# Tackling Defeasible Reasoning in Bochum:

## the Research Group for Non-Monotonic Logic and Formal Argumentation

Christian Straßer and Dunja Šešelja

April 10, 2017

# Outline

# The NMLFA

# The Research Group for Non-Monotonic Logic and Formal Argumentation (NMLFA)

Research Group for
Non-Monotonic Logic
and Formal Argumentation

- funding: 2015–2019 (Alexander von Humboldt-Foundation)
- aim: study defeasible reasoning with methods of formal argumentation
- location: Institute for Philosophy II, Ruhr-University Bochum
- online:
  - `http://homepage.ruhr-uni-bochum.de/defeasible-reasoning/index.html`
  - `mailto:defeasible-reasoning@rub.de`

# Members

- AnneMarie Borg (PhD candidate)

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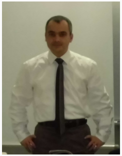

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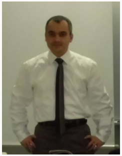


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  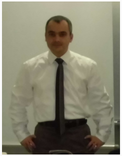 

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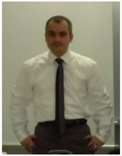


# Some research themes

1. Extending the expressive power of structured argumentation
    1.1 reasoning by cases and hypothetical reasoning
    1.2 expressing doubt – non-greedy argumentative reasoning
    1.3 unrestricted rebut
2. Comparative studies of different nonmonotonic formalisms with special attention to argumentation formalisms (ASPIC, ABA, etc.)
3. Applications of argumentation theory to deontic logic
4. Sequent-based argumentation (with Ofer Arieli, Tel Aviv)
5. Agent-based models based on techniques from abstract argumentation

# Reasoning by Cases

Mathieu Beirlaen, Jesse Heyninck, and Christian Straßer, *Reasoning by Cases in Structured Argumentation* forthcoming in Proceedings KRR/SAC 2017, ACM Digital Library (2017)

# Reasoning by Cases, Defeasibly

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- or, more generally:

$$\frac{A \vee B \quad A \mid\!\sim C \quad B \mid\!\sim C}{C}$$

Read $A \mid\!\sim C$: "$C$ follows defeasibly from $A$" or "There is a (defeasible) argument for $C$ based on $A$."

Are there good formal accounts of defeasible Reasoning by Cases?

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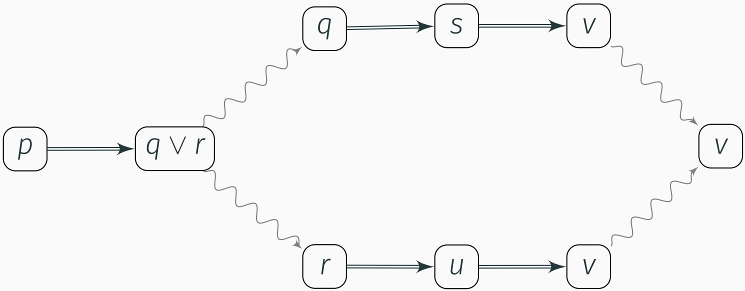
| 4. | $A \vee B \Rightarrow C$ | 1,2; OR |
| 5. | $C$ | 3,4; DefeasibleMP |

# A Problematic Example for OR

Suppose we have
$\Sigma = \{p \Rightarrow q \vee r, q \Rightarrow s, s \Rightarrow v, r \Rightarrow u, u \Rightarrow v, p\}$.



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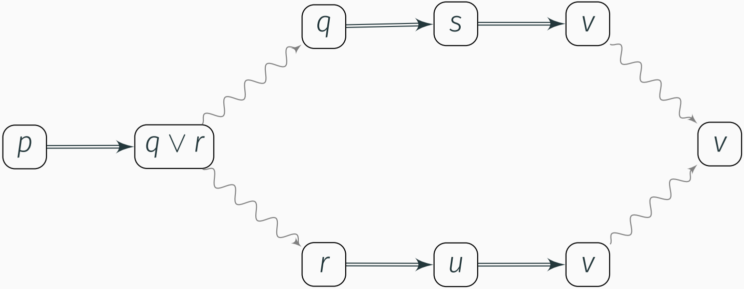

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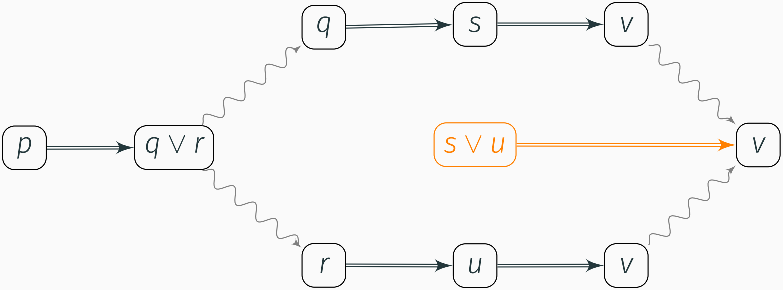


