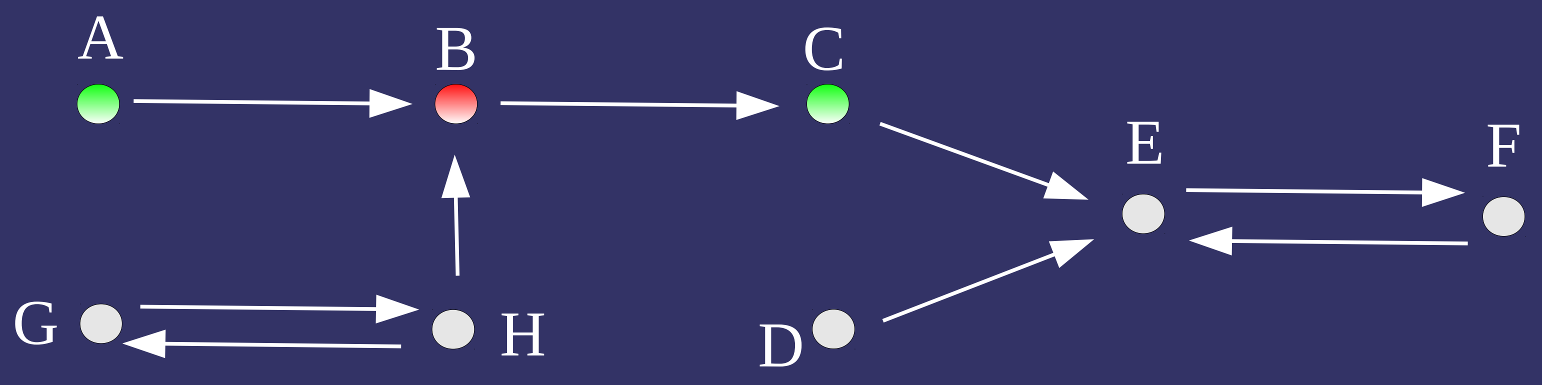
P: HTB(C)

Example



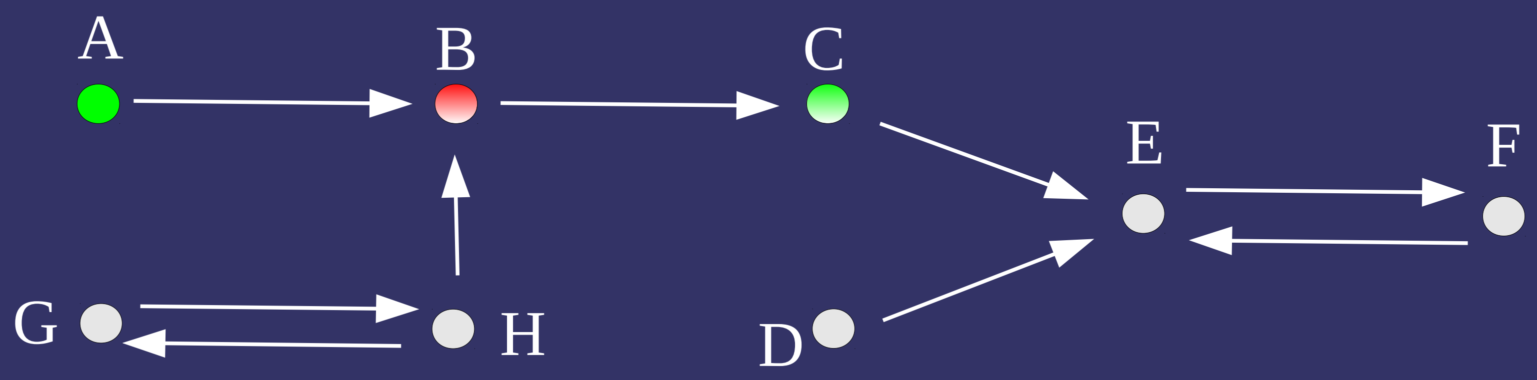
P: HTB(C)
O: CB(B)

Example



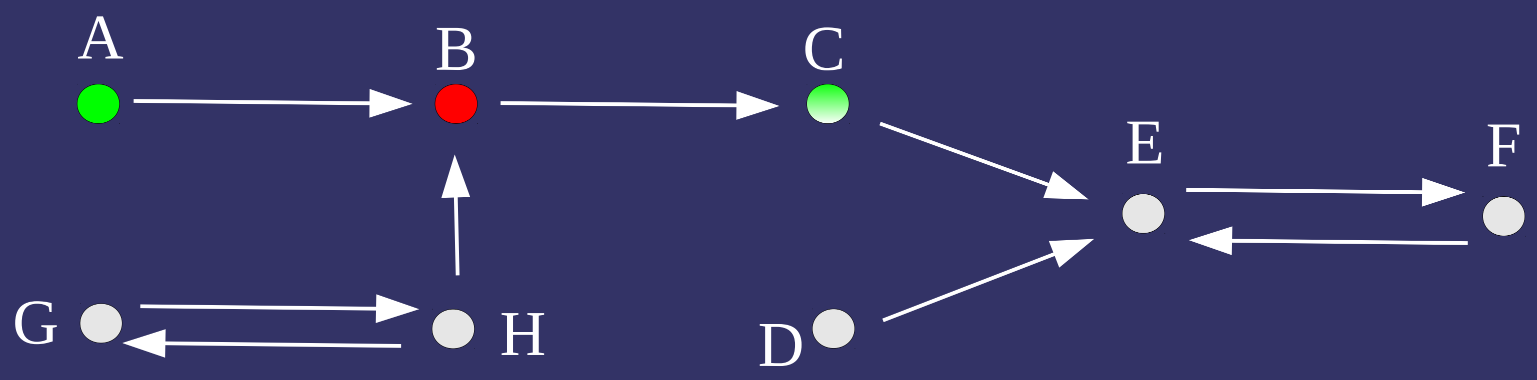
P: HTB(C)
O: CB(B)
P: HTB(A)

Example



P: HTB(C)
O: CB(B)
P: HTB(A)
O: CONCEDE(A)

Example



P: HTB(C)
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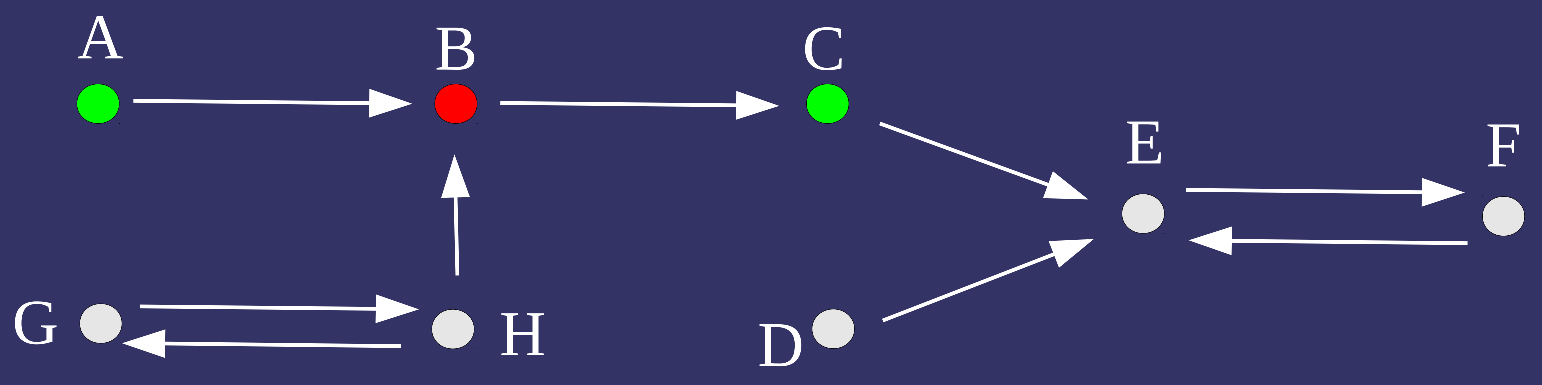
P: HTB(A)
O: CONCEDE(A)
O: RETRACT(B)

Example



P: HTB(C)
O: CB(B)
P: HTB(A)
O: CONCEDE(A)
O: RETRACT(B)
O: CONCEDE(C)

A Discussion Game for Grounded Semantics (2/3)

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HTB(A) This is either the first move, or

- preceding move was CB(B) and A attacks B
- no CONCEDE or RETRACT move is applicable

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CB(B)

- B attacks the last HTB(A) statement that is not yet CONCEDEd
- preceding move was not a CB statement
- B has not yet been RETRACTed
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CONCEDE(A)

- there has been a HTB(A) statement in the past...
- ...of which every attacker has been RETRACTed
- and CONCEDE(A) hasn't yet been moved

A Discussion Game for Grounded Semantics (2/3)

HTB(A)   This is either the first move, or

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CONCEDE(A)

- there has been a HTB(A) statement in the past...
- ...of which every attacker has been RETRACTed
- and CONCEDE(A) hasn't yet been moved

RETRACT(B)

- there has been a CB(B) statement in the past...
- ...of which an attacker has been CONCEDEd
- and RETRACT(B) hasn't yet been moved

A Discussion Game for Grounded Semantics (2/3)

HTB(A) This is either the first move, or

- preceding move was CB(B) and A attacks B
- no CONCEDE or RETRACT move is applicable

CB(B)

- B attacks the last HTB(A) statement that is not yet CONCEDEd
- preceding move was not a CB statement
- B has not yet been RETRACTed
- no CONCEDE or RETRACT move is applicable

CONCEDE(A)

- there has been a HTB(A) statement in the past...
- ...of which every attacker has been RETRACTed
- and CONCEDE(A) hasn't yet been moved

RETRACT(B)

- there has been a CB(B) statement in the past...
- ...of which an attacker has been CONCEDEd
- and RETRACT(B) hasn't yet been moved

additional condition for all moves: no HTB-CB repeats have occurred

Example

Example

P: HTB(D)

Example

P: HTB(D)
O: CB(C)

Example

P: HTB(D)
O: CB(C)
P: HTB(B)

Example

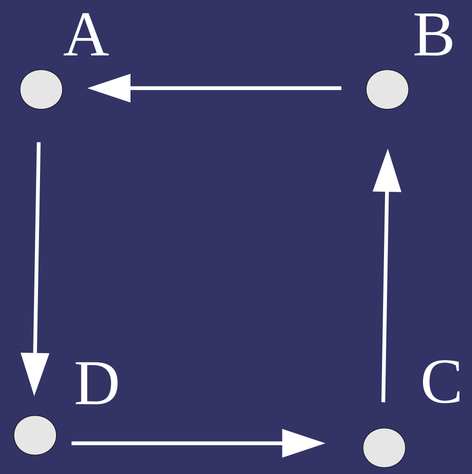
P: HTB(D)
O: CB(C)
P: HTB(B)
O: CB(A)

Example

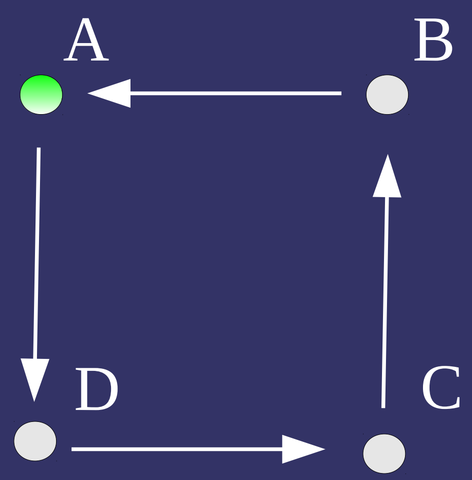
P: HTB(D)
O: CB(C)
P: HTB(B)
O: CB(A)

Proponent cannot move anymore, so discussion is terminated.
Main claim not CONCEDEd, so proponent loses.

Example

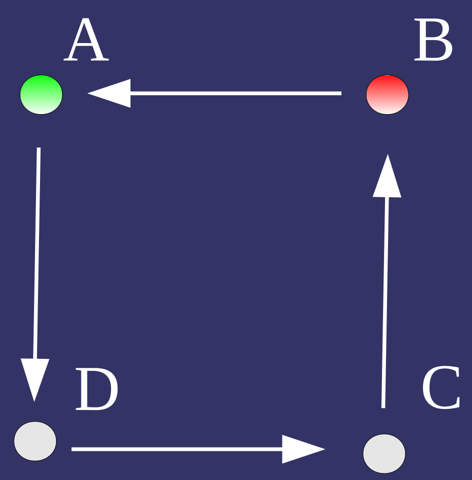


Example



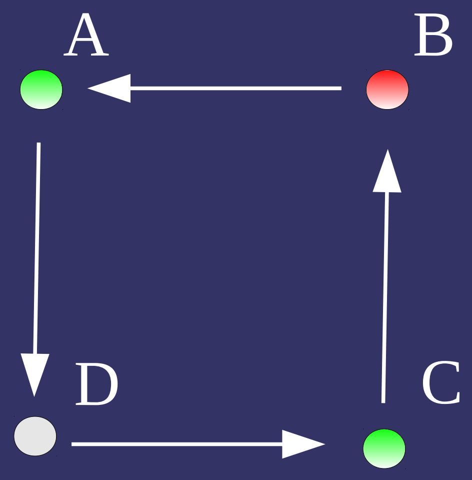
P: HTB(A)

Example



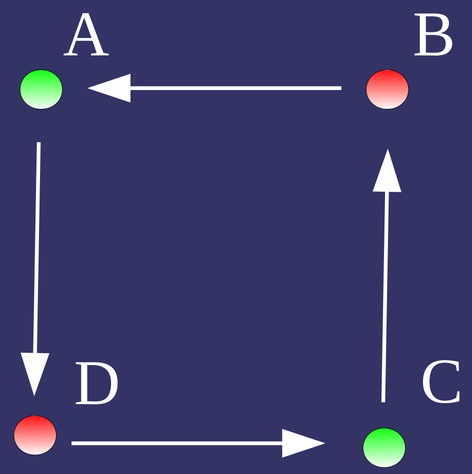
P: HTB(A)
O: CB(B)

Example



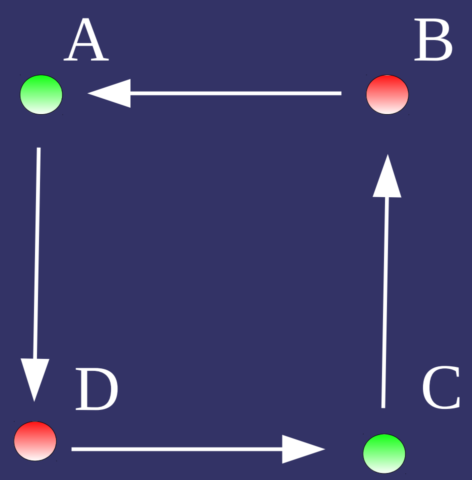
P: HTB(A)
O: CB(B)
P: HTB(C)

Example



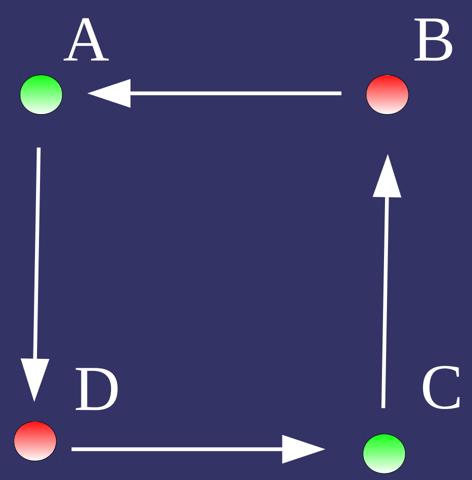
P: HTB(A)
O: CB(B)
P: HTB(C)
O: CB(D)

Example



P: HTB(A)
O: CB(B)
P: HTB(C)
O: CB(D)
P: HTB(A)

Example



P: HTB(A)
O: CB(B)
P: HTB(C)
O: CB(D)
P: HTB(A)

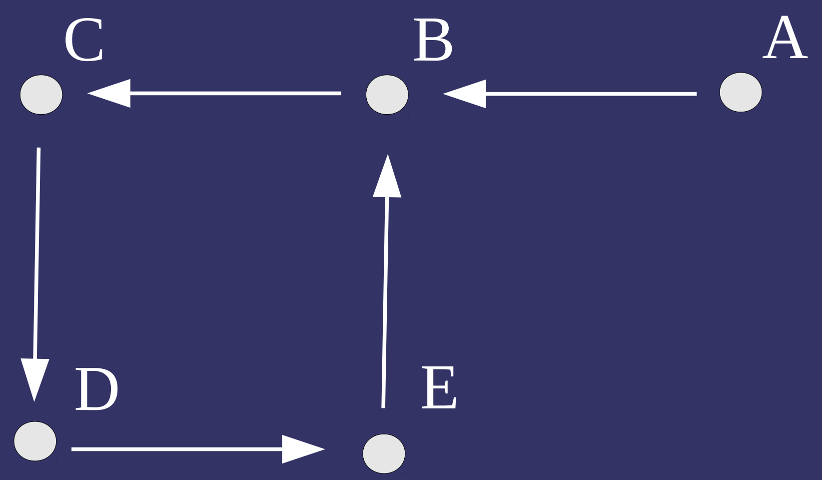
Now we have a HTB(A)-HTB(A) repeat, so all following moves are blocked: discussion terminated.

