Introduction to Probabilistic Argumentation

Anthony Hunter[1]

Department of Computer Science
University College London

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[1]Much of the work in this talk was done in collaboration with Sylwia Polberg (UCL) and Matthias Thimm (Universität Koblenz)

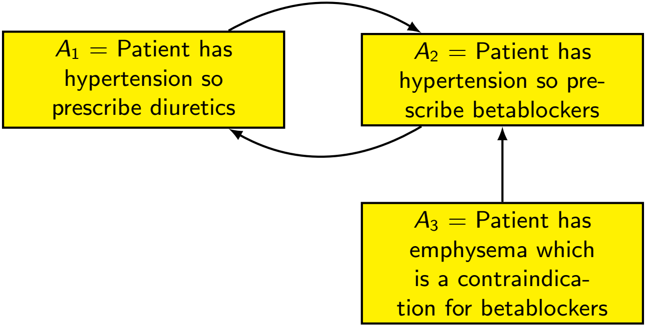
Overview

1. Brief review of abstract argumentation
2. Motivation for probabilistic argumentation
3. Constellations approach to probabilistic argumentation
4. Epistemic approach to probabilistic argumentation
    - Extended epistemic approach
    - Epistemic approach with logical arguments
5. Studies with participants
    - Dialogue study
    - Crowdsource study
6. Conclusions

Overview

Abstract argumentation: Graphical representation

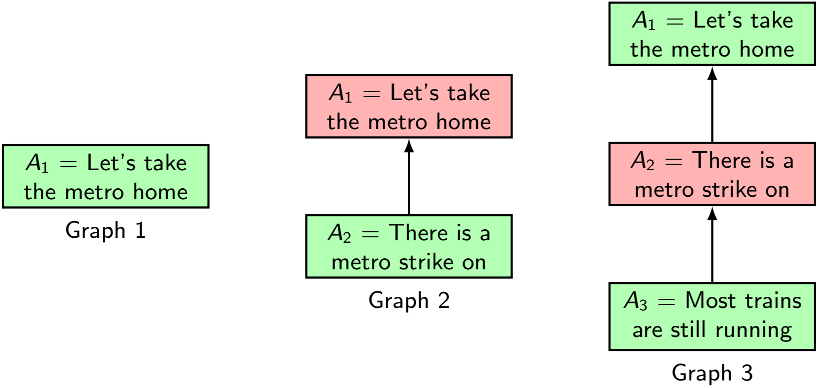
Graphical representations of argumentation have a long history (see for example Wigmore, Toulmin, etc.)



[Dung 1995]

Abstract argumentation: Winning arguments

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

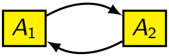


[Simari+Loui (AIJ 1992); Pollock (AIJ 1995),etc.]

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 1995]

Abstract argumentation: Extensions

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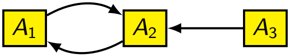

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$\{A_1, A_3\}$	✓	✓	✓	✓	✓

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Motivation for probabilistic argumentation

Strength of an argument

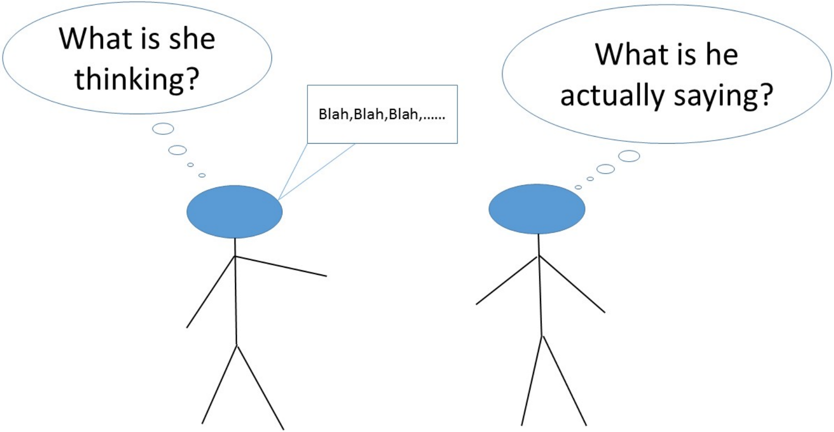
- Abstract argumentation treats each argument as equal
- Real world arguments are not equal
  - Some arguments are "stronger" than others
  - Uncertainty can affect whether one argument is stronger than another
- Therefore, we need to enrich our models of argumentation.