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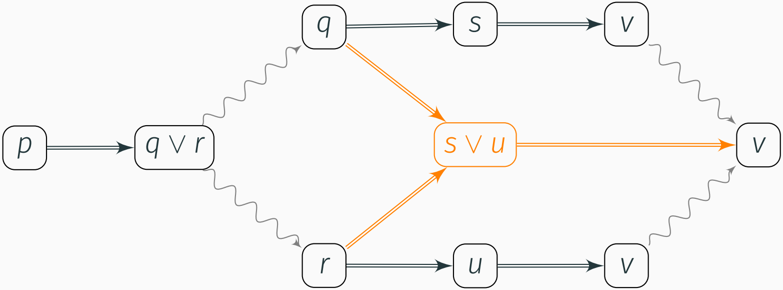


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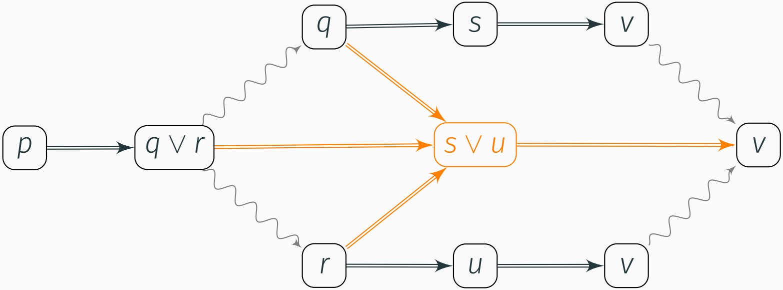


- by (OR): from $s \Rightarrow v$ and $u \Rightarrow v$
- by (Right-Weakening), from $q \Rightarrow s$ and $r \Rightarrow u$
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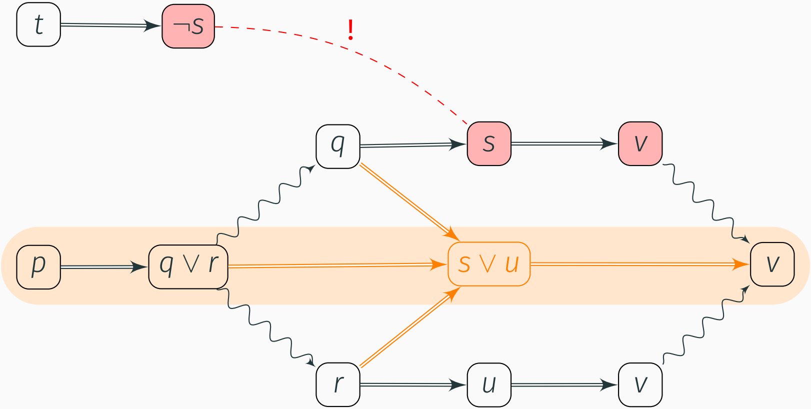


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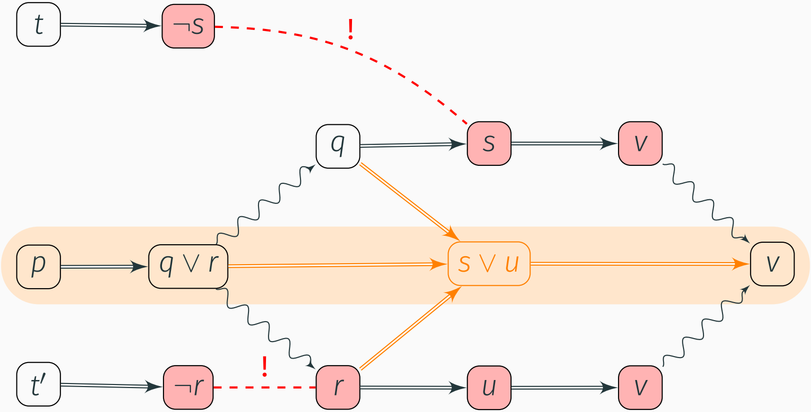


- Suppose now we also have $t'$ and $t' \Rightarrow \neg r$.
- the additional possible defeater has no effect on the generalized path

# Extension-based Approaches: Default Logic (Reiter)

- Input: set of defaults and a set of formulas ("facts")
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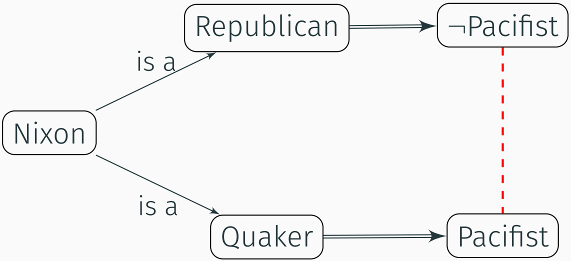