Main claim not CONCEDEd, so proponent loses

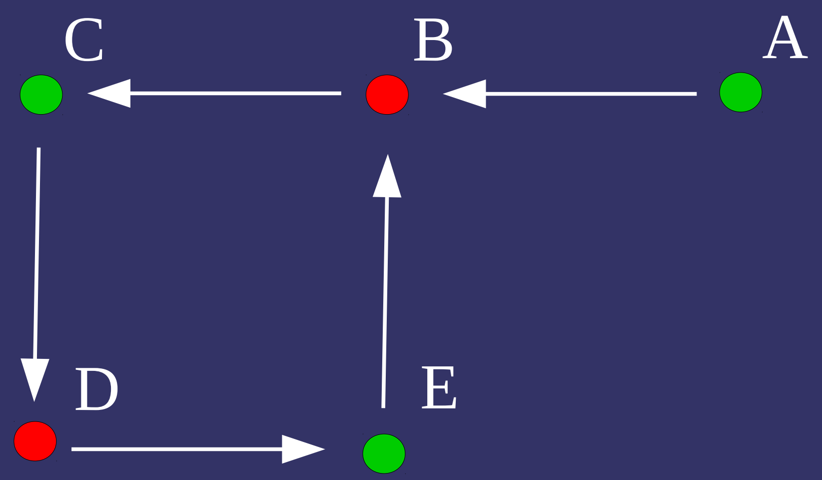
A Discussion Game for Grounded Semantics (3/3)

- A discussion is *terminated* iff no next move is possible
- A terminated discussion (starting with HTB(A))
  is won by the proponent iff
  the opponent has moved CONCEDE(A)
- <u>soundness:</u> if a discussion is won by the proponent,
  then the main argument is in in the grounded labelling
- <u>completeness</u>: if an argument is in in the grounded labelling,
  then the proponent has a winning strategy for it

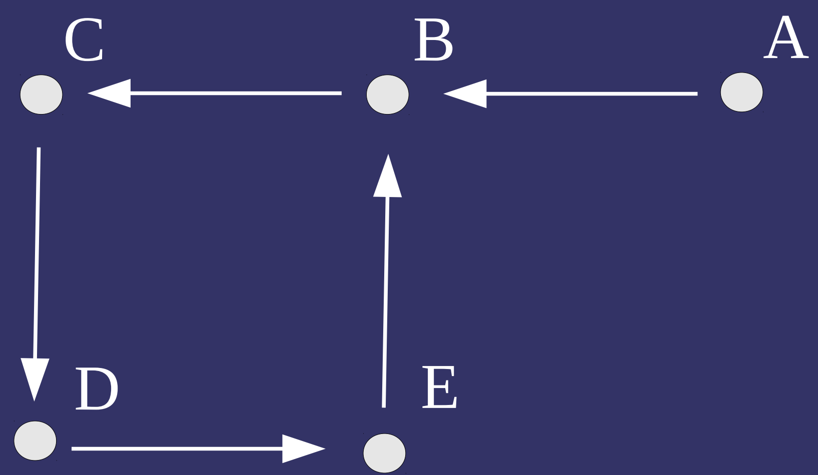
Example



Example



Example



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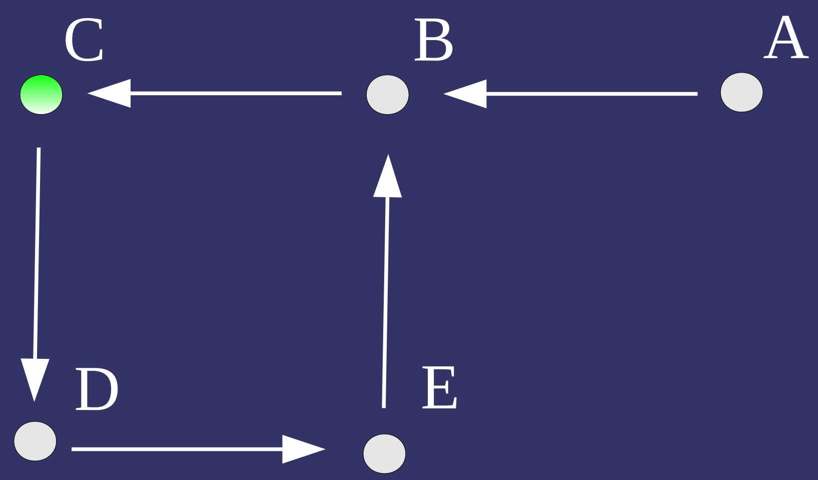
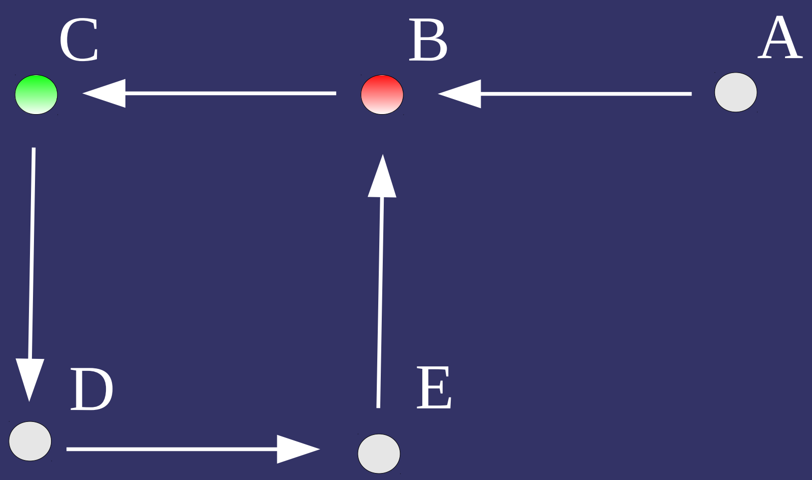


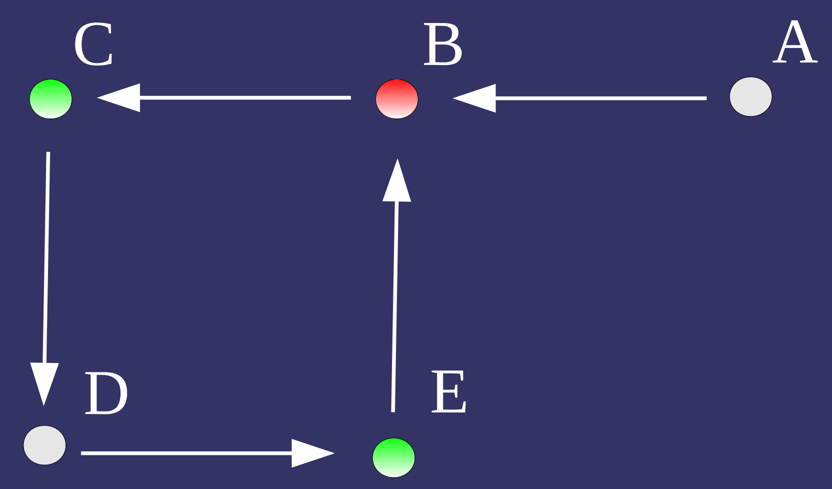
P: HTB(C)

Example



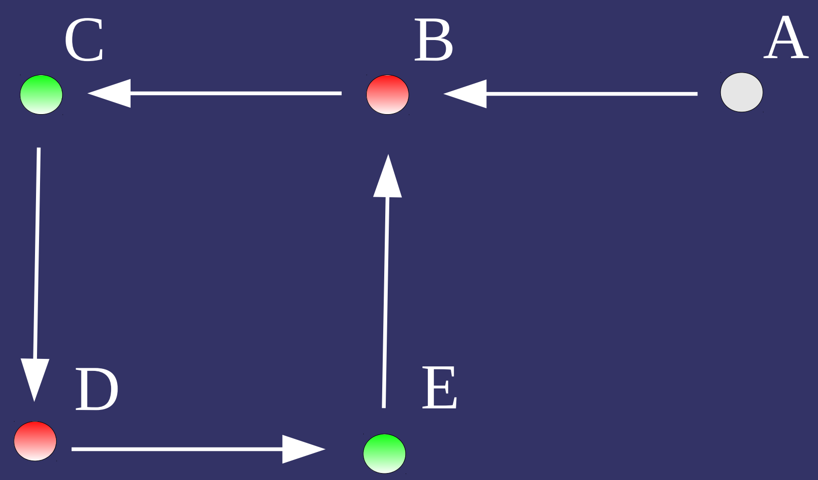
P: HTB(C)
O: CB(B)

Example



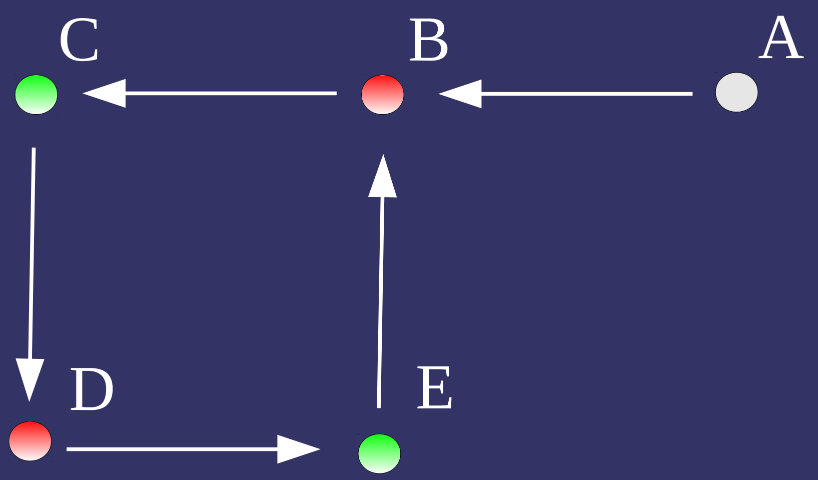
P: HTB(C)
O: CB(B)
P: HTB(E)

Example



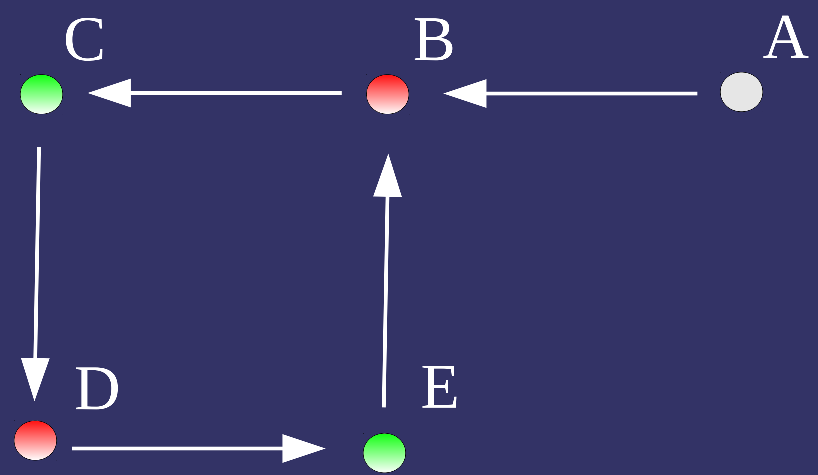
P: HTB(C)
O: CB(B)
P: HTB(E)
O: CB(D)

Example



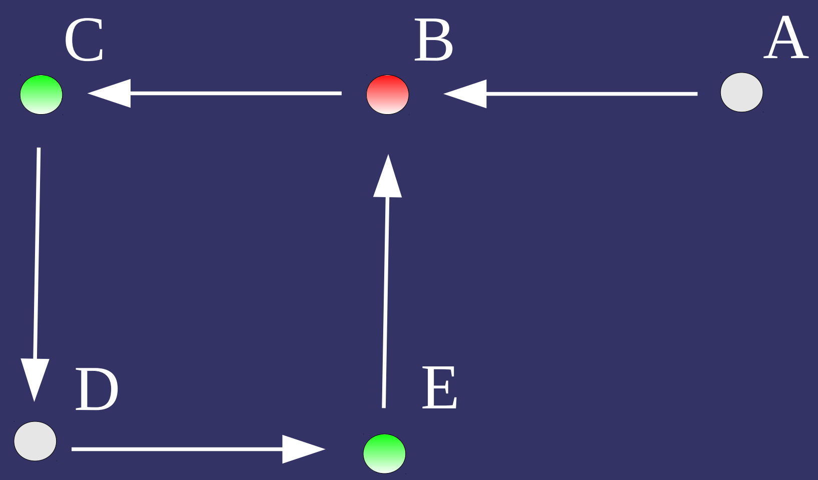
P: HTB(C)
O: CB(B)
P: HTB(E)
O: CB(D)
P: HTB(C)

Example



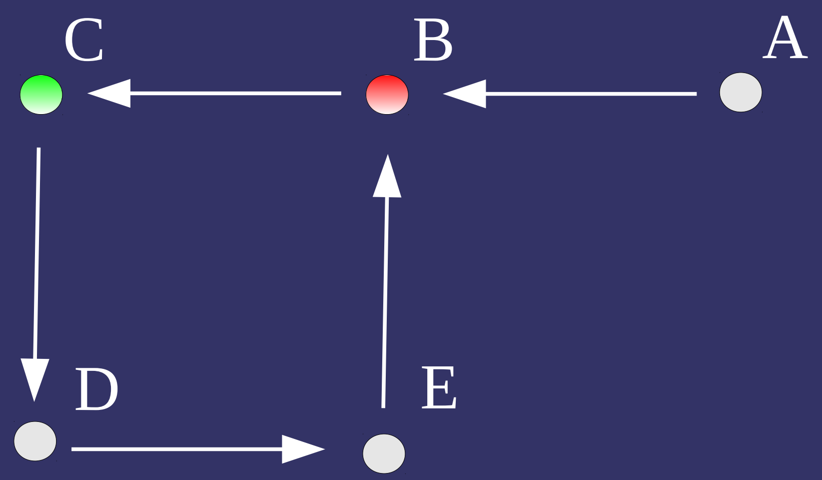
P: HTB(C)
O: CB(B)
P: HTB(E)
O: CB(D)

Example



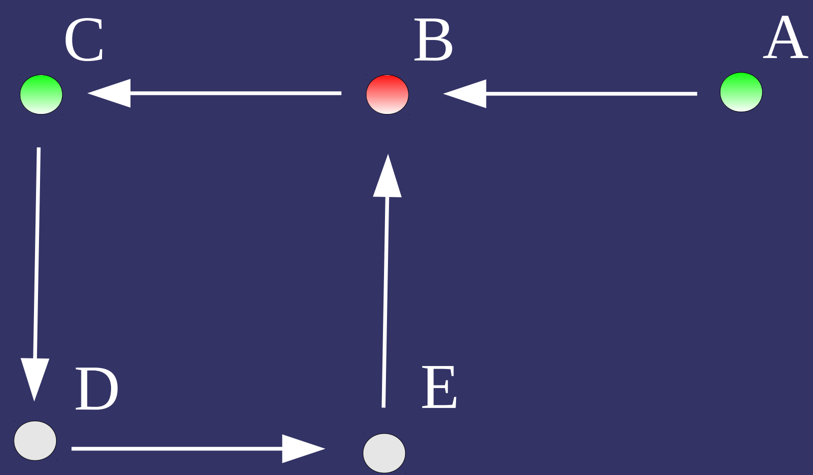
P: HTB(C)
O: CB(B)
P: HTB(E)

