Introduction to Probabilistic Approaches to Computational Argumentation

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Overview

1. What is argumentation?
2. Key dimensions of computational argumentation
   - Abstract argumentation
     - Constellations approach to probabilistic argumentation
     - Epistemic approach to probabilistic argumentation
   - Structured argumentation
     - Instantiation with probabilistic logics
   - Dialogical argumentation
     - Probabilistic models of other participants
3. Some application areas
4. Conclusions

Argumentation as a cognitive process

A key way humans deal with conflicting information or situations

Arguments are normally constructed from information that is incomplete, inconsistent, uncertain and/or subjective, and from multiple heterogeneous sources.

Diverse examples of arguments

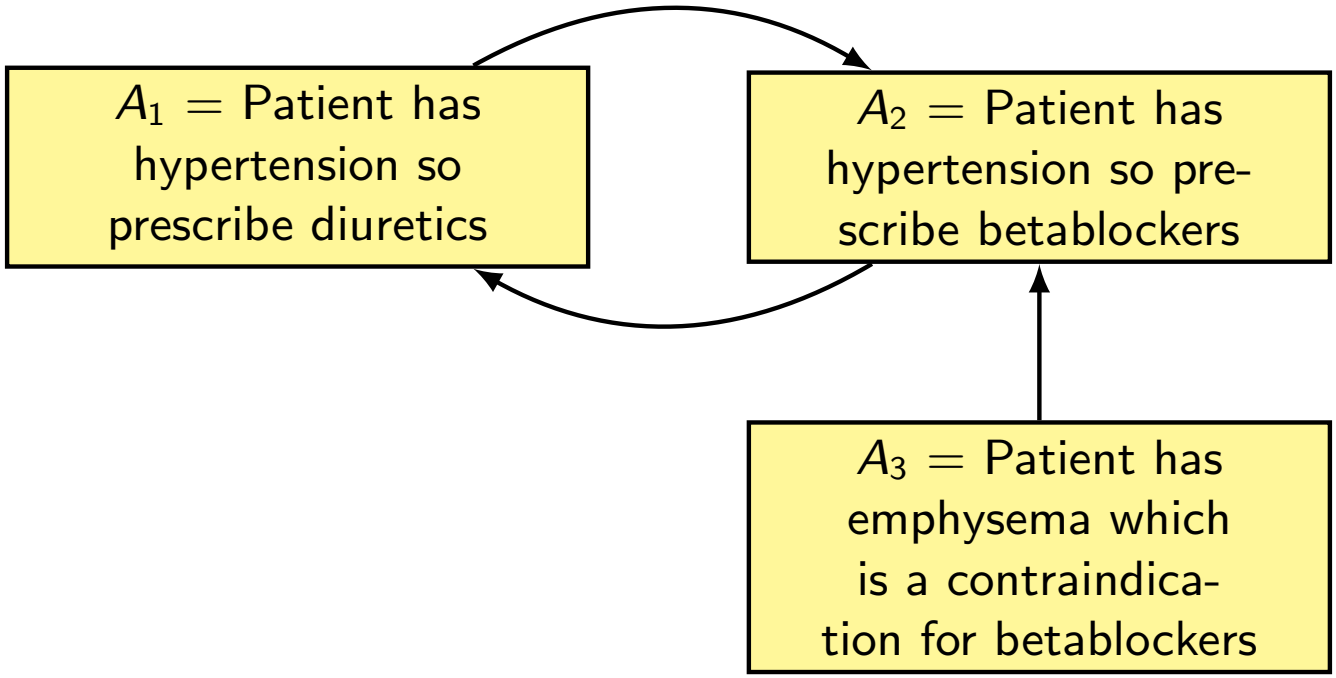
Mathematical	All squares have fours corners. That is a square, and so it has four corners.
Epsitemic	If I had a sister, I would know about it. As I don't know about it, I don't have a sister.
Scientific	Mr Jones has angina, therefore prescribe him daily aspirin.
Subjective	This film should have won an Oscar because it was a good movie with an edge.

Counterarguments

Since arguments are normally constructed from imperfect information, there are often counterarguments.

Abstract argumentation: Graphical representation

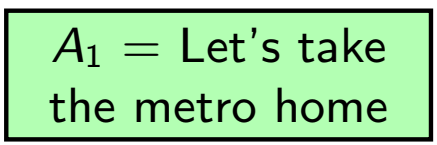
Graphical representations of argumentation have a long history (see for example Wigmore, Toulmin, etc.)



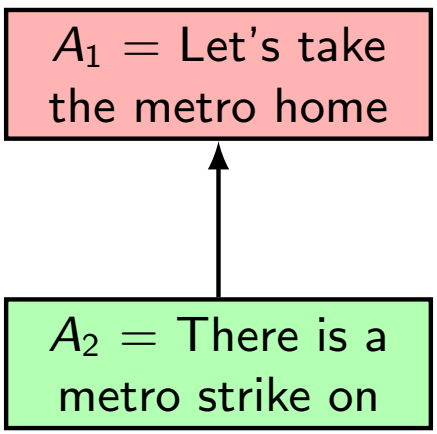
[Dung (AIJ 1995)]

Abstract argumentation: Winning arguments

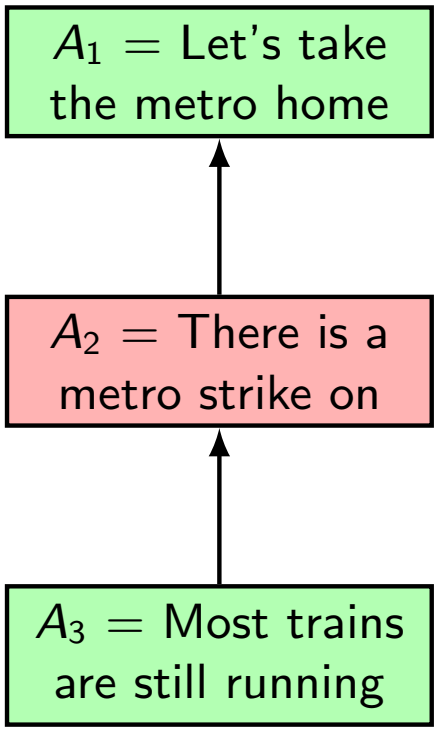
Green means the argument "wins" and red means the argument "looses".