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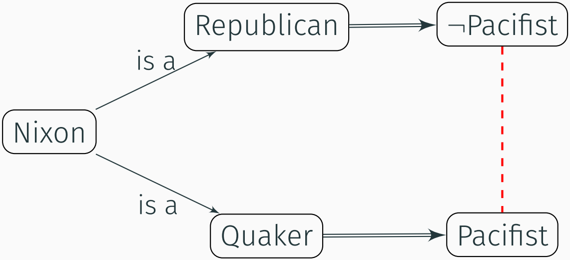
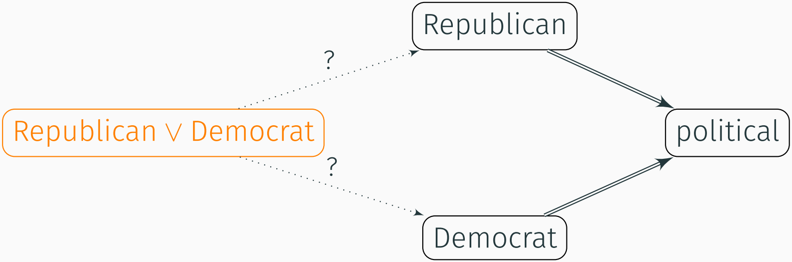



- Extensions:
  1. {Nixon, Republican, Quaker, ¬Pacifist}
  2. {Nixon, Republican, Quaker, Pacifist}

- no handling of disjunctive facts “out-of-the-box”
- for instance: $\Sigma = \{\text{Republican} \vee \text{Democrat}, \text{Republican} \Rightarrow \text{political}, \text{Democrat} \Rightarrow \text{political}\}$.




- since the default is not triggered by the fact, MP cannot be applied

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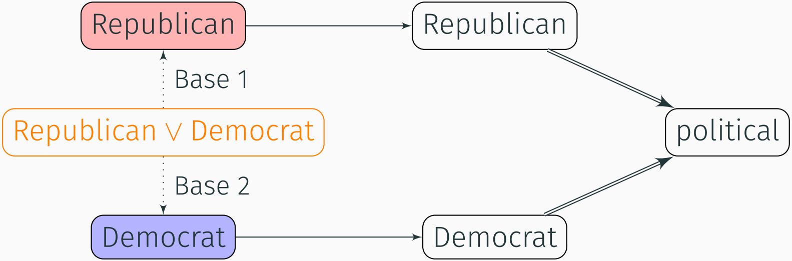
- idea: split the factual part of the knowledge base (Gelfond, Lifschitz, Przymusinska, 1991)



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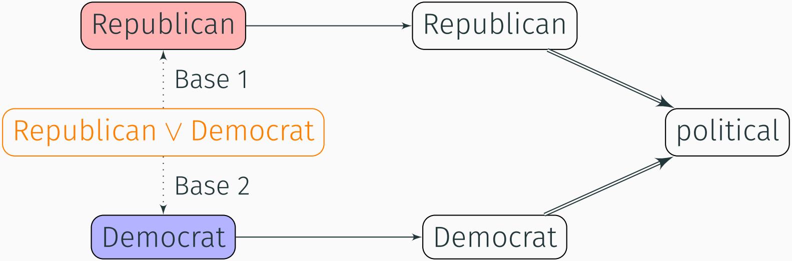


- two extensions:
  1. Republican, political
  2. Democrat, political

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3. He writes legibly. $\boxed{\text{wl}}$

With disjunctive default logic we get two extensions:

1. wl, ¬rhb, lhb
2. wl, rhb

# General Stratagem

So far: Manipulate the database!

1. produce new defeasible rules from the given ones
2. produce new factual knowledge bases when confronted with disjunctive information

# Enters: the Argumentative Approach

- Instead of manipulating the knowledge base and reasoning on top of the manipulated database,
- we will, in what follows, use a more direct approach to the modeling of Reasoning by Cases in the context of defeasible reasoning, following the inference scheme:

$$\frac{A \vee B \quad A \Rightarrow \cdots \Rightarrow C \quad B \Rightarrow \cdots \Rightarrow C}{C}$$

  or, more generally:

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- This will allow us to have more control over defeating conditions …
- … and to avoid pitfalls as the ones demonstrated above.

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we introduce a new RbC-Argument $\boxed{\langle a_1, [a_2], [a_3] \rightsquigarrow C \rangle}$.