Example



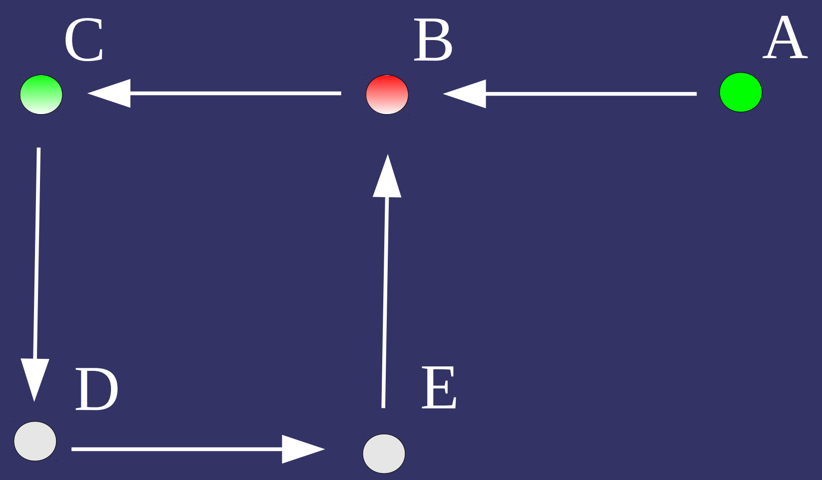
P: HTB(C)
O: CB(B)

Example



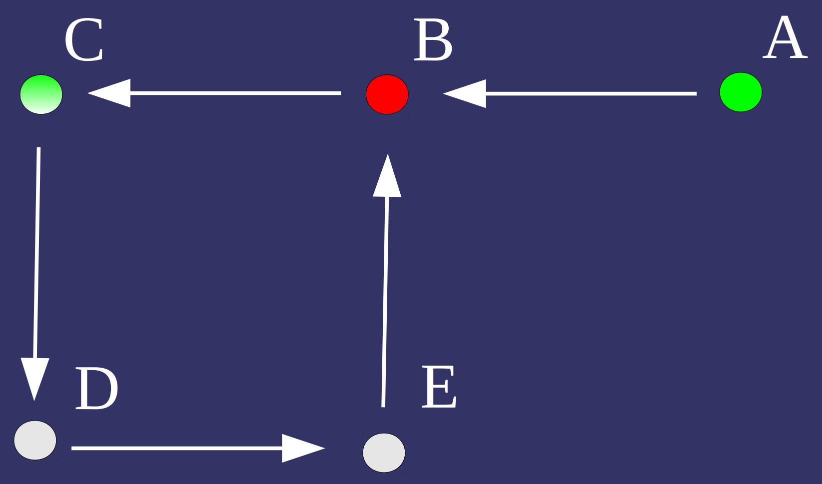
P: HTB(C)
O: CB(B)
P: HTB(A)

Example



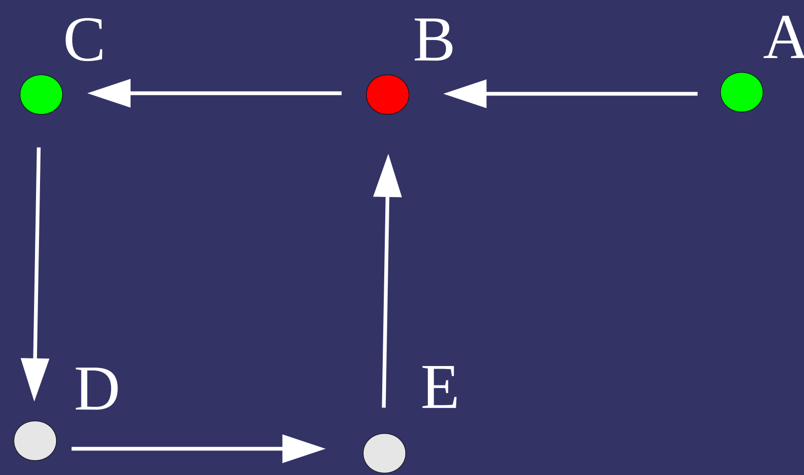
P: HTB(C)
O: CB(B)
P: HTB(A)
O: CONCEDE(A)

Example



P: HTB(C)
O: CB(B)
P: HTB(A)
O: CONCEDE(A)
O: RETRACT(B)

Example



P: HTB(C)
O: CB(B)
P: HTB(A)
O: CONCEDE(A)
O: RETRACT(B)
O: CONCEDE(C)

Example [Prakken]

Example [Prakken]

Paul: My car is very safe, because it has an airbag.
Olga: I do not think having an airbag makes your car safe, because airbags are unreliable: the newspapers had several reports on cases where airbags did not work.
Paul: A recent scientific study shows that airbags are in fact 99% reliable, and scientific studies are more important than newspaper reports.
Olga: OK, I admit that airbags are reliable.
However, your car is not very safe,
since its maximum speed is much too high.

Example [Prakken]

P: My car is very safe, because it has an airbag.

O: I do not think having an airbag makes your car safe, because airbags are unreliable: the newspapers had several reports on cases where airbags did not work.

P: A recent scientific study shows that airbags are in fact 99% reliable, and scientific studies are more important than newspaper reports.

O: OK, I admit that airbags are reliable.
However, your car is not very safe,
since its maximum speed is much too high.

Example [Prakken]

P: HTB(airbag $\Rightarrow$ safe)

O: I do not think having an airbag makes your car safe, because airbags are unreliable: the newspapers had several reports on cases where airbags did not work.

P: A recent scientific study shows that airbags are in fact 99% reliable, and scientific studies are more important than newspaper reports.

O: OK, I admit that airbags are reliable.
However, your car is not very safe,
since its maximum speed is much too high.

Example [Prakken]

P: HTB(airbag ⇒ safe)
O: CB(npr ⇒ ¬airbagrel ⇒ ¬[airbag ⇒ safe])

P: A recent scientific study shows that airbags are in fact 99% reliable, and scientific studies are more important than newspaper reports.
O: OK, I admit that airbags are reliable.
However, your car is not very safe,
since its maximum speed is much too high.

Example [Prakken]

P: HTB(airbag $\Rightarrow$ safe)
O: CB(npr $\Rightarrow$ $\neg$airbagrel $\Rightarrow$ $\neg$[airbag $\Rightarrow$ safe])

P: HTB(study $\Rightarrow$ airbagrel)

O: OK, I admit that airbags are reliable.
However, your car is not very safe,
since its maximum speed is much too high.

Example [Prakken]

P: HTB(airbag $\Rightarrow$ safe)
O: CB(npr $\Rightarrow$ $\neg$airbagrel $\Rightarrow$ $\neg$[airbag $\Rightarrow$ safe])

P: HTB(study $\Rightarrow$ airbagrel)

O: CONCEDE(study $\Rightarrow$ airbagrel)
However, your car is not very safe,
since its maximum speed is much too high.

Example [Prakken]

P: HTB(airbag ⇒ safe)
O: CB(npr ⇒ ¬airbagrel ⇒ ¬[airbag ⇒ safe])

P: HTB(study ⇒ airbagrel)

O: CONCEDE(study ⇒ airbagrel)
RETRACT(npr ⇒ ¬airbagrel ⇒ ¬[airbag ⇒ safe])

Example [Prakken]

P: HTB(airbag $\Rightarrow$ safe)
O: CB(npr $\Rightarrow$ ¬airbagrel $\Rightarrow$ ¬[airbag $\Rightarrow$ safe])

P: HTB(study $\Rightarrow$ airbagrel)

O: CONCEDE(study $\Rightarrow$ airbagrel)
RETRACT(npr $\Rightarrow$ ¬airbagrel $\Rightarrow$ ¬[airbag $\Rightarrow$ safe])
CB(highspeed $\Rightarrow$ ¬safe)

Next Topic

The Preferred Discussion Game

Socratic Discussion

Answer me this. As soon as one man loves another, which of the two becomes the friend? the lover of the loved, or the loved of the lover? Or does it make no difference?

None in the world, that I can see

How? Are both friends, if only one loves?

I think so

Indeed! is it not possible for one who loves, not to be loved in return (…) ?

It is.

Nay, is it not possible for him even to be hated? (…) Don't you believe this to be true?

Quite true.

Well, in such a case as this, the one loves, the other is loved.

Just so.

Which of the two, then, is the friend of the other? The lover of the loved, whether or not he be loved in return, and even if he be hated, or the loved of the lover? or is neither the friend of he other, unless both love each other?

The latter certainly seems to be the case, Socrates.

If so, I continued, we think differently now from what we did before. (…)

Yes, I'm afraid we have contradicted ourselves.

Traditional Dialogue vs. Socratic Dialogue

P: claim tr

“I think that there will be a tax relief.”

O: why tr

“Why do you think so?”

P: because pmp $\Rightarrow$ tr

“Because of the fact that the politicians made a promise.”

O: concede tr

“OK, you are right.”

Traditional Dialogue vs. Socratic Dialogue

P: claim tr

“I think that tr.”

O: but-then tr ⇒ bd

“Then you implicitly also hold that bd.”

P: concede bd

“Yes I do.”

O: but-then bd ⇒ feu

“Then you implicitly also hold that feu.”

P: concede feu

“Yes I do.”

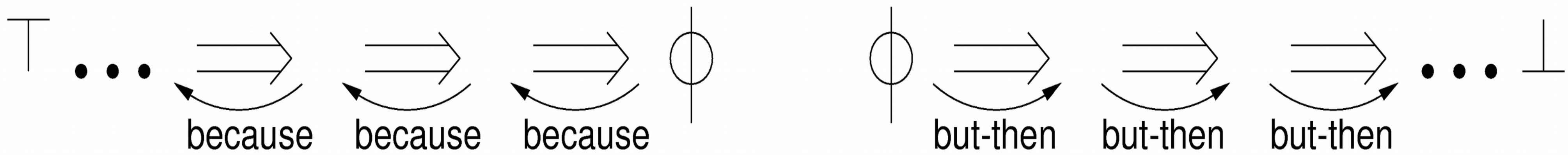
O: but-then feu ⇒ ¬tr

“Then you implicitly also hold that ¬tr.”

P: concede ¬*tr*

“Oops, you’re right; I caught myself in...”

“because” versus “but-then”



reasoning goes backward

reasoning goes forward

proponent constructs path

opponent constructs path

originates from *true*

leads to *false*

both parties
become committed

only proponent
becomes committed

Preferred Semantics as Socratic Discussion

Preferred Semantics as Socratic Discussion

definition

admissible labelling:

if argument is in then all its attackers are out

if argument is out then it has an attacker that is in

Preferred Semantics as Socratic Discussion

definition

admissible labelling:

if argument is in then all its attackers are out

if argument is out then it has an attacker that is in

proposition

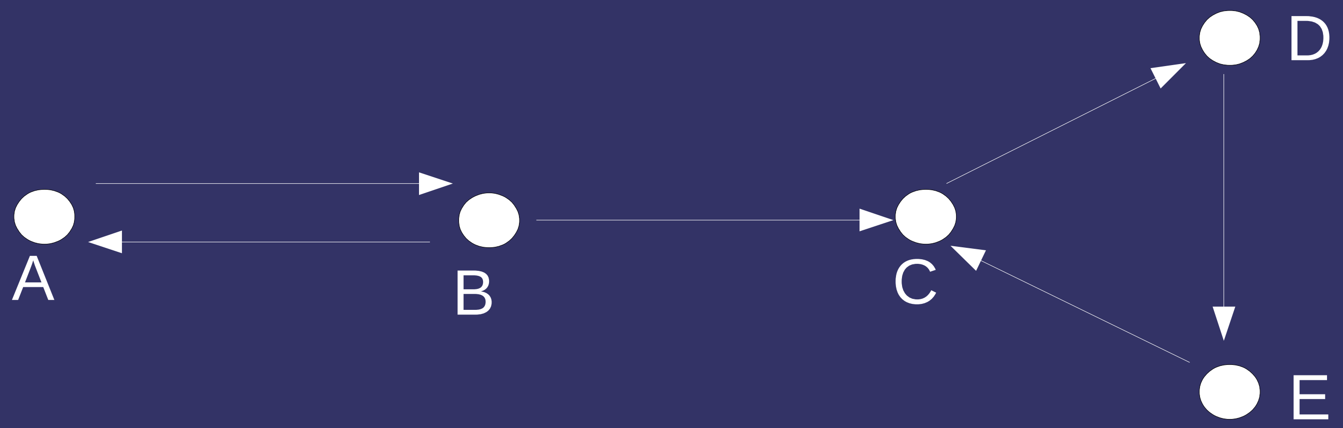
An argument is in a preferred extension

iff it is in a complete extension

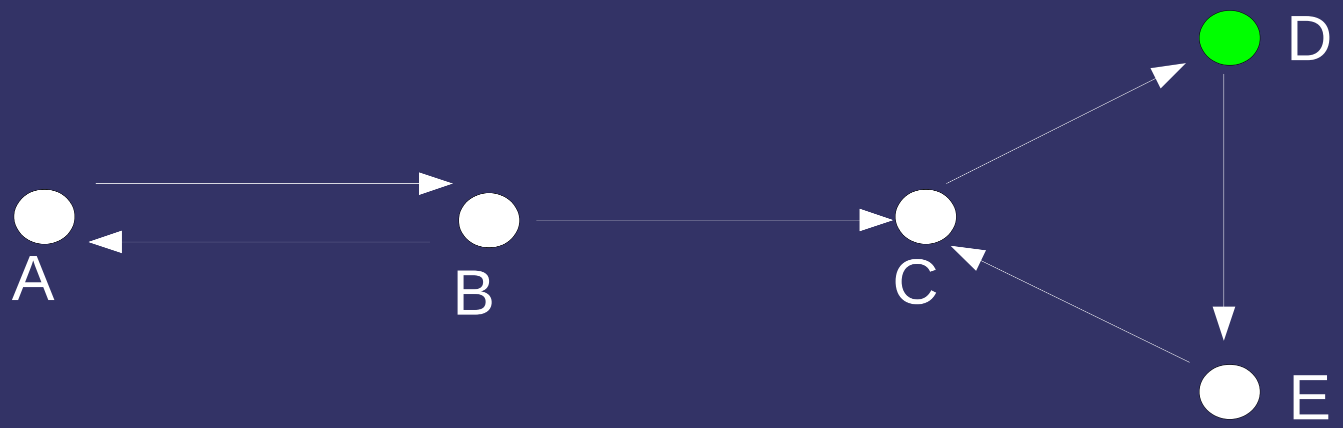
iff it is in an admissible set

iff it is labelled in by an admissible labelling

Preferred Semantics as Socratic Discussion

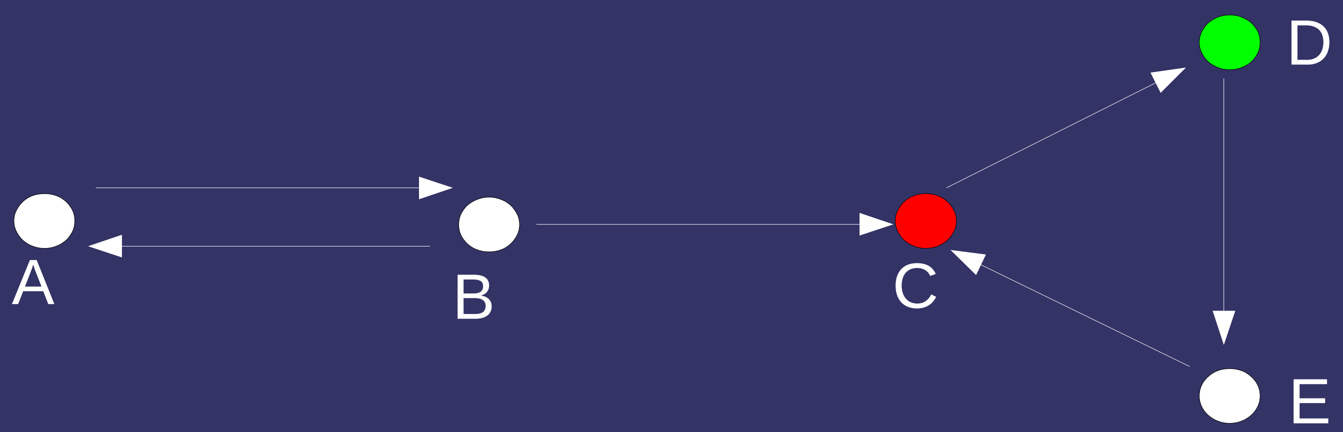


Preferred Semantics as Socratic Discussion



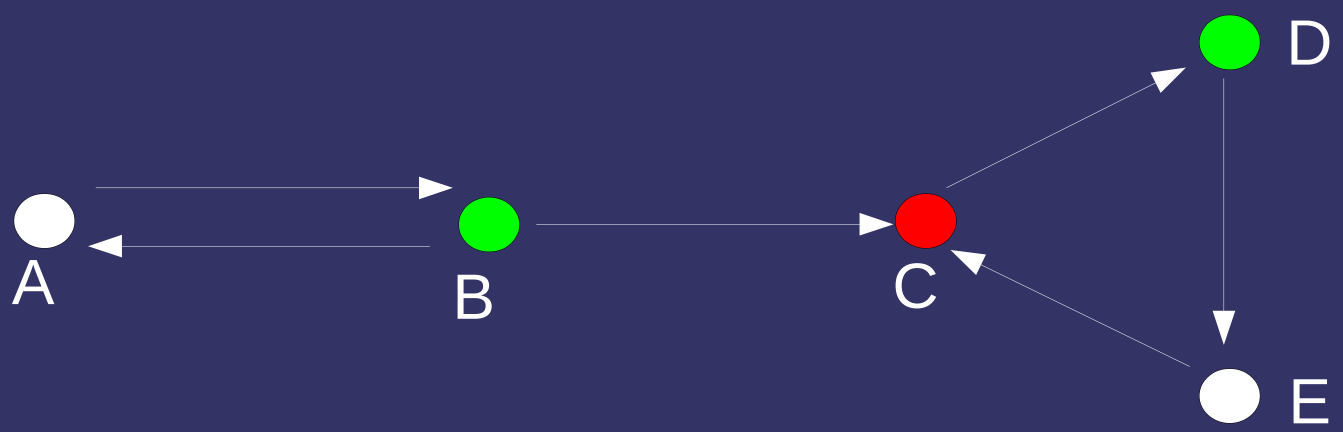
M: in(D) “I have an admissible labelling in which D is labelled in.”