Graph 1



Graph 2



Graph 3

[Simari+Loui (AIJ 1992); Pollock (AIJ 1995),etc.]

Abstract argumentation: Extensions

Types of extension for a set of arguments

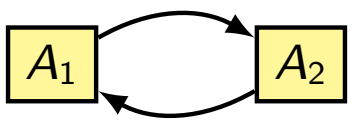
Admissible iff it is conflictfree and defends all its members

Complete iff it is admissible and all arguments it defends are in it

Grounded iff it is minimal (w.r.t set inclusion) complete

Preferred iff it is maximal (w.r.t set inclusion) complete

Stable iff it is preferred and attacks all arguments not in it



	admissible	complete	grounded	preferred	stable
$\{\}$	✓	✓	✓		
$\{A_1\}$	✓	✓		✓	✓
$\{A_2\}$	✓	✓		✓	✓
$\{A_1, A_2\}$					

[Dung (AIJ 1995)]

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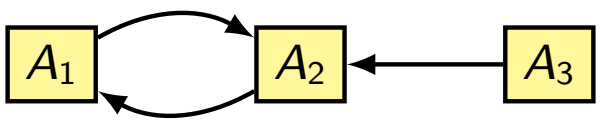


	admissible	complete	grounded	preferred	stable
$\{\}$	✓				
$\{A_1\}$	✓				
$\{A_3\}$	✓				
$\{A_1, A_3\}$	✓	✓	✓	✓	✓

[Dung (AIJ 1995)]

Abstract argumentation: Probabilistic approaches

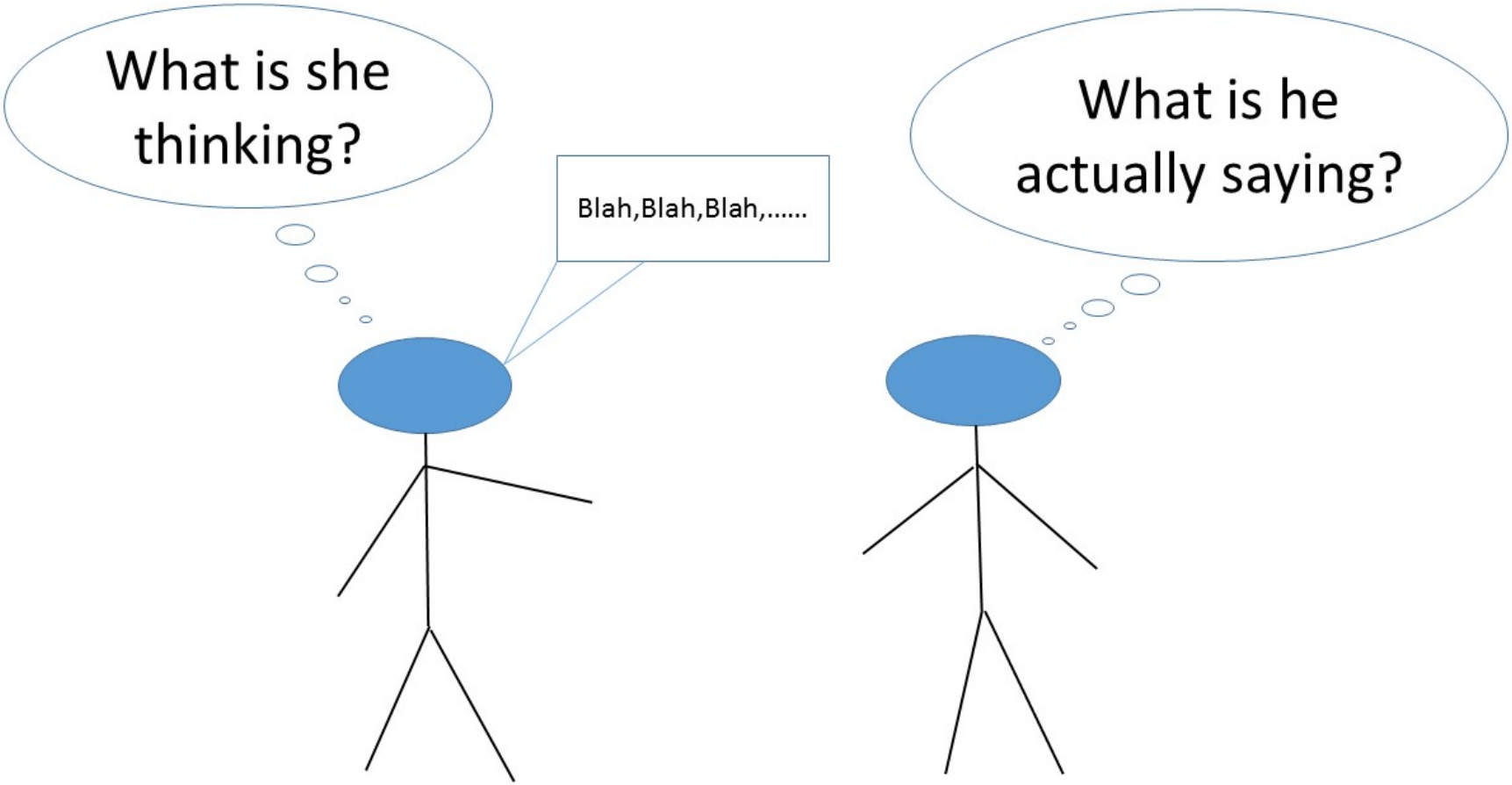
Strength of an argument

- Abstract argumentation treats each argument as equal
- Real world arguments are not equal
  - Some are "stronger" than others
  - Uncertainty can affect "strength"