# More general: RbC-Argument

**Definition**

Where

- $a_0 \in \text{Arg}(T)$ with $\text{Conc}(a_0) = \bigvee_{i=1}^{n} A_i$ and
- $a_i \in \text{Arg}(\langle \mathcal{D}, \mathcal{K} \cup \{A_i\} \rangle) \setminus \text{Arg}(T)$ $(1 \leq i \leq n)$,

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- We say that $a_1, \ldots, a_n$ are hypothetical sub-arguments of $a$, in signs: $a_1, \ldots, a_n \in \mathrm{HSub}(a)$.
- For each $a_i$, $\mathrm{Hyp}(a_i) = A_i$.

Let $T = \langle \mathcal{D}, \mathcal{K} \rangle$ consist of
$\mathcal{D} = \{p \Rightarrow q \vee r, q \Rightarrow s, s \Rightarrow v, r \Rightarrow u, u \Rightarrow v, t \Rightarrow \neg s\}$ and
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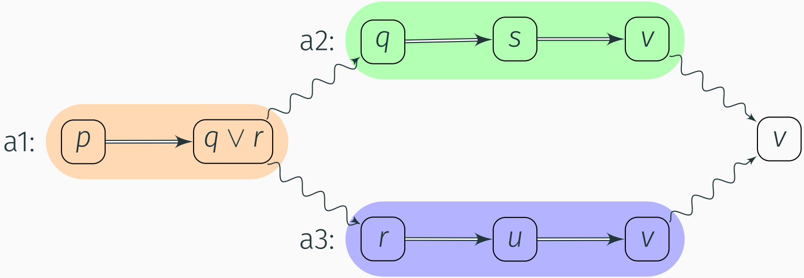
We have for instance the arguments:

- $a_1 = \langle \langle p \rangle \Rightarrow q \vee r \rangle \in \mathrm{Arg}(T)$
- $a_2 = \langle \langle q \rangle \Rightarrow s \Rightarrow v \rangle \in \mathrm{Arg}(\langle \mathcal{D}, \mathcal{K} \cup \{q\} \rangle)$
- $a_3 = \langle \langle r \rangle \Rightarrow u \Rightarrow v \rangle \in \mathrm{Arg}(\langle \mathcal{D}, \mathcal{K} \cup \{r\} \rangle)$
- $a_4 = \langle a_1, [a_2], [a_3] \leadsto v \rangle \in \mathrm{Arg}(T)$.



What about attacks?

- $a_1 = \langle\langle p\rangle \Rightarrow q \vee r\rangle \in \mathrm{Arg}(T)$
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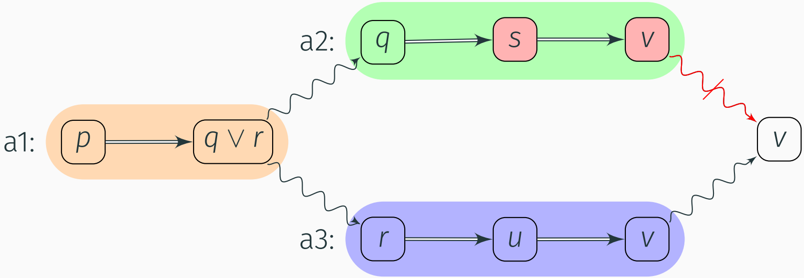

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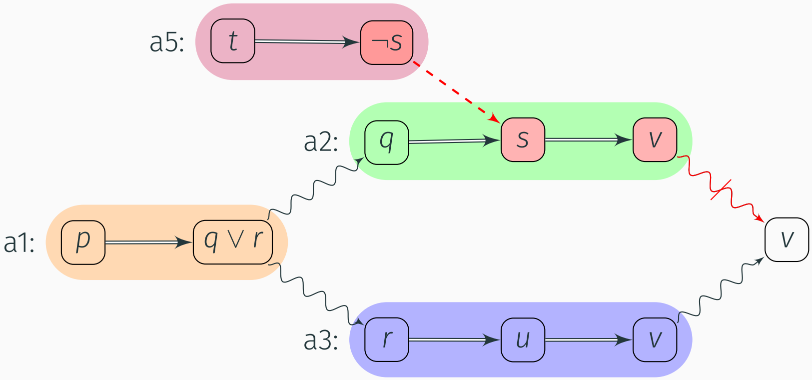

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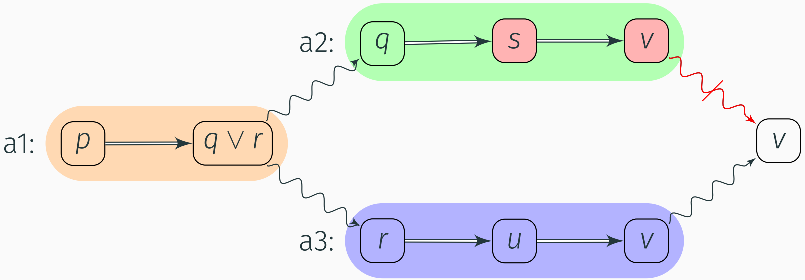