Probabilistic abstract argumentation

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

Motivation for probabilistic argumentation



Uncertainty from speaker and hearer perspectives

Probabilistic abstract argumentation

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** [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

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

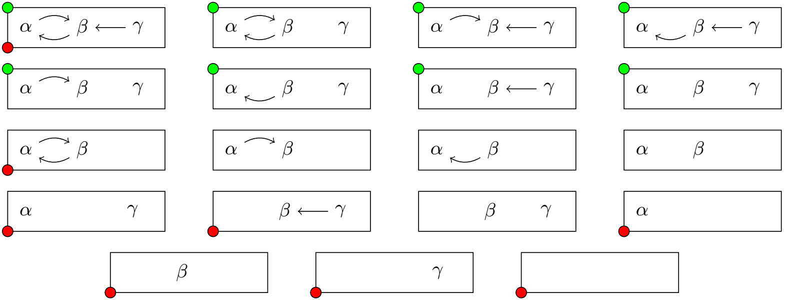
Subgraph

For $G = (\mathcal{A}, \mathcal{R})$ and $G' = (\mathcal{A}', \mathcal{R}')$,

$$G' \sqsubseteq G \text{ iff } \mathcal{A}' \subseteq \mathcal{A} \text{ and } \mathcal{R}' \subseteq \mathcal{A}' \times \mathcal{A}'$$

Overview

Constellations Approach: Subgraphs



- If we are only uncertain about which arguments appear, then we use the full (induced) subgraphs of the argument graph (red dot).
- If we are only uncertain about which attacks appear, then we use the spanning subgraphs of the argument graph (green dot).

Constellations Approach: Probability of extension

Example

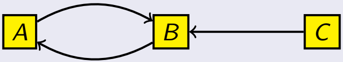
	Subgraph	Probability
G_1	$A \leftrightarrow B$	0.09
G_2	A	0.81
G_3	B	0.01
G_4		0.09

$$
\begin{aligned}
P_{\text{gr}}(\{A,B\}) &= & &= 0.00\\
P_{\text{gr}}(\{A\}) &= P(G_2) & &= 0.81\\
P_{\text{gr}}(\{B\}) &= P(G_3) & &= 0.01\\
P_{\text{gr}}(\{\}) &= P(G_1) + P(G_4) & &= 0.18
\end{aligned}
$$

[Li, Oren and Norman 2011]

Constellations Approach: Probability of an inference

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 $P_{\text{gr}}(C) = 0.5$.

[Hunter 2012, Rienstra 2012]

Constellations Approach: Modelling enthymemes

A husband is clearing up breakfast as his wife is preparing to go to work.

Husband thinks The weather report predicts rain and if the weather report predicts rain, then you should take an umbrella, so you should take an umbrella (intended argument)

Husband speaks The weather report predicts rain, so you should take an umbrella (enthymeme)

Wife thinks The weather report predicts rain and if the weather report predicts rain, then you should take an umbrella, so you should take an umbrella (received argument)

Since "if the weather report predicts rain, then you should take an umbrella" is common knowledge, it is not communicated.

Constellations Approach: Modelling enthymemes

A conversation prior to Christmas

- John says "Tabby is a member of the family. Let's buy her an xmas present" (Argument A).
- Mary replies "She is a cat" (Argument B).

Constellations Approach: Modelling enthymemes

A conversation prior to Christmas

- A = "Tabby is a member of the family. Let's buy her an xmas present".
- B = "She is a cat".

Some decodings of the enthymeme

- B_1 = "She is a cat, I hate cats, and I don't buy presents for those that I hate, therefore we shouldn't buy her a present".
- B_2 = "She is a cat, and so she is not a member of the family".
- B_3 = "She is a cat, she doesn't have a concept of xmas, and so it's impossible to say that she'll like a xmas present".
- B_4 = "She is a cat, they love to be spoiled, and so she'll love a present."

Suppose B_1 to B_3 are counterarguments to A. If each of B_1 to B_4 is equally likely, then there is a 0.75 probability that B attacks A.