Some types of uncertainty in argumentation

- implicit premises and/or claim
- truth of premises
- validity of conclusions drawn from premises
- whether one argument attacks another

Abstract argumentation: Probabilistic approaches



Uncertainty from speaker and hearer perspectives

Abstract argumentation: Probabilistic approaches

Two approaches to modelling uncertainty in argumentation

Let G be an argument graph, let $\sqsubseteq$ be the subgraph relation, and let P be a probability distribution.

1. **Constellations approach** [Li *et al* 2011, Hunter 2012, 2013, Hunter & Thimm 2014] for handling uncertainty over the structure of the argument graph

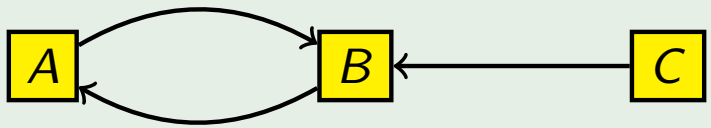
$$P : \{G' \sqsubseteq G\} \rightarrow [0, 1]$$

2. **Epistemic approach** [Thimm 2012, Hunter 2013, Hunter & Thimm 2018] for handling uncertainty in the belief in the arguments

$$P : \wp(\text{Nodes}(G)) \rightarrow [0, 1]$$

Abstract argumentation: Constellations approach

Example



Suppose there are four subgraphs, G_1 to G_4, with non-zero probability.

	Graph	Probability	Grounded extension
G_1	$A \leftrightarrow B \leftarrow C$	0.25	$\{A, C\}$
G_2	$A \qquad C$	0.25	$\{A, C\}$
G_3	$A \leftrightarrow B$	0.25	$\{\}$
G_4	A	0.25	$\{A\}$

Therefore $P_{\text{gr}}(A) = 0.75$, $P_{\text{gr}}(B) = 0$, and $P_{\text{gr}}(C) = 0.5$.

[Li, Oren and Norman 2011, Hunter 2012, Rienstra 2012]

Abstract argumentation: Epistemic approach

Epistemic approach to probabilistic argumentation

For argument graph G, the probability of an argument A being acceptable is

$$P(A) = \sum_{X \subseteq \text{Nodes}(G) \text{ s.t. } A \in X} P(X)$$

where $P : \wp(\text{Nodes}(G)) \to [0, 1]$.

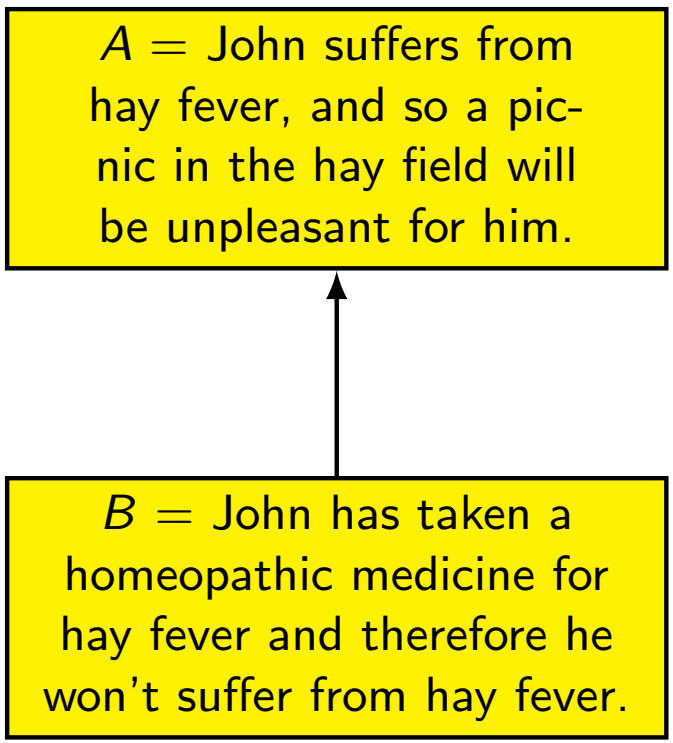
Example

$$P(\{A, B\}) = 0.6 \quad P(\{A\}) = 0.3 \quad P(\{B\}) = 0 \quad P(\{\}) = 0.1$$

- $P(A) = 0.9$
- $P(B) = 0.6$

Abstract argumentation: Epistemic approach

Suppose I hear one of my friends saying argument A and another saying argument B.



If I believe that homeopathic medicine is just water, then I have high belief in A and low belief in B (e.g. $P(A) = 0.9$ and $P(B) = 0$).