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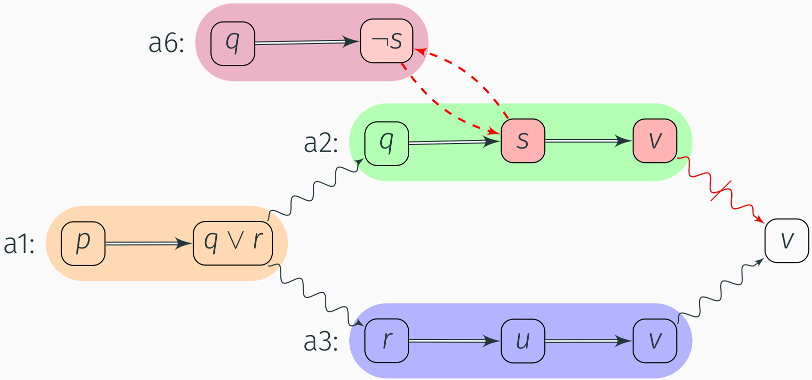
- $a_4 = \langle a_1, [a_2], [a_3] \rightsquigarrow v\rangle \in \mathrm{Arg}(T)$
- $a_6 = \langle\langle q \rangle \Rightarrow \neg s\rangle \in \mathrm{Arg}(\langle \mathcal{D}, \mathcal{K} \cup \{q\}\rangle)$



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Altogether attacks are defined as follows:

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where $a$ rebuts $b = \langle b_1, \ldots, b_n \Rightarrow B \rangle$ iff $\text{Conc}(a) = \neg B$ or $B = \neg\text{Conc}(a)$ and

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# Attacks again (non-nested case)

Let HArg($T$) be the set of all arguments $a$ for which there is a $b \in \text{Arg}(T)$ for which $a \in \text{HSub}(b)$.

Argumentation frameworks are now triples $\langle \text{Arg}(T), \text{HArg}(T), \text{Attacks}(T) \rangle$.

Altogether attacks are defined as follows:

$$\begin{aligned}\text{Attacks}(T) \subseteq (\text{Arg}(T) \times \text{Arg}(T)) \\ \cup (\text{Arg}(T) \times \text{HArg}(T)) \\ \cup (\text{HArg}(T) \times \text{HArg}(T))\end{aligned}$$

where $a$ rebuts $b = \langle b_1, \ldots, b_n \Rightarrow B \rangle$ iff $\text{Conc}(a) = \neg B$ or $B = \neg\text{Conc}(a)$ and

1. $a \in \text{Arg}(T)$ and $b \in \text{Arg}(T) \cup \text{HArg}(T)$ or
2. $a \in \text{HArg}(T)$ and $b \in \text{HArg}(T)$ and $\text{Hyp}(a) = \text{Hyp}(b)$.

# Unrestricted Rebut

joint work: Jesse Heyninck and Christian Straßer

# Status quo

- in ASPIC$^+$ only restricted rebut: $a$ rebuts $b$ iff
    1. the conclusion of $a$ is contrary to the conclusion of $b$
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  1. the conclusion of $a$ is contrary to the conclusion of $b$
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- unrestricted rebut: only the first requirement
  - pro: natural (Caminada)
  - contra: leads to trouble for many semantics such as preferred, stable, etc

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    - Consistency: $\{\mathsf{Conc}(a) \mid a \in \mathcal{E}\}$ is consistent.

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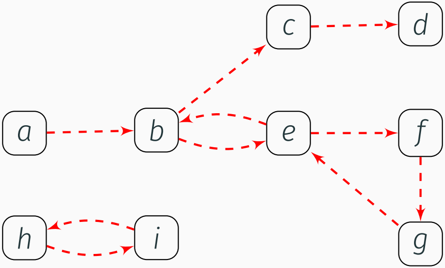

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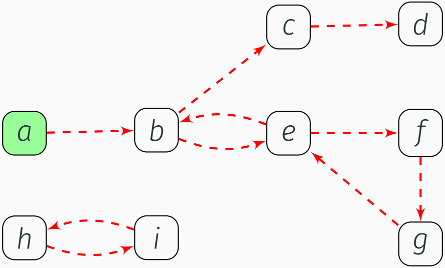