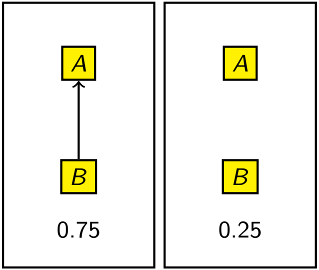
Constellations Approach: Modelling enthymemes

Arguments

- A = "Tabby is a member of the family. Let's buy her an xmas present".
- B = "She is a cat".

Probabilistic inferences

- $P_{\text{gr}}(A) = 0.25$
- $P_{\text{gr}}(B) = 1$



Constellations approach

Advantages of constellations approach

- It provides insights into the meaning of an argument or attack being known or unknown.
- It can be analysed with a generalization of Dung's dialectical semantics
- It can be used to handle enthymemes [Hunter 2013].
- It can be used to model what other agents are aware of in dialogical argumentation [Hunter & Thimm 2014, 2017].

Background to constellations approach

- Li, Oren and Norman (2011) proposed a probability assignment to arguments and attacks, and then assumed independence to generate probability distribution assignment to argument graphs.
  - But, not all probability distributions over subgraphs can be obtained.
  - Also, the independence assumption may be questionable.

Overview

Epistemic Approach: Motivation

Background

- "Strength of an argument" is a common phrase.
- It is not well-understood formally
- Probability is part of the conceptualization of it.

Many argumentation situations are asymmetric

It is often impossible/undesirable to give counterarguments

- Listening to discussions, debates, etc.
- Reading current affairs articles, discussion documents, etc.
- Dialogue with your boss, with your doctor, with a salesperson,

To facilitate handling of asymmetric situations, we can assign our belief in each argument.

Epistemic Approach: Degree of belief

Epistemic approach for handling uncertainty in the belief in the arguments

For an argument graph G, an epistemic probability distribution is such that

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

Example

Suppose $\text{Nodes}(G) = \{A, B\}$, and so assignment is to each of the following:

- $\{A, B\}$ which is equivalent to possible world "A and B"
- $\{A\}$ which is equivalent to possible world "A and not B"
- $\{B\}$ which is equivalent to possible world "not A and B"
- $\{\}$ which is equivalent to possible world "not A and not B"

For instance,

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

Epistemic Approach: Degree of belief

Epistemic approach for handling uncertainty in the belief in the arguments

For an argument graph G, an epistemic probability distribution is such that

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

The belief in an argument α is

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

Example

Consider

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

Hence,

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

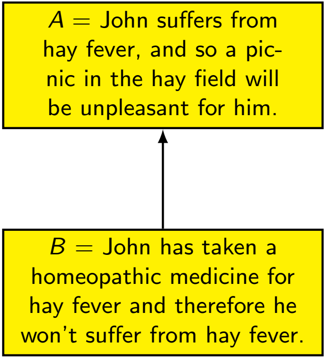
Epistemic Approach: Degree of belief

Probability assignment expresses the degree of belief in an argument

- $P(\alpha) = 0$ represents that α is believed to be false with certainty.
- $P(\alpha) < 0.5$ represents that α is believed to be false to some degree.
- $P(\alpha) = 0.5$ represents that α is neither believed to be true nor false.
- $P(\alpha) > 0.5$ represents that α is believed to be true to some degree.
- $P(\alpha) = 1$ represents that α is believed to be true with certainty.

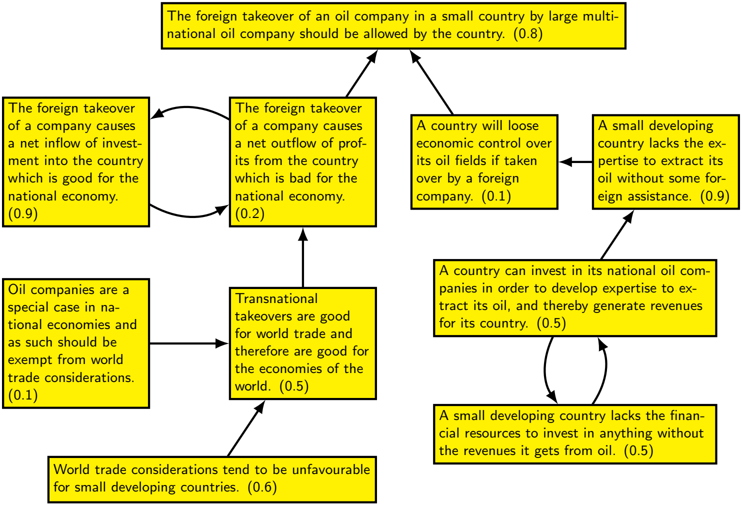
Epistemic Approach: Example

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 $P(B) = 0$).