Abstract argumentation: Epistemic approach

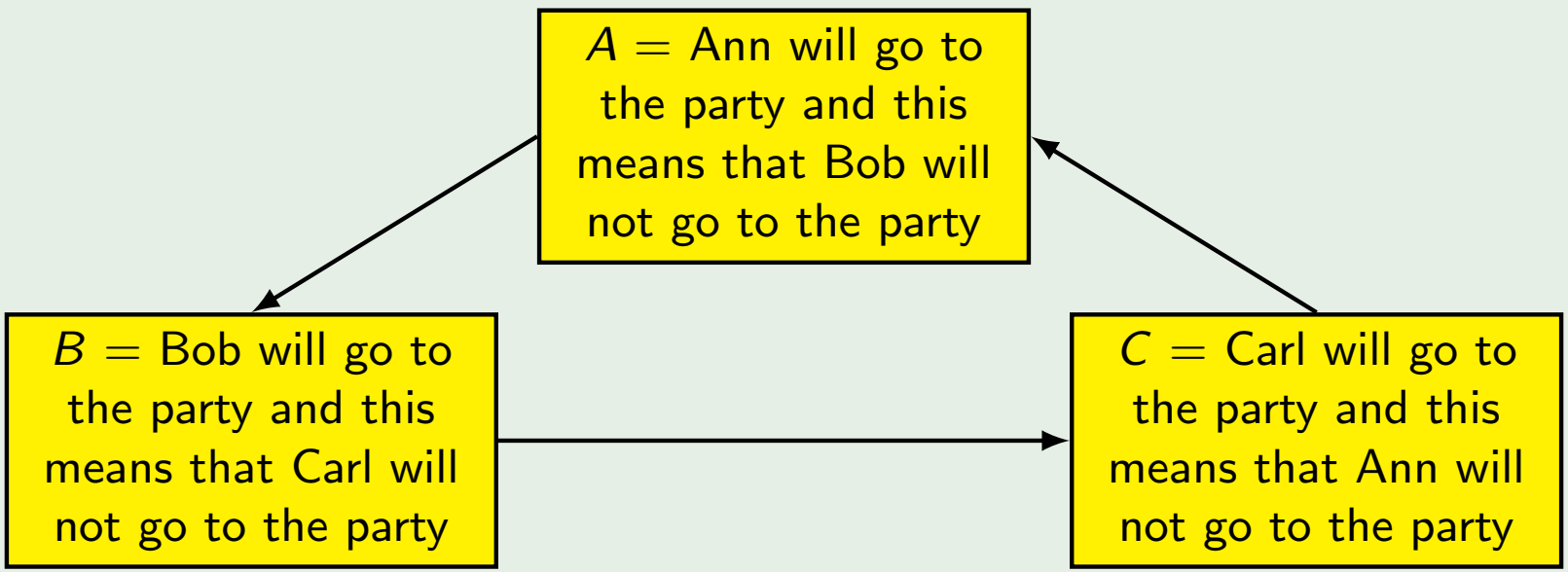
Definition

For an argument graph G, and a probability assignment P, the **epistemic extension** is

$$\{A \in \text{Nodes}(G) \mid P(A) > 0.5\}$$

Example

Suppose we have $P(A) = 0.9$, $P(B) = 0.1$, and $P(C) = 0.1$, then the epistemic extension is $\{A\}$.

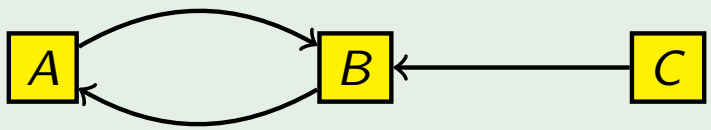


Abstract argumentation: Epistemic approach

Definition

A probability distribution P is **rational** for an argument graph G iff for each $(A, B) \in \text{Arcs}(G)$, if $P(A) > 0.5$, then $P(B) \leq 0.5$.

Example



A	B	C	rational?	epistemic extension
0.3	0.1	0.9	yes	$\{C\}$
0.9	0.1	0.9	yes	$\{A, C\}$
0.1	0.8	0.1	yes	$\{B\}$
0.1	0.8	0.9	no	$\{B, C\}$
0.7	0.8	0.5	no	$\{A, B\}$

[Hunter 2013, Hunter + Thimm 2017, Hunter, Polberg + Thimm 2017, 2018]

Abstract argumentation: Epistemic graphs

Epistemic graphs[1] are a generalization of the epistemic approach

Relationships A graph can model both **attack** and **support** as well as relations that are neither positive nor negative.

Constraints A graph is augmented with a set of constraints to restrict belief in arguments and their influence on each other.

Some advantages

- **Subjective reasoning** by allowing different agents to be modelled by a different set of constraints.
- **Context-sensitive reasoning** by basing constraints on what arguments represent rather than the just the structure of graph.
- **Modelling of imperfect agents**[2] in dialogical argumentation (e.g. persuasion, negotiation, etc.).

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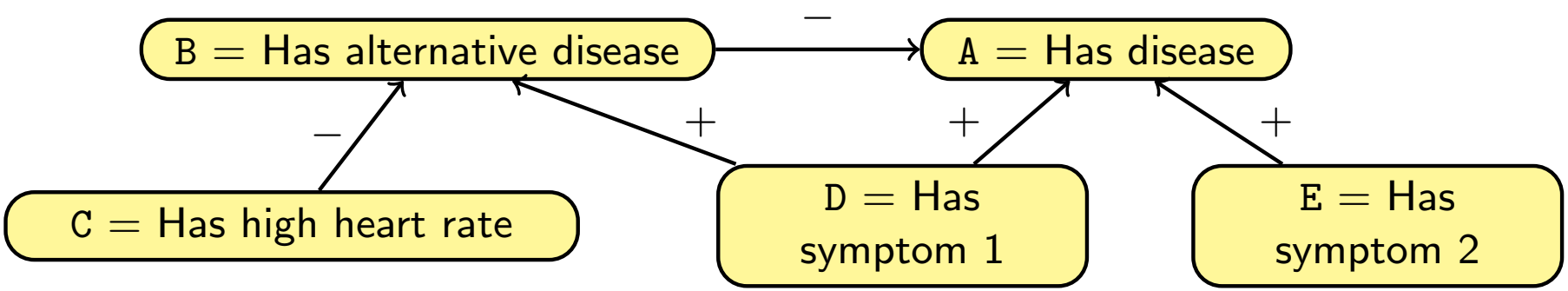
[1] A Hunter, S Polberg, and M Thimm (2020) Epistemic graphs for representing and reasoning with positive and negative influences of arguments. *Artificial Intelligence*, 281:103236.