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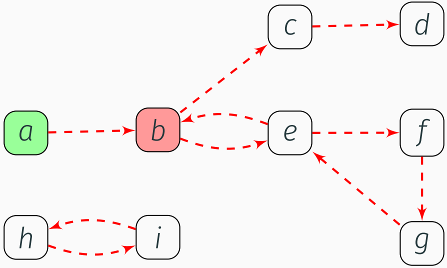


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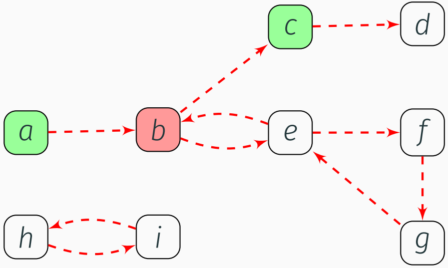


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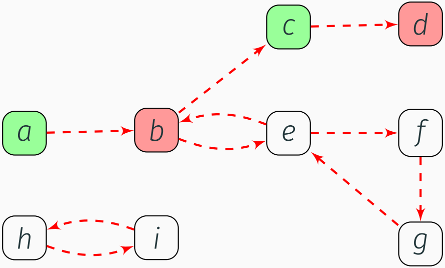


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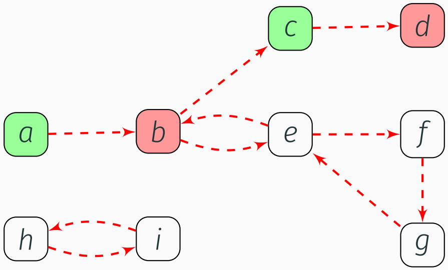


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- and so on … until fixed point is reached

For a set of formulas $\mathcal{F}$ let $\mathsf{Atoms}(\mathcal{F})$ be the set of all propositional atoms in $\mathcal{F}$.

[1] Caminada, Carnielli, Dunne (JLC, 2012). Avron (2016) calls this the basic relevance criterion.

# Non-Interference

For a set of formulas $\mathcal{F}$ let Atoms($\mathcal{F}$) be the set of all propositional atoms in $\mathcal{F}$.

- Non-interference[1] Where $T = \langle \mathcal{D}, \mathcal{K} \rangle$ and $T' = \langle \mathcal{D}', \mathcal{K}' \rangle$ are argumentation theories and $A$ is a formula such that $\text{Atoms}(\mathcal{D} \cup \mathcal{K} \cup \{A\}) \cap \text{Atoms}(\mathcal{D}' \cup \mathcal{K}') = \emptyset$ then:

$$T \mathrel{|\!\sim} A \text{ iff } \langle \mathcal{D} \cup \mathcal{D}', \mathcal{K} \cup \mathcal{K}' \rangle \mathrel{|\!\sim} A.$$

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- As a consequence, $a$ is not in the grounded extension.
- Thus, Non-Interference doesn't hold for unrestricted rebut.

# Prima Facie solution

- sort out inconsistent arguments (Wu, 2012: this works in ASPIC$^+$)
- however, this doesn't work with unrestricted rebut

# Prima Facie solution ii

Let $\{\top \Rightarrow_1 p, p \Rightarrow_1 q, \top \Rightarrow_2 \neg(p \land q)\}$ be our knowledge base.

We have, e.g., the following arguments:

- $a = \langle \top \Rightarrow_1 p \rangle$
- $b = \langle a \Rightarrow_1 q \rangle$
- $a \oplus b = \langle a, b \rightarrow p \land q \rangle$
- $c = \langle \top \Rightarrow_2 \neg(p \land q) \rangle$
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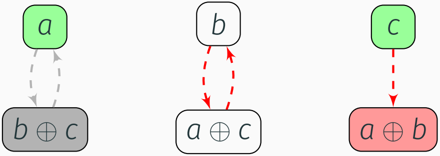

# Prima Facie solution ii

Let $\{\top \Rightarrow_1 p, p \Rightarrow_1 q, \top \Rightarrow_2 \neg(p \wedge q)\}$ be our knowledge base.

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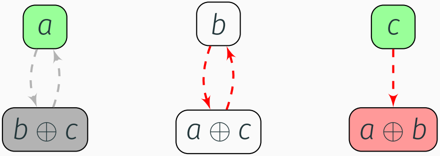


Problem:

- $b \oplus c$ is inconsistent and thus filtered out
- this leaves $a$ and $c$ in but $a \oplus c$ out of the grounded extension.
- Failure of closure!

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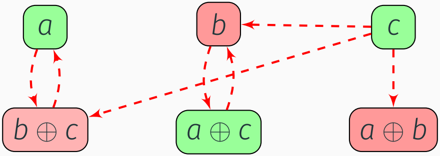
**Definition**

$a$ gen-rebuts $b$ iff $b$ is defeasible and $\text{Conc}(a) = \overline{\Delta}$ for some $\Delta \subseteq \text{Concs}(b)$.