Preferred Semantics as Socratic Discussion



M: in(D) “I have an admissible labelling in which D is labelled in.”
S: out(C) “But then in your labelling it must also be the case that D’s attacker C is labelled out. Based on which grounds?”

Preferred Semantics as Socratic Discussion



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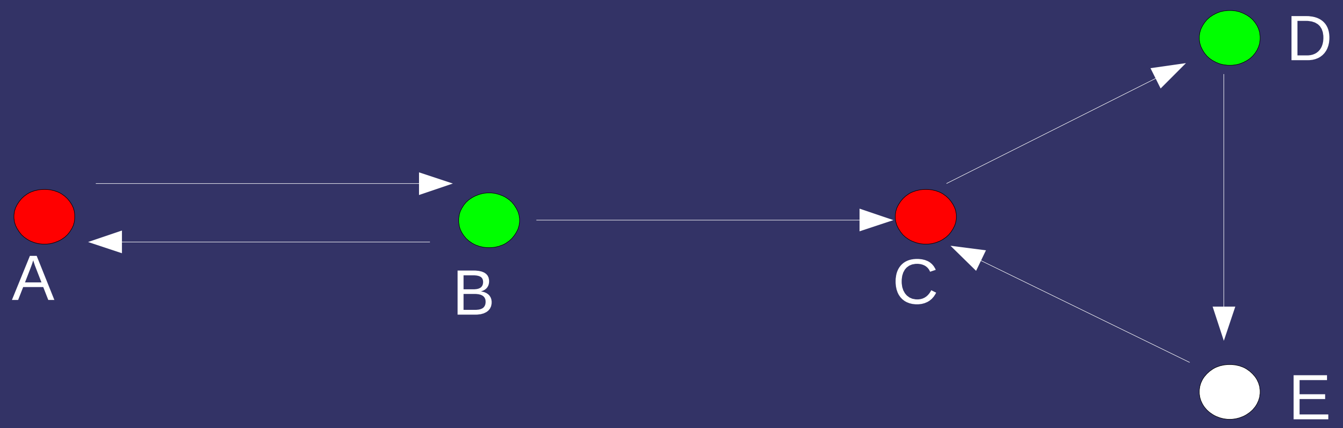

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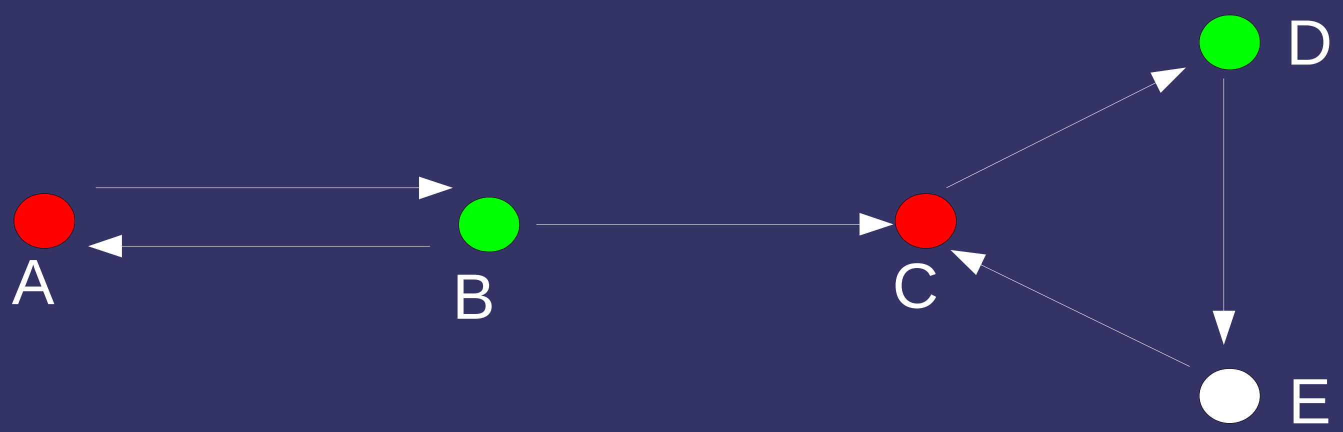
Preferred Semantics as Socratic Discussion



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M: in(B) "A is labelled out because B is labelled in."

Preferred Semantics as Socratic Discussion

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(1) Each move of M (except the first)
contains an attacker of the directly preceding move of S.

Preferred Semantics as Socratic Discussion

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M: in(B) “A is labelled out because B is labelled in.”

(2) Each move of S
contains an attacker of <u>some</u> previous move of M.

Preferred Semantics as Socratic Discussion

M: in(D) "I have an admissible labelling in which D is labelled in."

S: out(C) "But then in your labelling it must also be the case that D's attacker C is labelled out. Based on which grounds?"

M: in(B) "C is labelled out because B is labelled in."

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M: in(B) "A is labelled out because B is labelled in."

(3) S is not allowed to repeat his moves.

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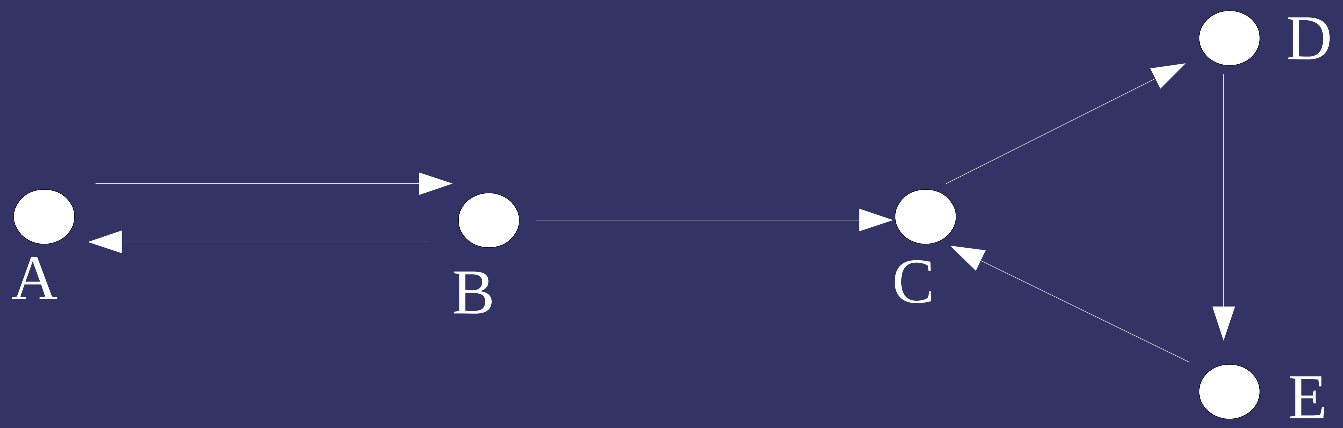
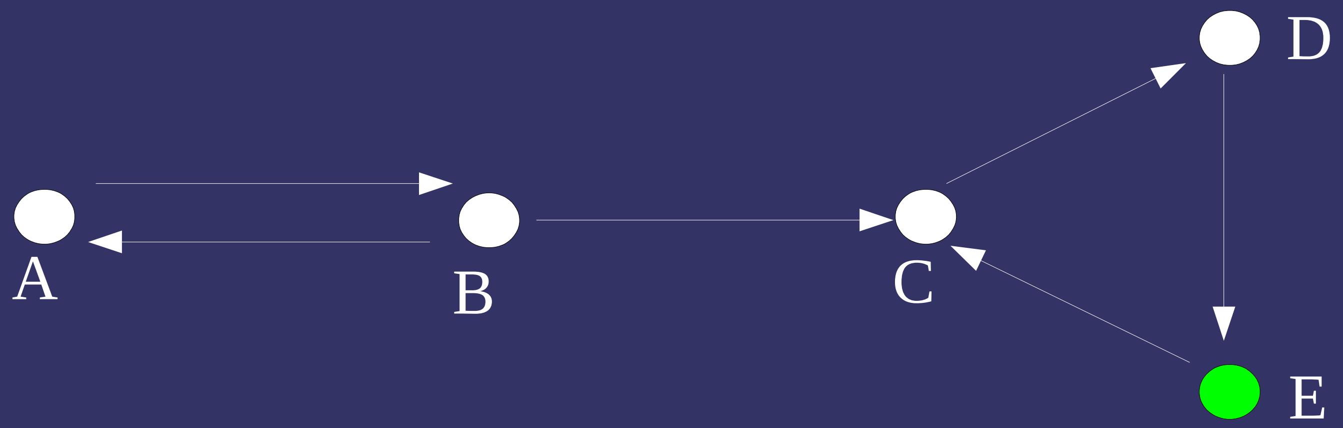


Preferred Semantics as Socratic Discussion



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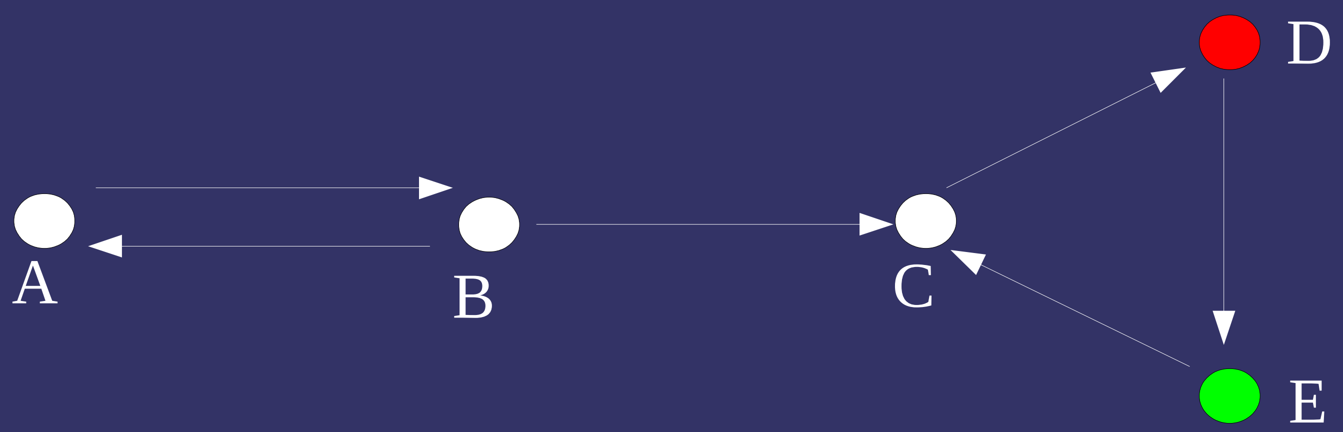
Preferred Semantics as Socratic Discussion



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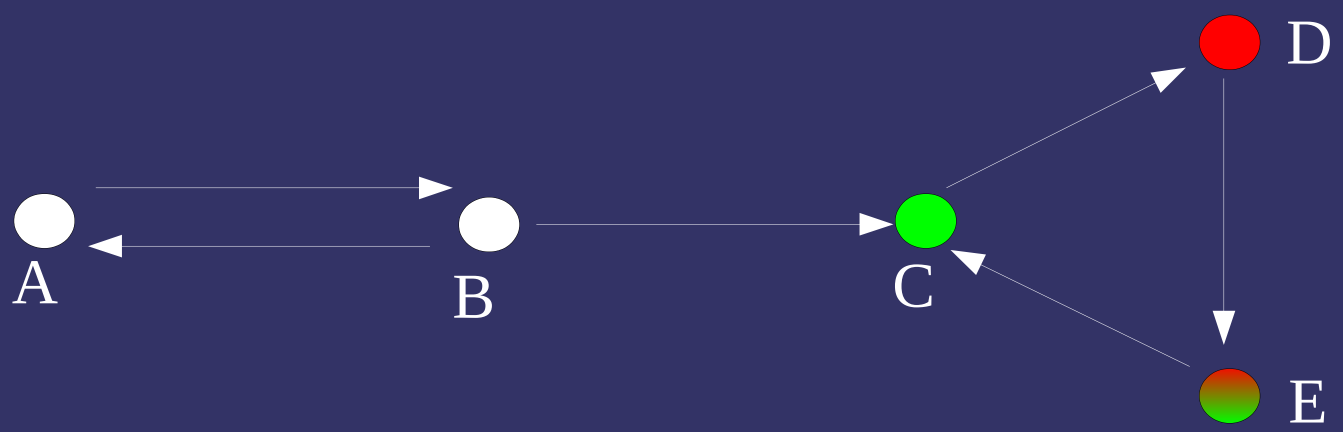

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M: in(C) "D is labelled out because C is labelled in."

S: out(E) "But then in your labelling it must also be the case that C's attacker E is labelled out. This <u>*contradicts*</u> with your earlier claim that E is labelled in."

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(5) If S uses an argument previously used by M, then S wins the discussion.

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(6) If M uses an argument previously used by S, then S wins the discussion.

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(7) If M cannot make a move anymore,
then S wins the discussion.

Preferred Semantics as Socratic Discussion

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(8) If S cannot make a move anymore,
then M wins the discussion.

Preferred Semantics as Socratic Discussion

THEOREM

Argument A is labelled in by at least one admissible labelling iff M can win the Socratic discussion game (for A).

Preferred Semantics as Socratic Discussion

THEOREM

Argument A is in at least one preferred extension iff M can win the Socratic discussion game (for A).

Complete Semantics as Socratic Discussion

THEOREM

Argument A is in at least one complete extension iff M can win the Socratic discussion game (for A).

Skeptical Complete vs Credulous Complete

- Skeptical Complete (= grounded)
  The argument is accepted in every reasonable position (complete labelling)
  "*Therefore you have to hold that...*"
  <u>persuasion dialogue</u>

- Credulous Complete (= credulous preferred)
  The argument is accepted in at least one reasonable position (complete labelling)
  "*Therefore I can hold that...*"
  <u>Socratic dialogue</u>

Why These Results Matter

- classical logic:

- argumentation:

Why These Results Matter

- classical logic: based on notion of *truth*
  (entails what is model-theoretically true)

- argumentation:

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  (entails what can be defended in rational discussion)

Why These Results Matter

- classical logic: based on notion of *truth*
  (entails what is model-theoretically true)

- argumentation: based on notion of *justification*
  (entails what can be defended in rational discussion)

- discussions can be used by the system to *explain*
  its answer to the user

- different semantics express
  different types of rational discussion

- allows (in principle) for *dynamic* and *user-based* updating
  of the underlying knowledge base

Next Topic

Rationality Postulates

If we select arguments using only the structure of the graph, then how do we know their conclusions make sense?