[2] S. Polberg and A. Hunter (2018) Empirical Evaluation of Abstract Argumentation: Supporting the Need for Bipolar and Probabilistic Approaches, *International Journal of Approximate Reasoning*, 93: 487-543.

Abstract argumentation: Epistemic graphs



Labelled graph where each node denotes an argument, and the influence of each argument on others is (partly) captured by the following constraints.

- $P(\mathtt{B}) > 0.8 \wedge P(\mathtt{D} \vee \mathtt{E}) < 0.2 \Rightarrow P(\mathtt{A}) < 0.2$
- $P(\mathtt{B}) > 0.5 \wedge P(\mathtt{D} \vee \mathtt{E}) \leq 0.5 \Rightarrow P(\mathtt{A}) < 0.5$
- $P(\mathtt{D} \wedge \mathtt{E}) > 0.5 \Rightarrow P(\mathtt{A}) > 0.5$
- $P(\mathtt{C}) + P(\mathtt{B}) \leq 1$

[Hunter, Polberg, and Thimm (AIJ 2020)]

Abstract argumentation: Epistemic graphs

Labelled graph where each node denotes an argument, and the influence of each argument on others is (partly) captured by the following constraints.

- $P(\mathtt{B}) > 0.5 \wedge P(\mathtt{C}) \leq 0.5 \Rightarrow P(\mathtt{A}) > 0.5$
- $P(\mathtt{C}) > 0.5 \wedge P(\mathtt{B}) \leq 0.5 \Rightarrow P(\mathtt{A}) > 0.5$
- $P(\mathtt{B}) > 0.5 \wedge P(\mathtt{C}) > 0.5 \Rightarrow P(\mathtt{A}) \leq 0.5$

[Hunter, Polberg, and Thimm (AIJ 2020)]

Abstract argumentation: Pros and cons

Pros

- Abstract argumentation has formalized the notion of dialectics that is important in argumentation.
- Abstract argumentation has been extended in various ways (e.g. preferences, weights, probabilities, etc.)
- Argument graphs can be constructed using argument mapping tools
- Natural language processing (e.g. information extraction, sentiment analysis, text entailment, etc) is being used for argument mining from text (and thereby automatically construct argument graphs).

Cons

- However, abstract arguments are atomic, and so have no internal structure.
- To better understand, and to generate arguments, we require logical arguments.

Logical argumentation: Arguments

Argument (for classical logic)

An **argument** from a set of formulae Δ is a pair $\langle \Phi, \alpha \rangle$ such that

1. $\Phi \subseteq \Delta$
2. $\Phi \nvdash \bot$
3. $\Phi \vdash \alpha$
4. there is no $\Phi' \subset \Phi$ such that $\Phi' \vdash \alpha$.

We call Φ the **support** of the argument and α the **claim** of the argument. The support of an argument is the justification/explanation for the claim.

Example using classical logic

If $\Delta = \{\mathtt{a}, \mathtt{a} \rightarrow \mathtt{b}, \mathtt{b} \rightarrow \mathtt{c}, \mathtt{d} \rightarrow \neg\mathtt{b}\}$, then arguments from Δ include:

$$\langle \{\mathtt{a}\}, \mathtt{a} \rangle \qquad \langle \{\mathtt{a}, \mathtt{a} \rightarrow \mathtt{b}\}, \mathtt{b} \rangle$$
$$\langle \{\mathtt{a}, \mathtt{a} \rightarrow \mathtt{b}, \mathtt{b} \rightarrow \mathtt{c}\}, \mathtt{c} \rangle \qquad \langle \{\mathtt{a} \rightarrow \mathtt{b}\}, \mathtt{a} \rightarrow \mathtt{b} \rangle$$
$$\langle \{\mathtt{a} \rightarrow \mathtt{b}\}, \neg\mathtt{a} \vee \mathtt{b} \rangle \qquad \langle \{\}, \neg\mathtt{a} \vee \mathtt{a} \rangle$$

[See Besnard and Hunter (2008) *Elements of Argumentation*, MIT Press]

Logical argumentation: Attacks by counterarguments

Counterarguments

If $\langle \Phi, \alpha \rangle$ and $\langle \Psi, \beta \rangle$ are arguments, then

- $\langle \Phi, \alpha \rangle$ **rebuts** $\langle \Psi, \beta \rangle$ iff $\alpha \vdash \neg\beta$
- $\langle \Phi, \alpha \rangle$ **undercuts** $\langle \Psi, \beta \rangle$ iff $\alpha \vdash \neg \wedge \Psi$

Direct undercut

A **direct undercut** for an argument $\langle \Phi, \alpha \rangle$ is an argument of the form $\langle \Psi, \neg\phi_i \rangle$ where $\phi_i \in \Phi$.