**Definition**

$a$ gen-defeats $b$ iff $a$ gen-rebuts $c$ for some $c \in \text{Sub}(b)$ and $c \preceq a$.

# Back to the example



# Rationality

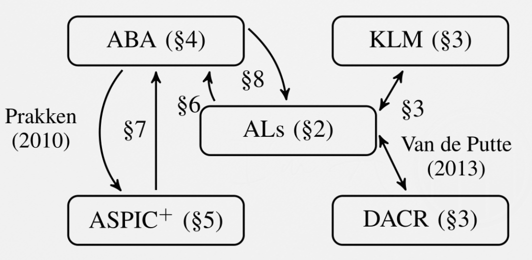
Where the strict rules are obtained from classical logic, for weakest link we get

- sub-argument closure
- closure under strict rules
- consistency
- non-interference

# Comparative Studies

Jesse Heyninck, Christian Straßer: *Relations between assumption-based approaches in nonmonotonic logic and formal argumentation* (NMR 2016, Cape Town, also available on Arxiv)

# The landscape




- ABA: assumption-based argumentation (Dung, Kowalski, Toni)
- ALs: adaptive logics (Batens)
- DACR: default assumptions (Makinson)
- KLM: preferential semantics (Shoham, Kraus/Lehman/Magidor)

# On the argumentative side

- ASPIC$^{+}$:
  - defeasible and strict rules
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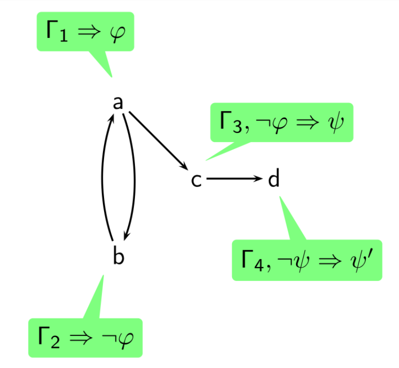
- ASPIC$^+$:
  - defeasible and strict rules
  - various attack types: rebuts, undercuts, undermine
  - arguments as proof trees
- ABA (Assumption-based argumentation)
  - only strict rules
  - higher level of abstraction: arguments as sets of defeasible assumptions
  - only “assumption-attacks” ($\approx$ undermine)
- our translation: without priorities

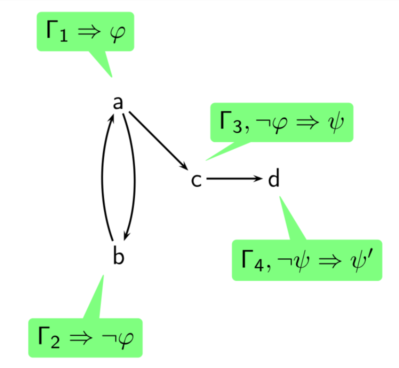
# Currently

- extending (Heyninck, Straßer, NMR 2016) with priorities
- relations between adaptive logics and parametrized logic programming (Jesse Heyninck, Pere Pardo, Christian Straßer)

# Sequent-based argumentation (with Ofer Arieli, Tel Aviv)

# Sequent-based Argumentation



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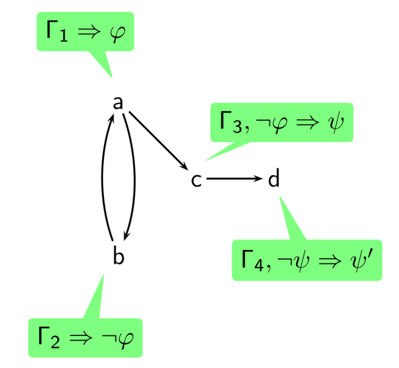
# Sequent-based Argumentation

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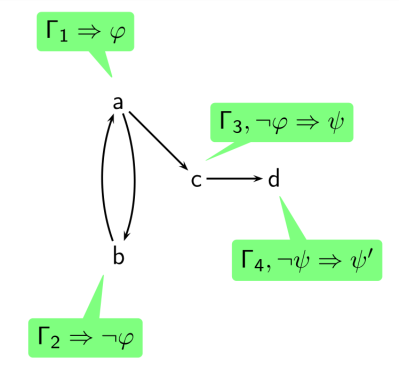


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- of a (Tarskian) core logic **L**

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- Specificity, etc.