Argumentation for Inference: 3-step process

Argumentation for Inference: 3-step process

knowledge base

Argumentation for Inference: 3-step process

argumentation framework

↑ *(1) argument (+attack) construction*

knowledge base

Argumentation for Inference: 3-step process

labellings
of arguments

(2) applying argumentation semantics

argumentation
framework

(1) argument (+attack) construction

knowledge
base

Argumentation for Inference: 3-step process

labellings
of conclusions

(3) determining status of conclusions

labellings
of arguments

(2) applying argumentation semantics

argumentation
framework

(1) argument (+attack) construction

knowledge
base

From Arguments to Conclusions

labelling of args → labelling of concs

for each conclusion, give it the label of the “best” (highest label) argument that yields it

How Things Go Wrong (1/5)

r	$r \Rightarrow m$	$m \rightarrow hs$
p	$p \Rightarrow b$	$b \rightarrow \neg hs$

$A1 = (r) \Rightarrow m$
$A2 = (p) \Rightarrow b$
$A3 = A1 \rightarrow hs$
$A4 = A2 \rightarrow \neg hs$

Conclusions m and b are justified under any semantics but what about hs and ¬hs?

How Things Go Wrong (2/5)

$r \qquad r \Rightarrow m \qquad m \supset hs \qquad$ ("$\rightarrow$"$\equiv$"$\vdash$")

$p \qquad p \Rightarrow b \qquad b \supset \neg hs$

A1: $(r) \Rightarrow m$

A2: $(p) \Rightarrow b$

A3: $(A1,\ m \supset hs) \rightarrow hs$

A4: $(A2,\ b \supset \neg hs) \rightarrow \neg hs$

A5: $(A3,\ b \supset \neg hs) \rightarrow \neg b$

A6: $(A4,\ m \supset hs) \rightarrow \neg m$

So far, so good...

How Things Go Wrong (3/5)

j $\quad j \Rightarrow s$ $\quad$ ("$\rightarrow$"$\equiv$"$\vdash$")

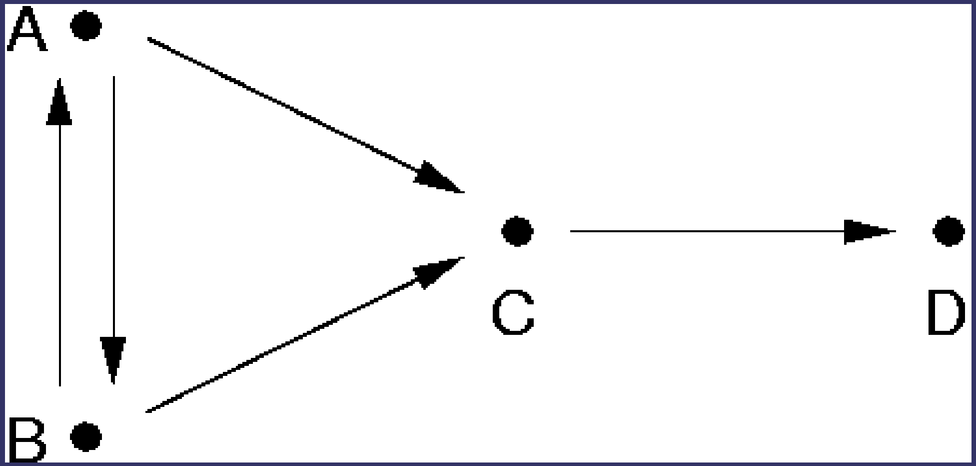
m $\quad m \Rightarrow \neg s$ $\quad wf$ $\quad wf \Rightarrow r$

There now exist the following arguments:

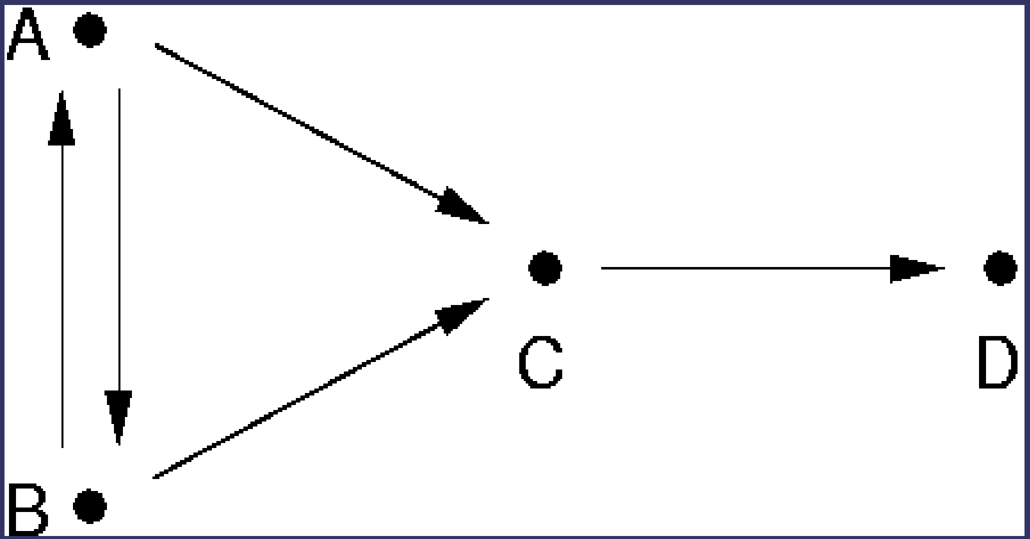
$A = (j) \Rightarrow s$ $\quad$ (unfortunately,

$B = (m) \Rightarrow \neg s$ $\quad$ there also exists:

$D = (wf) \Rightarrow r$ $\quad C = A, B \rightarrow \neg r$)



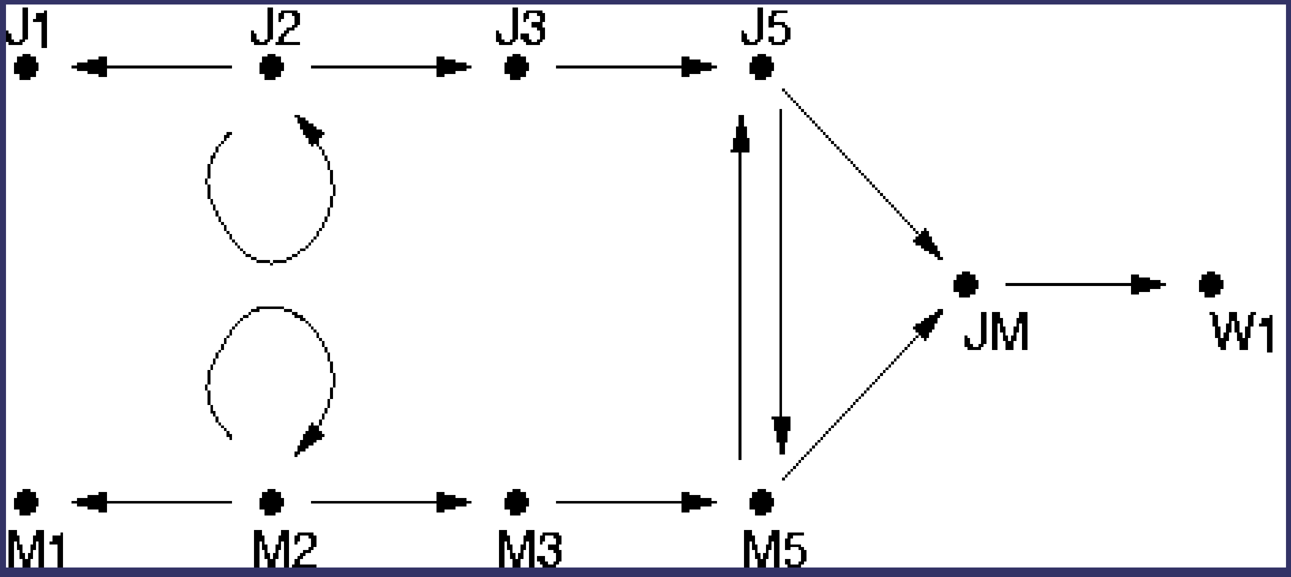
How Things Go Wrong (4/5)



- Grounded semantics: no justified arguments
- Why not use preferred or stable semantics?
- Reiter and Pollock also do this...

How Things Go Wrong (5/5)

John: “Cup of coffee contains sugar.”
Mary: “Cup of coffee doesn't contain sugar.”
John: “I'm unreliable.”
Mary: “I'm unreliable.”
Weather Forecaster: “Tomorrow rain.”



Rationality Postulates

Let J be a set of conclusions yielded by an argumentation formalism.

- *direct consistency*
  J does not contain contraries (p and ¬p)
- *closure*
  J is closed under the strict rules
- *indirect consistency*
  the closure of J under strict rules is directly consistent
- *crash-resistance*
  no set of formulas can make a totally unrelated set of formulas completely irrelevant, when being merged to it
- *non-interference*
  no set of formulas can influence the entailment of a totally unrelated set of formulas, when being merged to it

Rationality Postulates

direct consistency
closure
indirect consistency

Caminada & Amgoud
AIJ 2007

crash-resistance
non-interference
backwards compatibility

Caminada, Dunne & Carnielli
JLC 2011

Transposition

Take the following strict rule:

$a_1, ..., a_{i-1}, \; a_i, a_{i+1}, ..., a_n \rightarrow c$

A *transposition* of this rule is:

$a_1, ..., a_{i-1}, \neg c, a_{i+1}, ..., a_n \rightarrow \neg a_i$

(for some $1 \leq i \leq n$)

A set of strict rules S is closed under transposition iff it contains all transpositions of the rules in S.

Restricted versus unrestricted rebut

$((a) \Rightarrow b) \Rightarrow c$
$((d) \Rightarrow e) \Rightarrow \neg c$

Restricted versus unrestricted rebut

$((a) \rightarrow b) \rightarrow c$

$((d) \Rightarrow e) \Rightarrow \neg c$

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Restricted versus unrestricted rebut

$((a) \Rightarrow b) \rightarrow c$
$((d) \rightarrow e) \Rightarrow \neg c$

unrestricted rebut:
an argument can be rebutted on a conclusion derived by at least one defeasible rule

restricted rebut:
an argument can be rebutted only on the direct consequent of a defeasible rule

Satisfying the rationality postulates (1/2)

Satisfying the rationality postulates (1/2)

When using strict rules as primitives:

Satisfying the rationality postulates (1/3)

When using strict rules as primitives:

- Step 1:
  - close the strict rules under *transposition*
  - use *restricted rebut* for defining the attack relation
- Step 2:
  - use a *complete-based* semantics that yields at least one extension/labelling
- Step 3:
  (standard)

Satisfying the rationality postulates (2/3)

When using strict rules as primitives:

- Step 1:
  - close the strict rules under *transposition*
  - use *unrestricted rebut* for defining the attack relation

- Step 2:
  - use *grounded semantics*

- Step 3:
  (standard)

Satisfying the rationality postulates (2/2)

When using strict rules as classical entailment:

Satisfying the rationality postulates (3/3)

When using strict rules as classical entailment:

- Step 1:
  - use restricted rebut for defining the attack relation
  - remove all inconsistent arguments

- Step 2:
  - use a <u>*complete-based*</u> semantics that yields at least one extension/labelling

- Step 3:
  (standard)

Why Restricted Rebut

S = { w1; w2; w3;

D = { w1 $\Rightarrow$ b1;   w2 $\Rightarrow$ b2;   w3 $\Rightarrow$ b3 }

Why Restricted Rebut

$S = \{ w1;\ \ w2;\ \ w3;\ \ b2,b3 \rightarrow \neg b1;\ \ b1,b3 \rightarrow \neg b2;\ \ b1,b2 \rightarrow \neg b3 \}$

$D = \{ w1 \Rightarrow b1;\ \ \ w2 \Rightarrow b2;\ \ \ w3 \Rightarrow b3 \}$

Why Restricted Rebut

$S = \{ w1;\ \ w2;\ \ w3;\ \ b2,b3 \rightarrow \neg b1;\ \ b1,b3 \rightarrow \neg b2;\ \ b1,b2 \rightarrow \neg b3 \}$

$D = \{ w1 \Rightarrow b1;\ \ \ w2 \Rightarrow b2;\ \ \ w3 \Rightarrow b3 \}$

A_1: $(w1) \Rightarrow b1$

A_2: $(w2) \Rightarrow b2$

A_3: $(w3) \Rightarrow b3$

Why Restricted Rebut

$S = \{ w1;\ \ w2;\ \ w3;\ \ b2,b3 \rightarrow \neg b1;\ \ b1,b3 \rightarrow \neg b2;\ \ b1,b2 \rightarrow \neg b3 \}$
$D = \{ w1 \Rightarrow b1;\ \ \ w2 \Rightarrow b2;\ \ \ w3 \Rightarrow b3 \}$

A_1: $(w1) \Rightarrow b1$

A_2: $(w2) \Rightarrow b2$

A_3: $(w3) \Rightarrow b3$

A_4: $A_2, A_3 \rightarrow \neg b1$

A_5: $A_1, A_3 \rightarrow \neg b2$

A_6: $A_1, A_2 \rightarrow \neg b3$

Why Restricted Rebut

S = { w1; w2; w3; b2,b3→¬b1; b1,b3→¬b2; b1,b2→¬b3 }
D = { w1 ⇒ b1; w2 ⇒ b2; w3 ⇒ b3 }

A_1: (w1) ⇒ b1

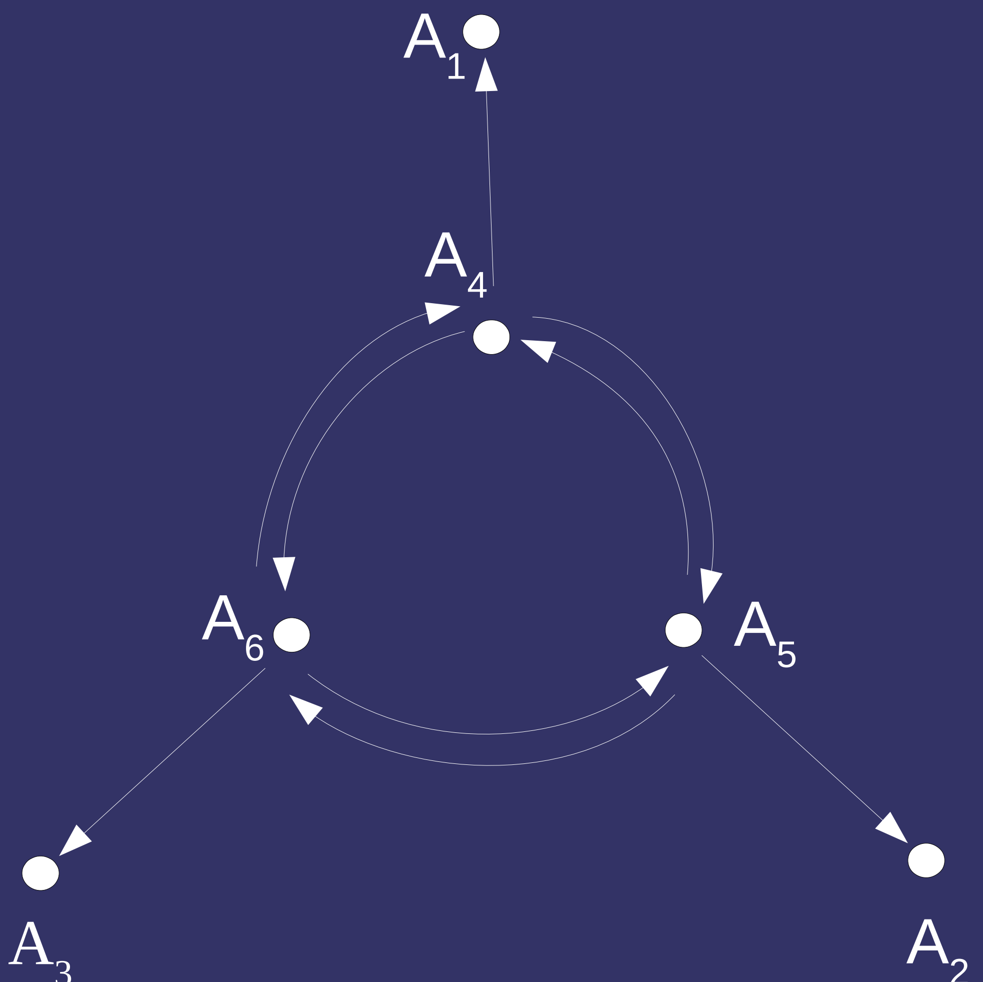
A_2: (w2) ⇒ b2

A_3: (w3) ⇒ b3

A_4: A_2, A_3 → ¬b1

A_5: A_1, A_3 → ¬b2

A_6: A_1, A_2 → ¬b3



Why Restricted Rebut

S = { w1; w2; w3; b2,b3→¬b1; b1,b3→¬b2; b1,b2→¬b3 }
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A_1: (w1) ⇒ b1