Example using classical logic

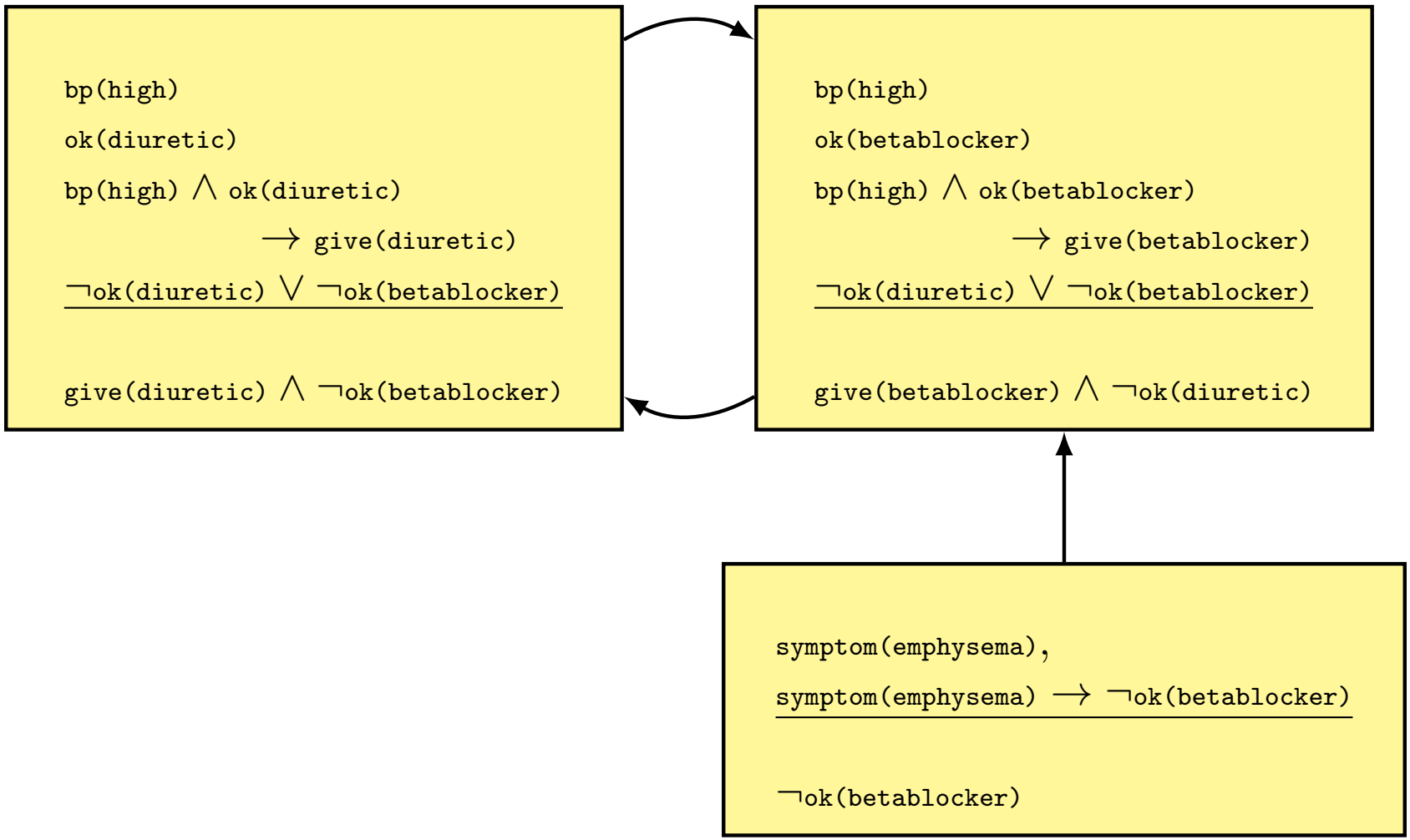
$\langle \{b, b \rightarrow a\}, a \rangle$ rebuts $\langle \{c, c \rightarrow \neg a\}, \neg a \rangle$

$\langle \{c, c \rightarrow \neg b\}, \neg(b \wedge (b \rightarrow a)) \rangle$ undercuts $\langle \{b, b \rightarrow a\}, a \rangle$

$\langle \{d \rightarrow \neg b\}, \neg b \rangle$ is a direct undercut for $\langle \{a, b\}, a \wedge b \rangle$

[See Besnard and Hunter (2008) *Elements of Argumentation*, MIT Press]

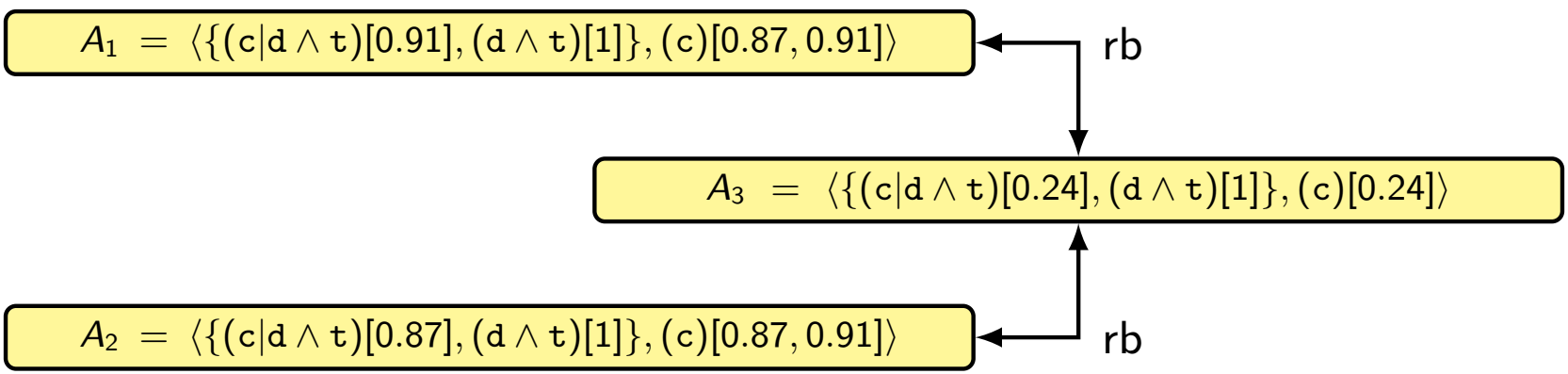
Logical argumentation: Argument graphs



[Ph Besnard and A Hunter (2018) A Review of Argumentation Based on Deductive Arguments, Handbook of Formal Argumentation, Volume 1, pages 435-482, College Publications]