# Dynamic proof theories

| | | | |
|---|---|---|---|
| 1. | $p \Rightarrow p$ | Axiom | |
| 2. | $\Rightarrow p, \neg p$ | $[\Rightarrow\neg]$, 1 | |
| 3. | $\Rightarrow p \vee \neg p$ | $[\Rightarrow\vee]$, 2 | |
| 4. | $p \vee \neg p \Rightarrow \neg(p \wedge \neg p)$ | ... | |
| 5. | $\neg(p \wedge \neg p) \Rightarrow p \vee \neg p$ | ... | |
| 6. | $q \Rightarrow q$ | Axiom | |
| 7. | $\neg p \Rightarrow \neg p$ | Axiom | |
| 8. | $p \not\Rightarrow p$ | Ucut, 7, 7, 7, 1 | $\neg p \Rightarrow \neg p$ |
| 9. | $p \Rightarrow \neg\neg p$ | ... | |
| 10. | $\neg\neg p \Rightarrow p$ | ... | |
| 11. | $\neg p \not\Rightarrow \neg p$ | Ucut, 1, 9, 10, 7 | $p \Rightarrow p$ |

# Dynamic proof theories (Retraction, Basic Idea)

```
function Evaluate(𝒟)  /* 𝒟
Attack := ∅;  Elim := ∅;  Derived := ∅;
while (𝒟 is not empty) do {
    if (Top(𝒟) = ⟨i, s, J, ∅⟩) then
        Derived := Derived ∪ {s};
    if (Top(𝒟) = ⟨i, s̄, J, r⟩) then
        if (r ∉ Elim) then
        Elim := Elim ∪ {s} and
        Attack := Attack ∪ {r};
    𝒟 := Tail(𝒟); }
Accept := Derived − Elim;
return (Attack, Elim, Accept)
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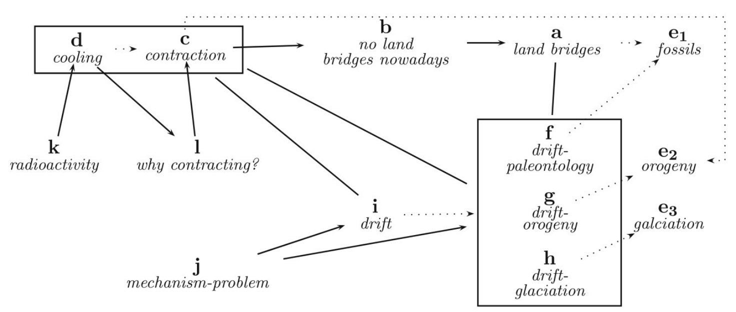
- A derivation must be *coherent*: Attack(D) $\cap$ Elim(D) $= \emptyset$
- A sequent $A$ is finally derived in a dynamic derivation $D$ if $A \in \mathrm{Accept}(D)$ and $D$ cannot be extended to a dynamic derivation $D'$ such that $A \in \mathrm{Elim}(D')$.

# Sequent-based Argumentation: some publications

- Ofer Arieli, Christian Straßer, *Sequent-Based Logical Argumentation*, in *Argument and Computation*, Vol. 6, Issue 1, pp. 73–99, 2015
- Ofer Arieli, Christian Straßer, *Dynamic Derivations for Sequent-Based Deductive Argumentation*, Proceedings of Computational Models of Argument (Editors: S. Parsons, N. Oren, C. Reed, and F. Cerutti) in the series *Frontiers in Artificial Intelligence and Applications*, Volume 266, IOS Press, pp. 89–100, 2014
- Christian Straßer and Ofer Ariel, *Normative Reasoning by Sequent-Based Argumentation*, Journal of Logic and Computation, doi.org/10.1093/logcom/exv050 (2015)
- Ofer Arieli and Christian Straßer, *Deductive argumentation by enhanced sequent calculi and dynamic derivations*, Electronic Notes in Theoretical Computer Science, 323, 21–37 (2016).
- Ofer Arieli, Annemarie Borg, and Christian Straßer, *Argumentative Approaches to Reasoning with Consistent Subsets of Premises* in proceedings of IEA/AIE'2017 (full paper), Lecture Notes in Artificial Intelligence series, Springer (2017)

# Agent-Based Models

- joint work: AnneMarie Borg, Daniel Frey, Dunja Šešelja and Christian Straßer
- Borg A., Frey D., Šešelja D. and Straßer C. (accepted) An Argumentative Agent-Based Model of Scientific Inquiry, forthcoming in the Proceedings of IEA/AIE, Springer-Verlag (extended version at: `https://arxiv.org/abs/1612.04432`
- Borg A., Frey D., Šešelja D. and Straßer C. (under revision) Epistemic Effects of Scientific Interaction: approaching the question with an argumentative agent-based model, special issue of Historical Social Research: "Agent Based Modelling across Social Science, Economics, and Philosophy"




Šešelja and Straßer, Synthese, 2013, 190:2195–2217

# Abstract argumentation in our ABM

We represent in an abstract way:

- arguments
- discovery relation
- attack relation