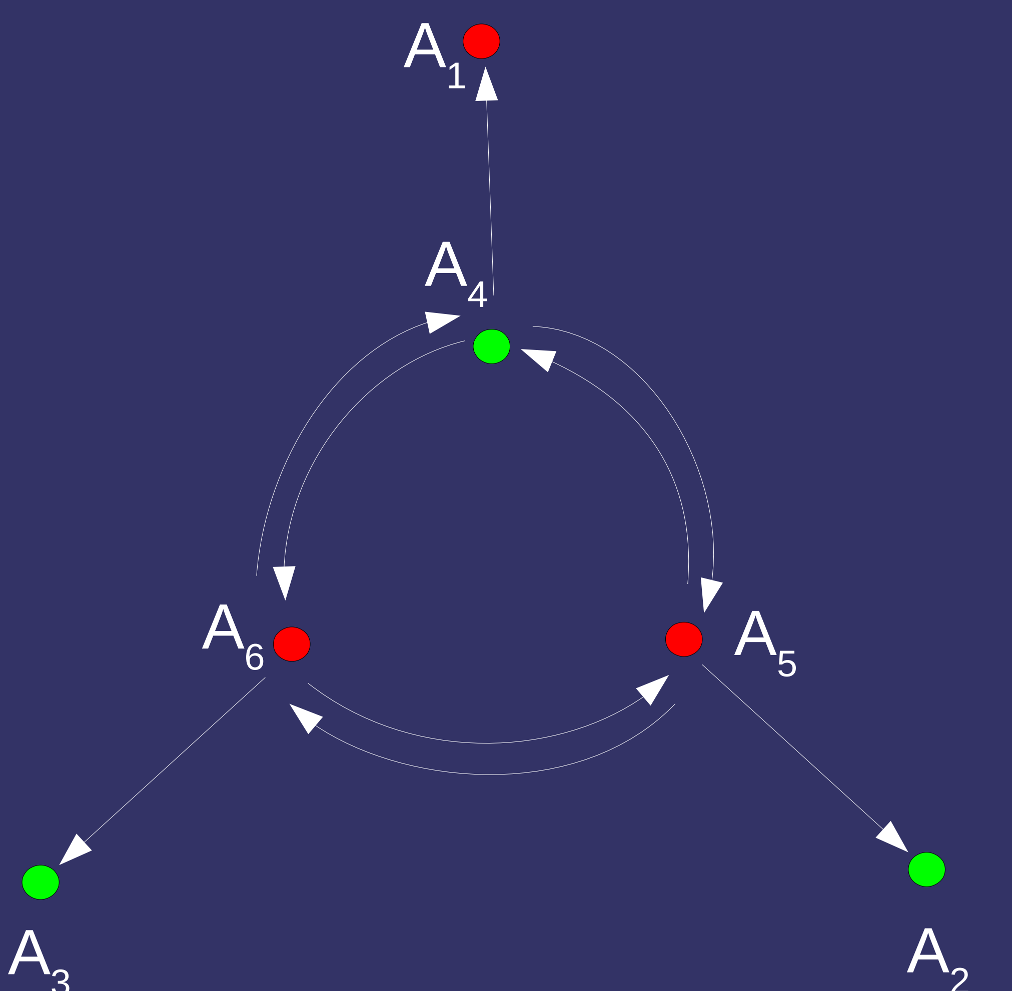
A_2: (w2) ⇒ b2

A_3: (w3) ⇒ b3

A_4: A_2, A_3 → ¬b1

A_5: A_1, A_3 → ¬b2

A_6: A_1, A_2 → ¬b3



Why Restricted Rebut

S = { w1; w2; w3; b2,b3→¬b1; b1,b3→¬b2; b1,b2→¬b3 }
D = { w1 ⇒ b1;   w2 ⇒ b2;   w3 ⇒ b3 }

A_1: (w1) ⇒ b1

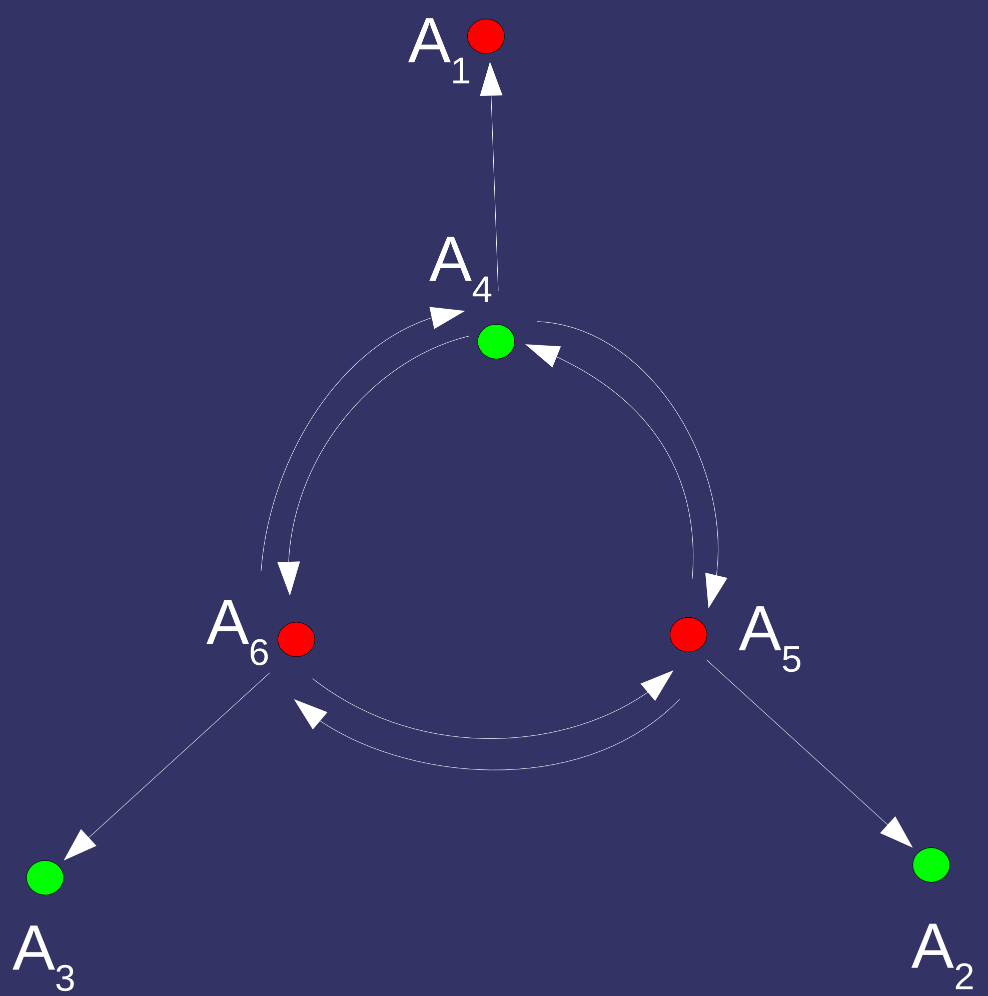
A_2: (w2) ⇒ b2

A_3: (w3) ⇒ b3

A_4: A_2, A_3 → ¬b1

A_5: A_1, A_3 → ¬b2

A_6: A_1, A_2 → ¬b3



b1 b2 b3   ¬b1 ¬b2 ¬b3

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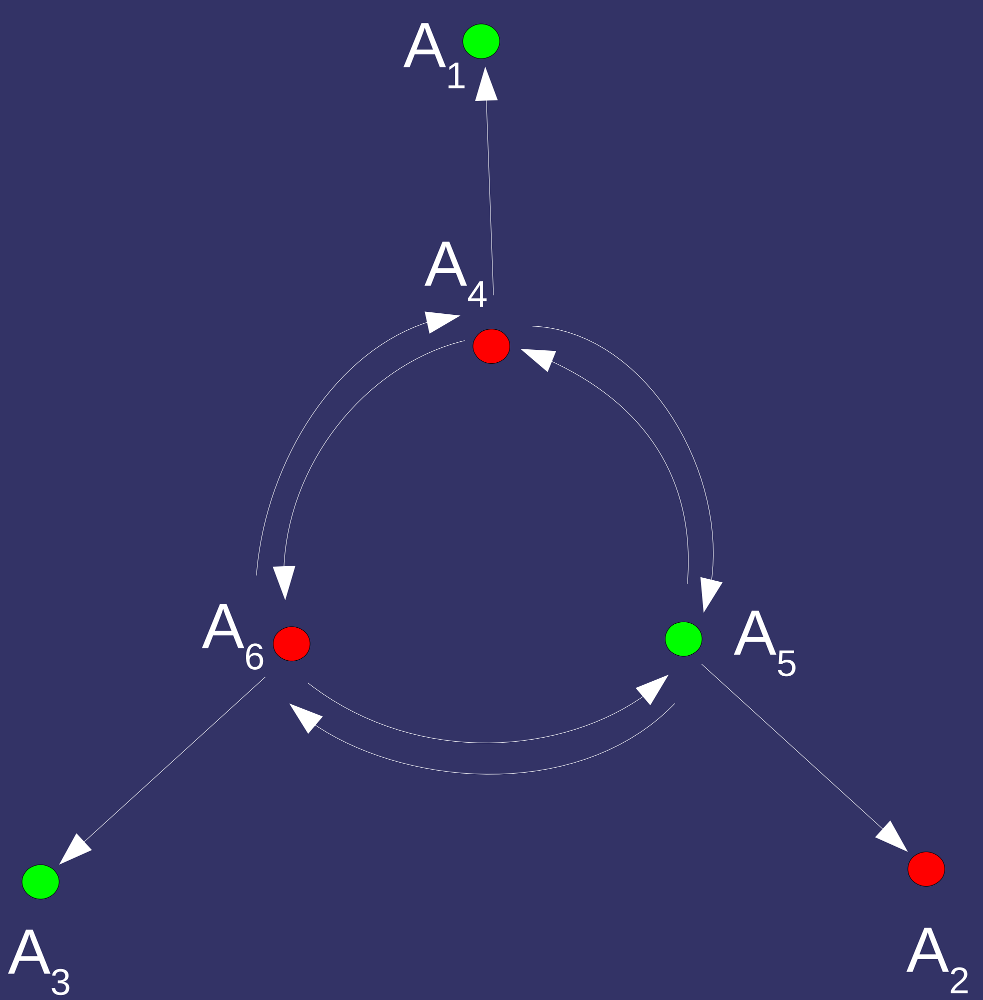

b1 b2 b3   ¬b1 ¬b2 ¬b3

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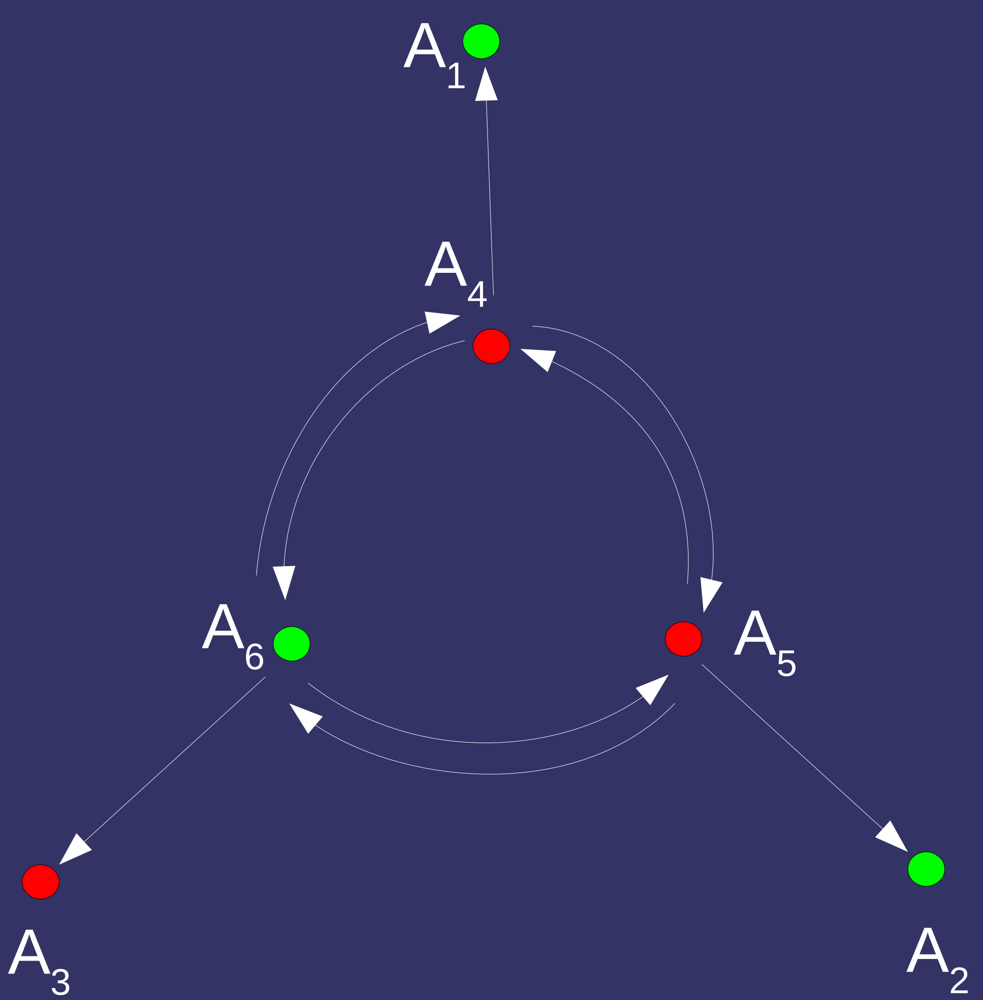

b1 b2 b3   ¬b1 ¬b2 ¬b3

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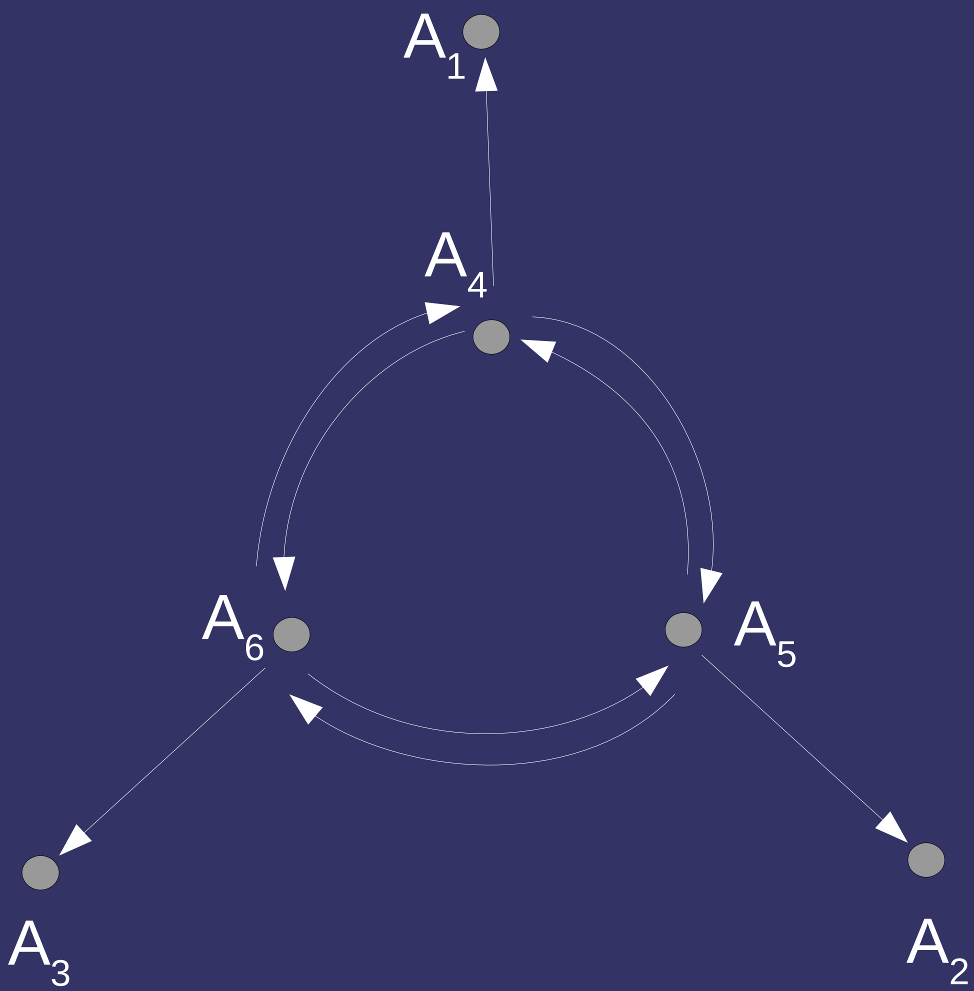