Logical argumentation: Probabilistic logic

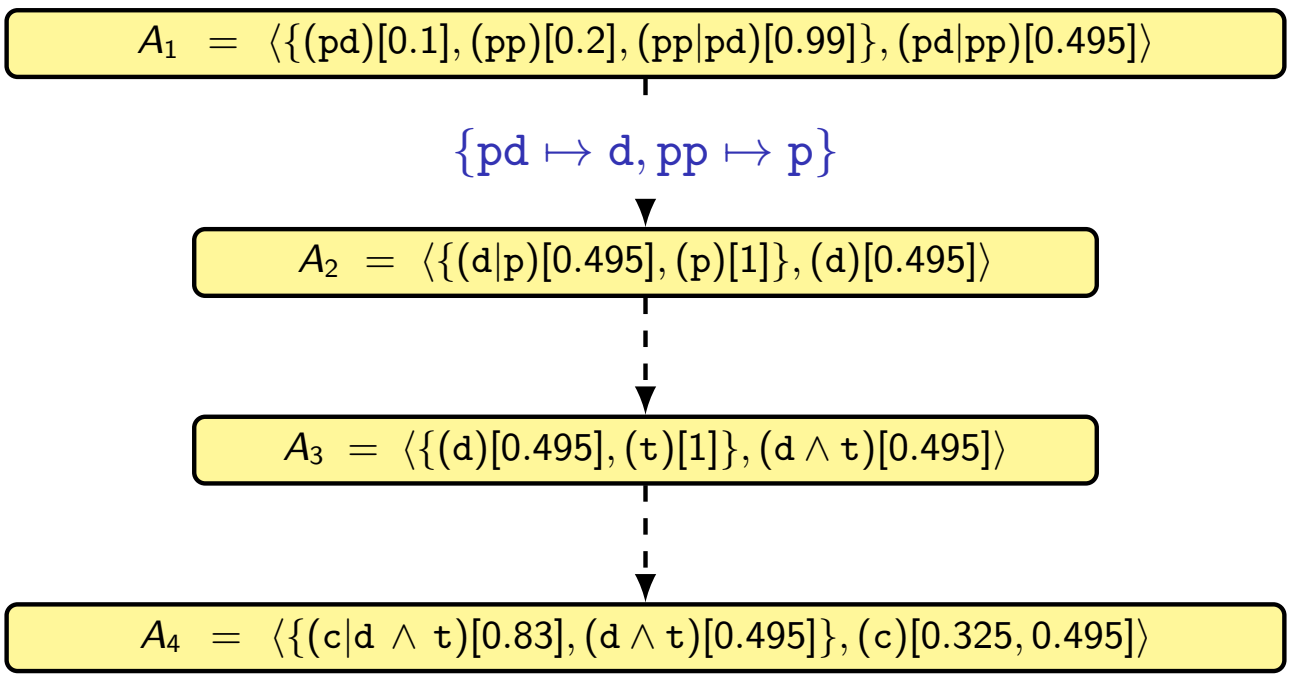
c	a randomly selected patient is cured of the disease
d	a randomly selected patient has the disease
t	a randomly selected patient has the drug treatment



[Hunter and Potyka (under review)]

Logical argumentation: Probabilistic logic

pp	a random individual in the population tests positive
pd	a random individual in the population has the disease
p	the patient we are concerned with tests positive
d	the patient we are concerned with has the disease
t	the patient we are concerned with has the treatment
c	the patient we are concerned with is cured

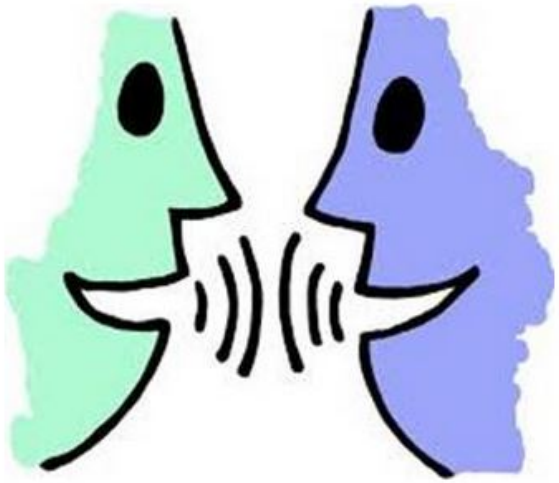


[Hunter and Potyka (under review)]

Some conclusions on logical argumentation

- Logical argumentation can instantiate abstract argumentation.
- A variety of logics have been considered for argumentation (e.g. defeasible logic, classical logic, temporal logic, probabilistic logic, & non-monotonic logic).
- A range of frameworks have been developed with implementations
  - Deductive argumentation (e.g. Amgoud, Besnard, Cayrol, Hunter, et al.)
  - Defeasible logic programming (Simari, et al)
  - Assumption-based argumentation (Toni, et al)
  - ASPIC+ (Prakken, et al)
  - Carneades (Gordon, et al)

Dialogical argumentation: Modelling



Components of a model of dialogical argumentation

Participants Specification of the information held by each agent (e.g. a knowlegebase, a set of goals, etc.)

Moves Specification of the moves that can be made (e.g. $\texttt{why}(\phi)$, $\texttt{claim}(\psi)$, $\texttt{posit}(A)$, etc.)

Protocol The rules of the game (i.e. the moves an agent is allowed, or is obliged, to make at each stage of the dialogue).

[See Hamblin (Theoria 1971); MacKenzie (JPL 1979)]

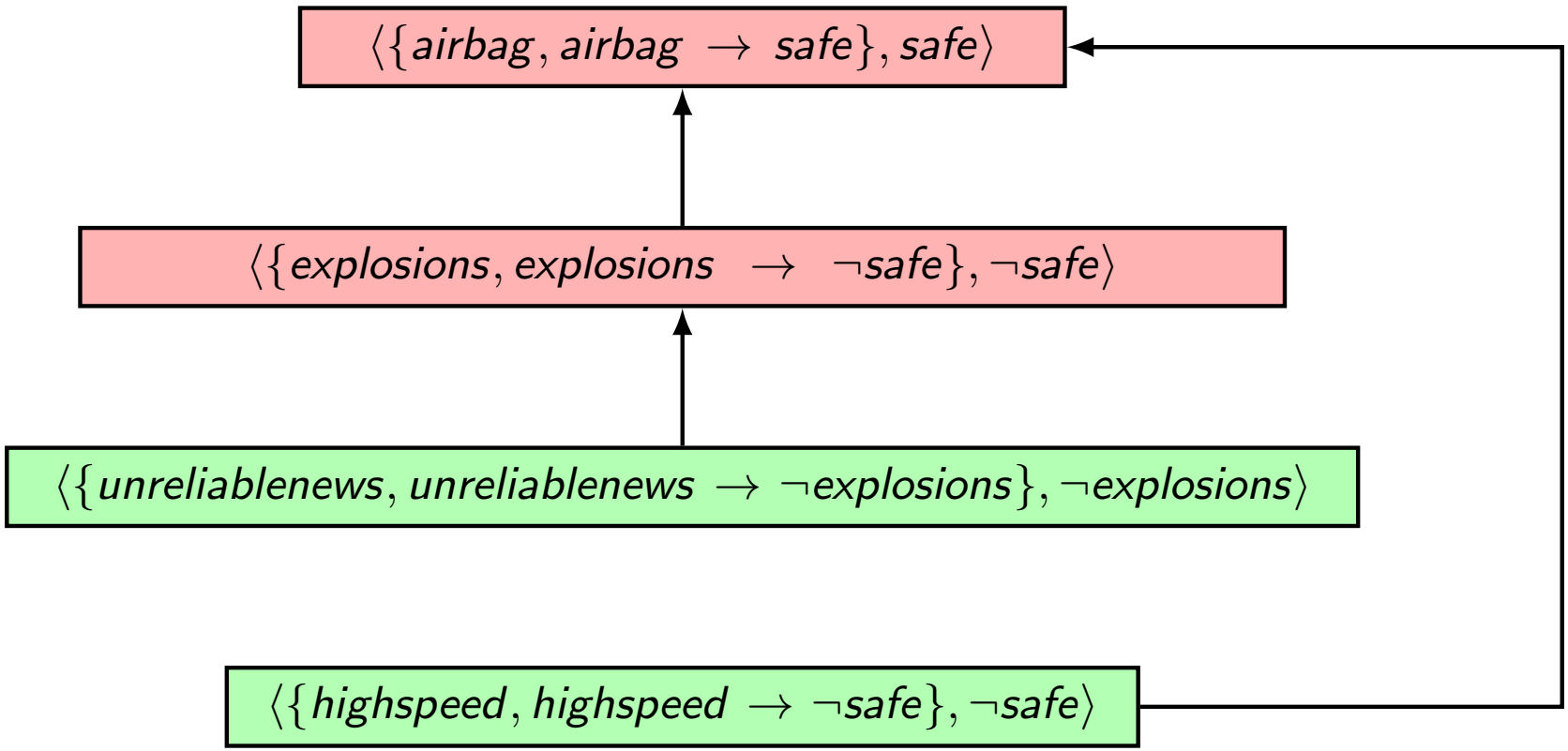
Dialogical argumentation: Modelling

Paul tries to persuade Olga that they should buy a particular car.

Step	Player	Move	Content
1	Paul	claim	the car is safe
2	Olga	why	the car is safe
3	Paul	explain	the car has airbags, if the car has airbags, then the car is safe
4	Olga	concede	the car has airbag
5	Olga	explain	the airbags explode excessively, if the airbags explode excessively, then the car is not safe
6	Paul	explain	the news reports are unreliable, if the news reports are unreliable, then the airbags do not explode excessively
7	Olga	explain	it is a very fast car, if it is a very fast car, then it is not safe

Example adapted from Prakken (KER 2006)

Dialogical argumentation: Modelling



Dialogical argumentation: Strategies

Dialogue strategies

These allow an agent to choose which moves to make in order to optimize its outcome from the dialogue including

- co-operating though not revealing too much information (i.e. privacy), to manipulating by being economical with the truth.
- selecting sequences of moves that are more likely to be persuasive (e.g. computational persuasion for behaviour change in healthcare[3]).

Managing uncertainty in dialogue strategies

Uncertainty about the other agent with respect to

- beliefs and concerns
- how enthymemes are decoded
- reasoning abilities

[3] www.computationalpersuasion.com

Conclusions

- Argumentation is an important cognitive activity.
- Argumentation can be used to handle inconsistent and incomplete information.
- Computational models of argument offer a range of formalisms.
- Probabilistic approaches need to be developed if we are to develop argumentation technologies.
  - We need to collaborate with researchers in probability theory/logics.
- A range of applications is being developed[4] in areas including law, healthcare, intelligence analysis, and egovernment.
- Many issues remain to be addressed to fully capture human argumentative abilities.

[4] K Atkinson, *et al* (2017) Towards Artificial Argumentation, *AI Magazine*, 38(3):25-36