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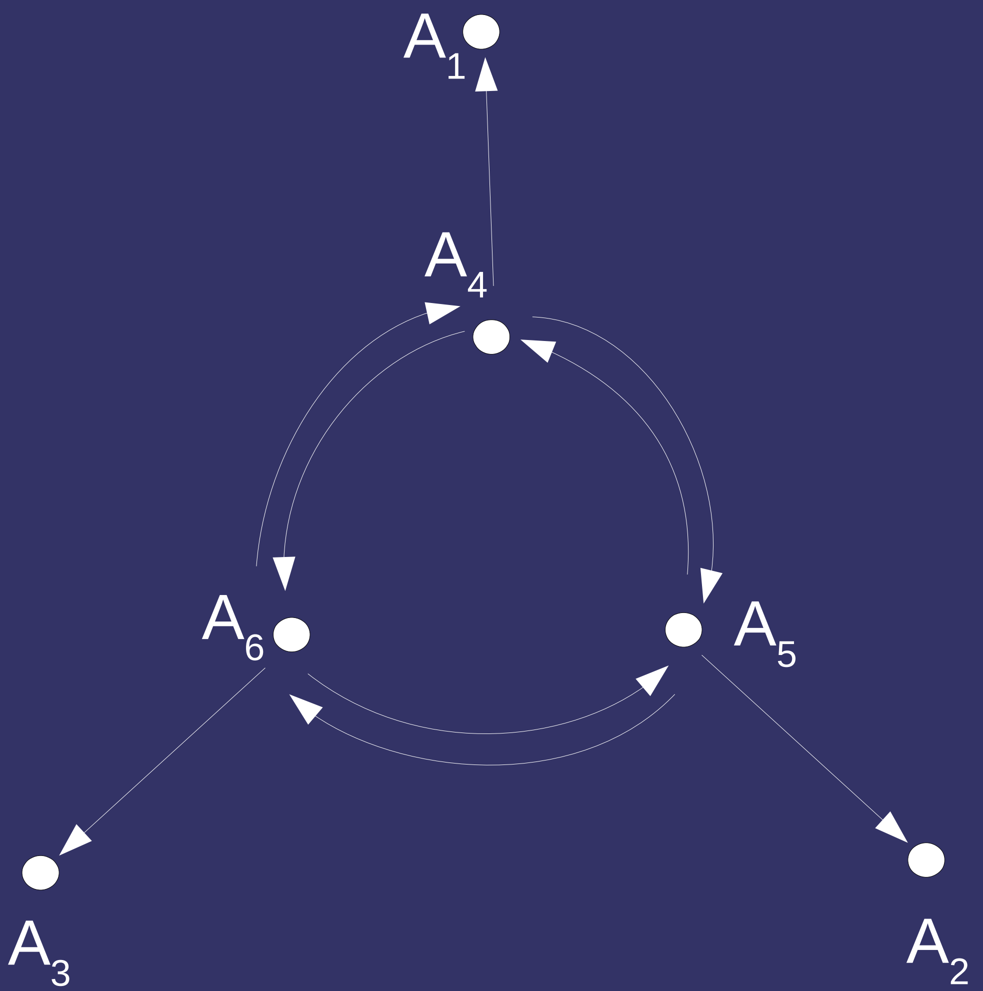

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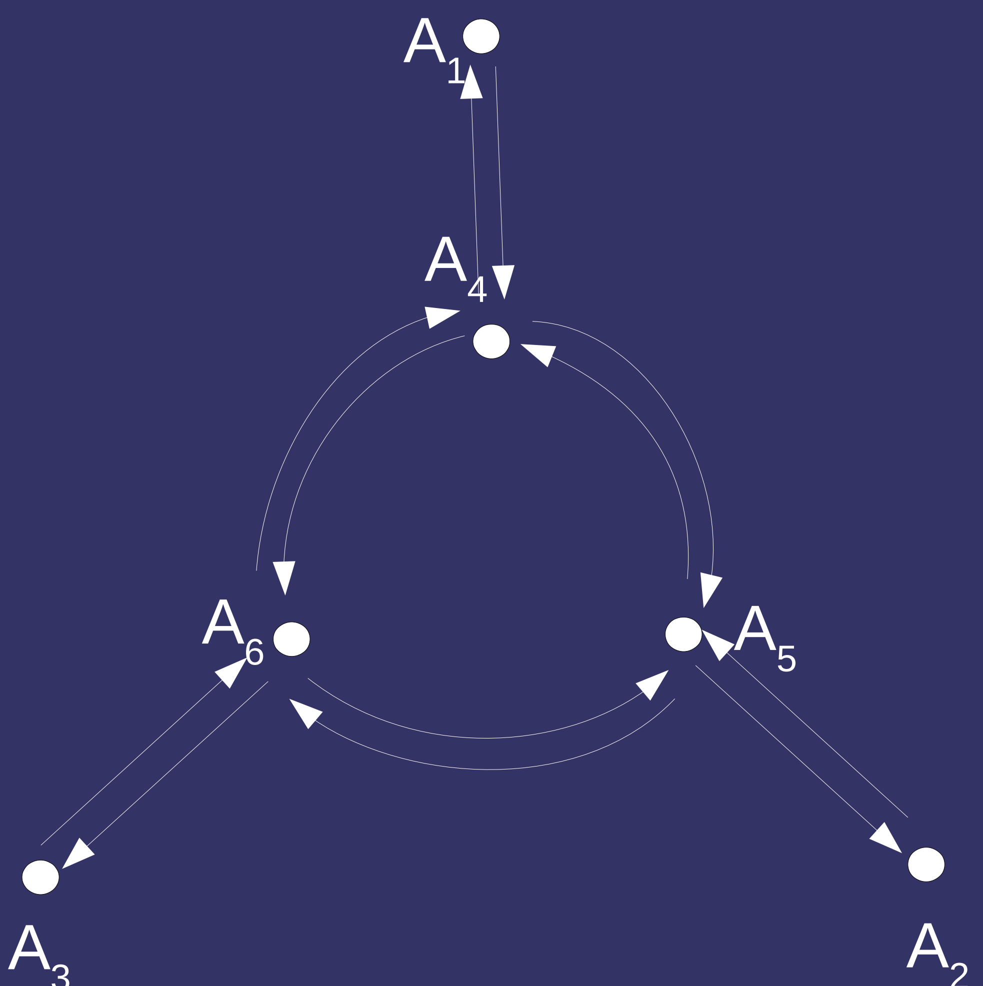

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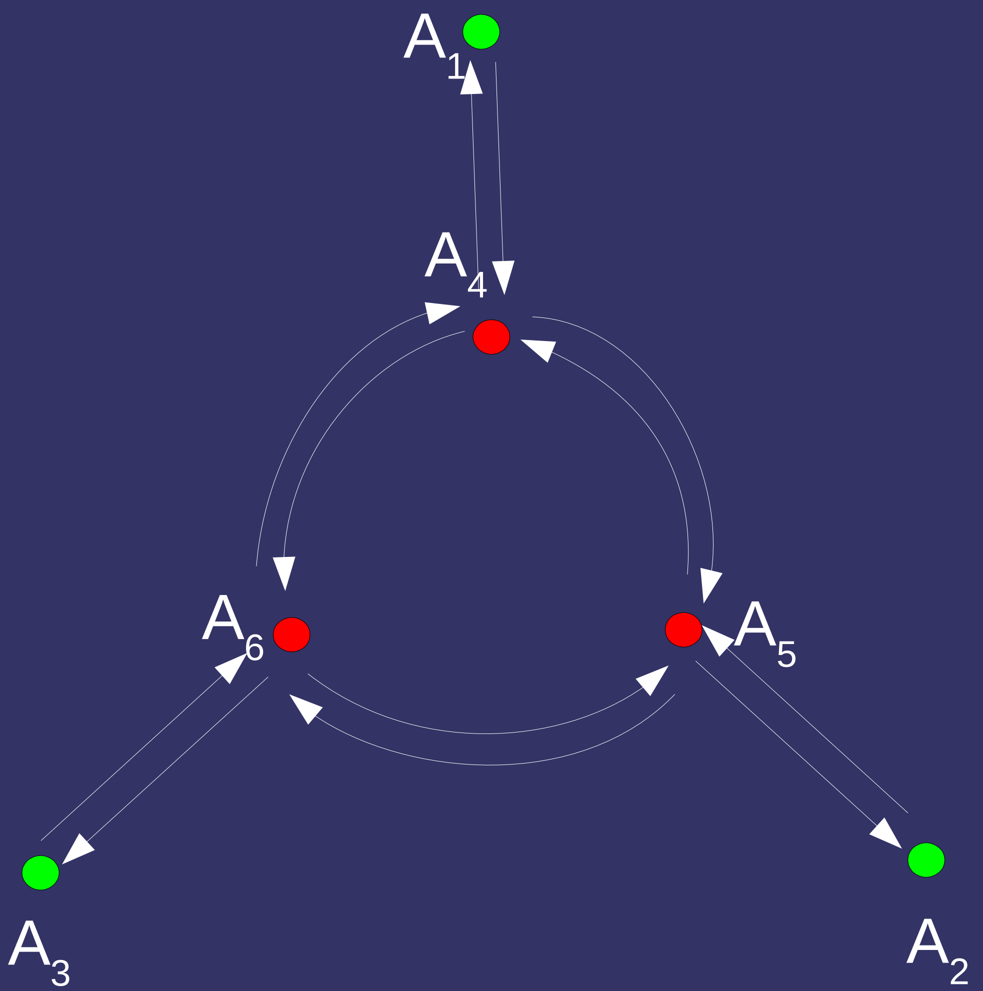


Why Restricted Rebut

$S = \{ w1;\ \ w2;\ \ w3;\ \ b2,b3 \rightarrow \neg b1;\ \ b1,b3 \rightarrow \neg b2;\ \ b1,b2 \rightarrow \neg b3 \}$

$D = \{ w1 \Rightarrow b1;\ \ \ w2 \Rightarrow b2;\ \ \ w3 \Rightarrow b3 \}$

$A_1: (w1) \Rightarrow b1$

$A_2: (w2) \Rightarrow b2$

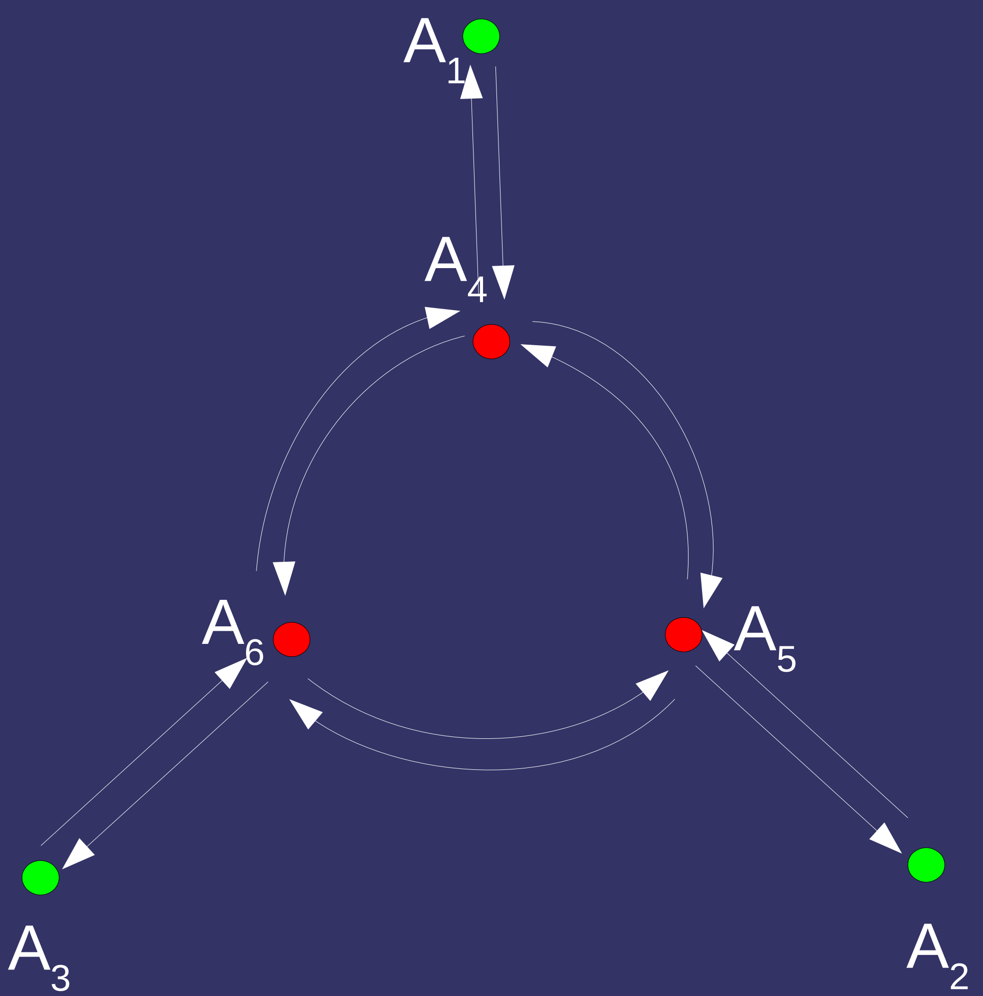
$A_3: (w3) \Rightarrow b3$

$A_4: A_2, A_3 \rightarrow \neg b1$

$A_5: A_1, A_3 \rightarrow \neg b2$

$A_6: A_1, A_2 \rightarrow \neg b3$

b1 b2 b3 ¬b1 ¬b2 ¬b3



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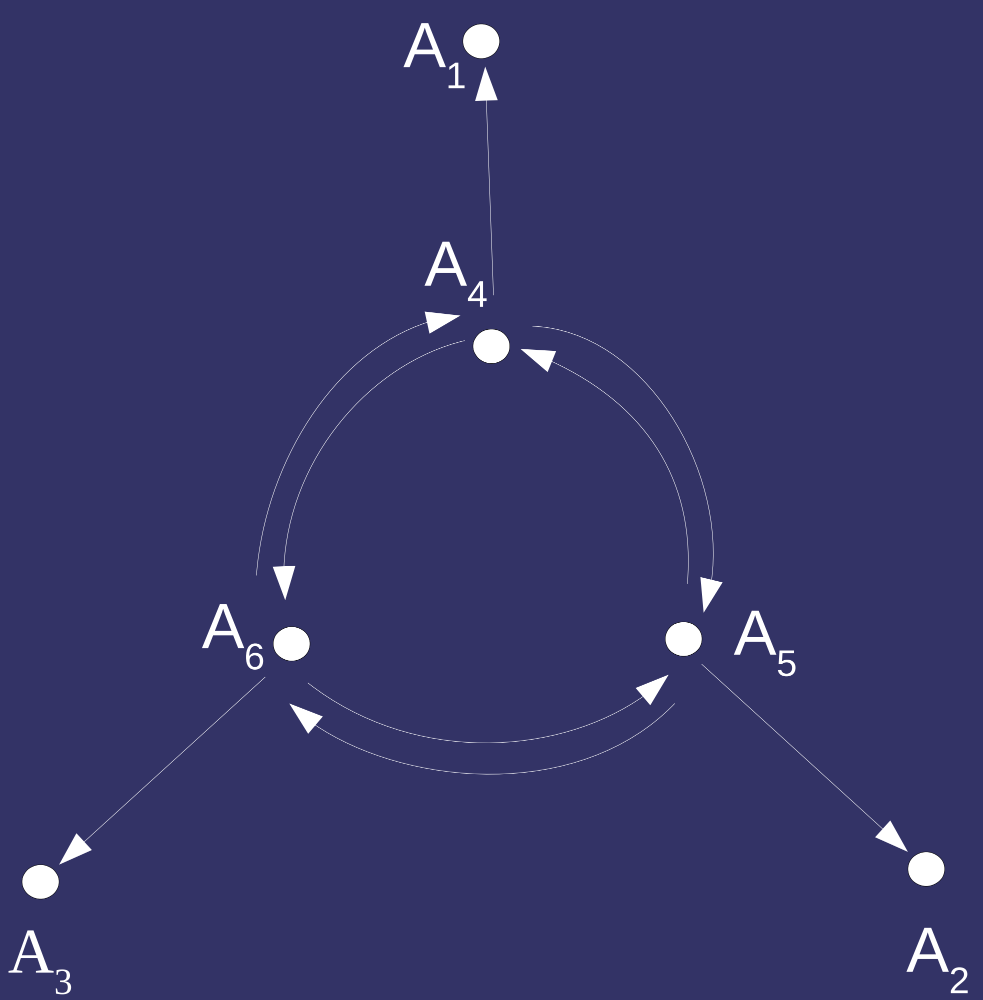

Why Admissibility

S = { w1; w2; w3; b2,b3→¬b1; b1,b3→¬b2; b1,b2→¬b3 }
D = { w1 ⇒ b1;   w2 ⇒ b2;   w3 ⇒ b3 }

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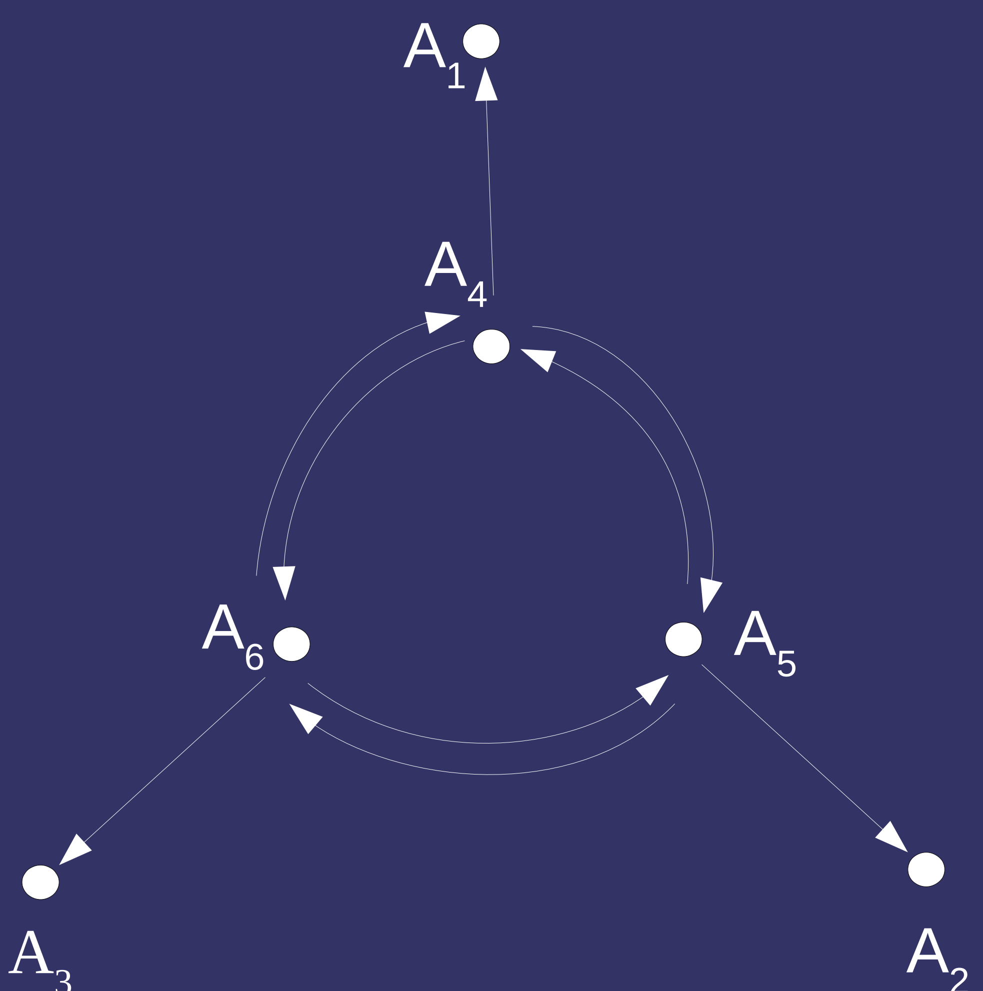

Why Admissibility

S = { w1; w2; w3; b2,b3→¬b1; b1,b3→¬b2; b1,b2→¬b3 }
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A_2: (w2) ⇒ b2
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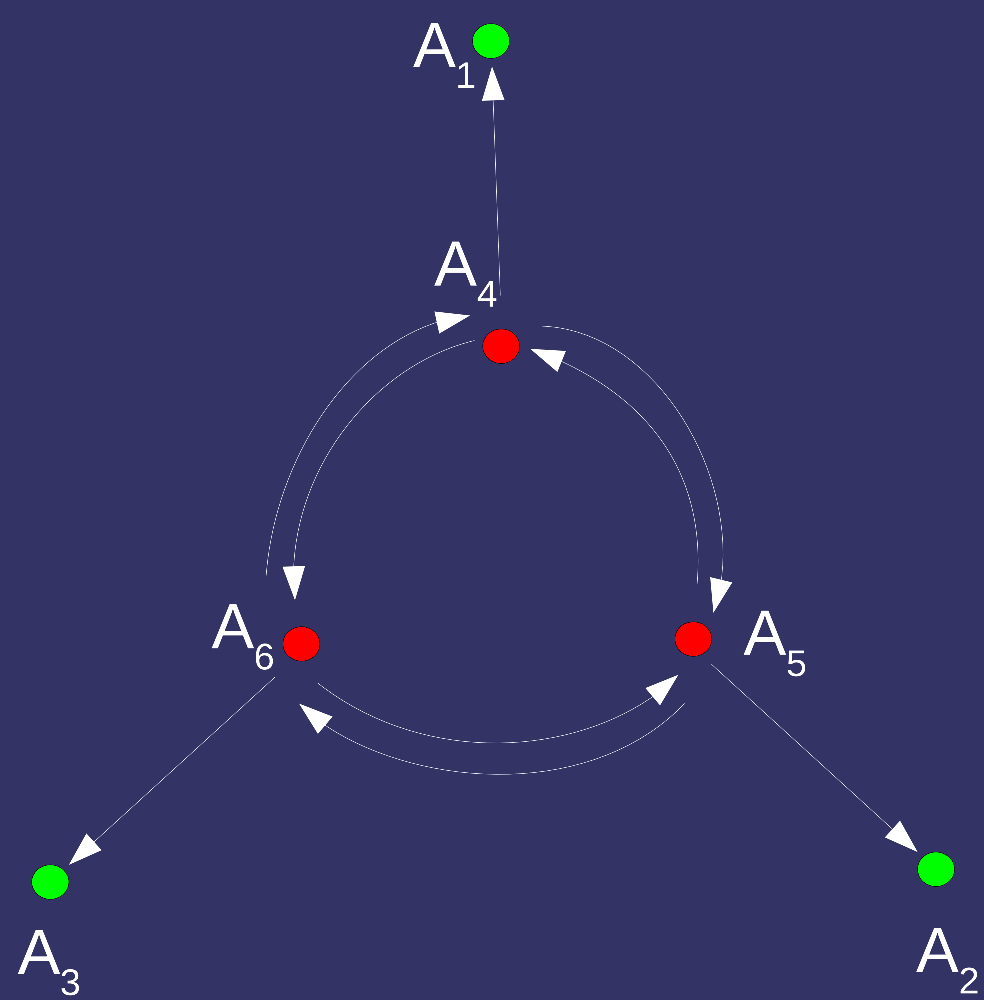


b1 b2 b3   ¬b1 ¬b2 ¬b3

Research Challenge: finding the magic combinations

extensions (labellings)
of conclusions

↑ *(3) determining status of conclusions*

extensions (labellings)
of arguments

↑ *(2) applying argumentation semantics*

argumentation
framework

↑ *(1) argument (+attack) construction*

knowledge
base

Open Research Questions:

1) How to satisfy crash resistance when strict rules are generated by classical logic and defeasible rules have different strength?
2) How to satisfy closure and consistency when applying unrestricted rebut and defeasible rules have different strength?

Further Reading:

M.W.A. Caminada

Rationality Postulates: applying argumentation theory for non-monotonic reasoning

(Handbook of Formal Argumentation)

Recent Developments: Heyninck & Straßer IJCAI17 / AAMAS19

$A \prec B$ iff $\mathrm{DefRules}(A) \neq \emptyset$ and
$\forall d_B \in \min(\mathrm{DefRules}(B))\ \exists d_A \in \mathrm{DefRules}(A): d_A < d_B$

Generalized Rebut:
A GeRe B iff
$\mathrm{Conc}(A) = \neg b_1 \vee \ldots \vee \neg b_n$ $(n \geq 1)$ and each b_i occurs in B

Example: $\Rightarrow \neg b \vee \neg d$ rebuts (GeRe) $((\Rightarrow b) \Rightarrow c) \Rightarrow d$

A defeats B iff A GeRe B and $A \not\prec B$

This approach satisfies all rationality postulates (direct/indirect consistency, closure, crash-resistance, non-interference)
but doesn’t (yet) support undercutting (rebut only)

Argumentation Research: the Good, the Bad and the Ugly

The Good

research on how to to meaningfully draw conclusions based on (sufficiently rich) arguments and how to explain it

Argumentation Research: the Good, the Bad and the Ugly

The Bad

research that only provides an abstraction without specifying what would be the full theory

always ask:
”What is it that your abstract theory provides an abstraction of”

Argumentation Research: the Good, the Bad and the Ugly

The Ugly

research that uses argumentation
for a purpose that could be done
in a much simpler way
(e.g. MCS and LP)

Argumentation versus Machine Learning Only

Why not use ML on a big corpus of reasoning cases?

1) because the corpus may contain <u>flawed reasoning</u> (e.g. biases or logical errors)

2) because you'd need to have a <u>huge corpus</u>, which might need to be generated

3) because you want to have <u>explainability</u>

idea: use argument mining
to obtain the argument schemes

Research Challenges

- How to satisfy closure, consistency and crash-resistance under different settings?
- Does exposure to argument-based discussion increase the user's confidence in the system's inferences?
- What would the discussion look like if the moves are <u>rules</u> instead of <u>arguments</u>?

Further Reading
(on topics in this presentation)

- Argumentation semantics
  - Dung, AIJ 1995 *(landmark paper)*
  - Baroni, Caminada & Giacomin (HOFA 2018, Ch4)
  - Caminada & Dunne (Argument&Computation 2019)

- Argumentation discussion games
  - Caminada (HOFA 2018, Ch10)

- Instantiated argumentation & rationality postulates
  - Modgil & Prakken (HOFA 2018, Ch6)
  - Caminada (HOFA 2018, Ch15)
  - Heyninck & Straßer (IJCAI 2017 / AAMAS 2019)

- Warnings against pure abstract argumentation
  - Caminada & Wu (BNAIC 2011)
  - Prakken & de Winter (COMMA 2018)

Further Reading (on topics <u>not</u> in this presentation)

- How argumentation captures other forms of NMR:
  - Default Logic:
    Dung (AIJ 1995), Caminada et al (JLC 2012)
  - Logic Programming:
    Dung (AIJ 1995), Caminada & Schulz (JAIR 2017)
  - Classical Logic and Maximal Consistent Sets:
    Besnard & Hunter (HOFA 2018 Ch9)

- Argument Schemes:
  - Macagno et al (HOFA 2018 Ch11)

- Formal argumentation and human intuitions:
  - Yu, Xu & Liao (Studies in Logic, 2018)
  - Cramer & Guillaume (COMMA 2018 / JELIA 2019)

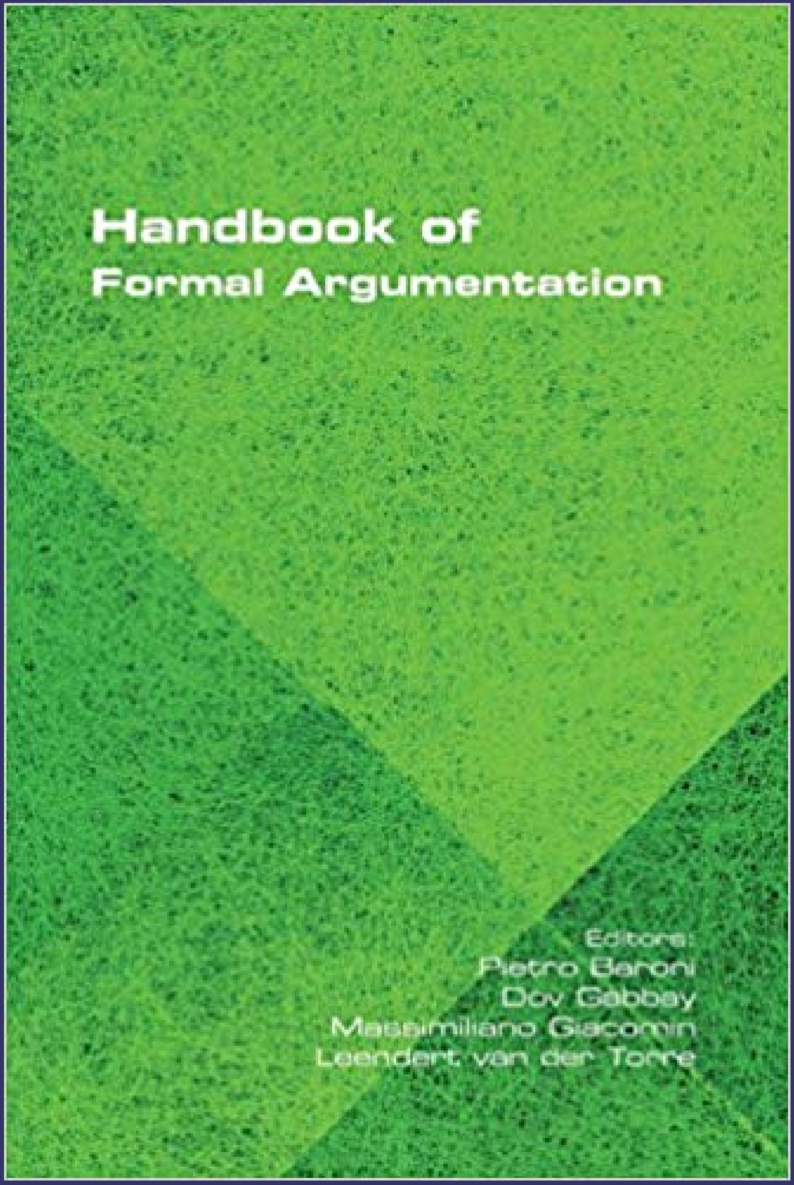
Further Reading (on topics not in this presentation)

- Argument Mining
  - Cabrio & Villata (IJCAI 2018)
  - IJCAI 2019 tutorial Federico Cerutti (tomorrow)

- Argumentation implementations
  - Cerutti et al (HOFA 2018, Ch14)
  - Nofal et al (AIJ 2014)
  - ICCMA 2015/2017/2019

- Online demonstrators:
  - DISCO: http://disco.cs.cf.ac.uk/
  - TOAST: http://toast.arg-tech.org/

Handbook of Formal Argumentation



Editors: Baroni, Gabbay, Giacomin & van der Torre

College Publications (2018)

1028 pages

$33.75 / €30.16 / £27.55

More on Argumentation at IJCAI

- Tutorial Federico Cerutti
  Argumentation and Machine Learning
  Monday 8.30am – 12.30pm

- Technical session
  Computational Models of Argument
  Friday 9.30am – 10.30am