Epistemic Approach: Example



Arguments from a radio documentary about the takeover of oil production companies in small developing countries by large multinationals. Belief given in argument in brackets.

Epistemic Approach: Epistemic extensions

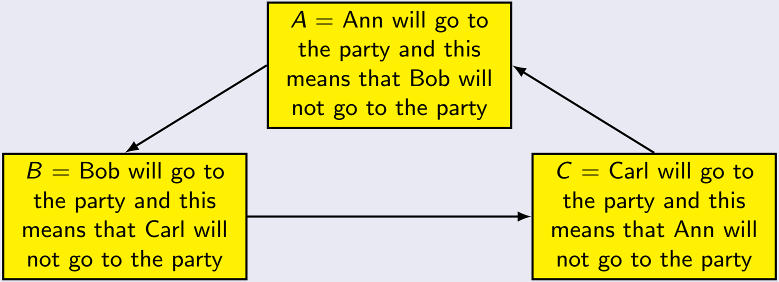
Definition

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

$$\{A \in \mathcal{A} \mid P(A) > 0.5\}$$

Example

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

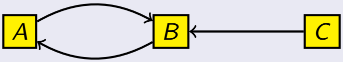


Epistemic Approach: Rational probability functions

Definition

A probability function P is **rational** for an argument graph $(\mathcal{A}, \mathcal{R})$ iff for each $(A, B) \in \mathcal{R}$, if $P(A) > 0.5$, then $P(B) \leq 0.5$.

Example



Some examples of probability functions.

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]

Epistemic Approach: Classes of probability functions

- **COH** P is *coherent* wrt. G if for every $A, B \in \text{Nodes}(G)$, if A attacks B then $P(A) \leq 1 - P(B)$.
- **SFOU** P is *semi-founded* wrt. G if $P(A) \geq 0.5$ for every unattacked $A \in \text{Nodes}(G)$.
- **FOU** P is *founded* wrt. G if $P(A) = 1$ for every unattacked $A \in \text{Nodes}(G)$.
- **SOPT** P is *semi-optimistic* wrt. G if $P(A) \geq 1 - \sum_{B \text{ attacks } A} P(B)$ for every $A \in \text{Nodes}(G)$ with at least one attacker.
- **OPT** P is *optimistic* wrt. G if $P(A) \geq 1 - \sum_{B \text{ attacks } A} P(B)$ for every $A \in \text{Nodes}(G)$.
- **JUS** P is *justifiable* wrt. G if P is coherent and optimistic.
- **TER** P is *ternary* wrt. G if $P(A) \in \{0, 0.5, 1\}$ for every $A \in \text{Nodes}(G)$.
- **RAT** P is *rational* wrt. G if for every $A, B \in \text{Nodes}(G)$, if A attacks B then $P(A) > 0.5$ implies $P(B) \leq 0.5$.
- **NEU** P is *neutral* wrt. G if $P(A) = 0.5$ for every $A \in \text{Nodes}(G)$.
- **INV** P is *involutary* wrt. G if for every $A, B \in \text{Nodes}(G)$, if A attacks B, then $P(A) = 1 - P(B)$.

[Thimm 2012, Hunter 2013, Hunter and Thimm 2014, 2017]

Epistemic Approach: Using epistemic extensions

Standard view Adopt constraints on the probability function so as to simulate Dung's dialectical semantics (e.g. if A is an unattacked argument, then $P(A) > 0.5$).

- via maximum/minimum entropy [Thimm 2012]
- via postulates [Hunter & Thimm 2017]

Non-standard view Adopt constraints on the probability function that diverge from Dung's dialectical semantics (e.g. allow an unattacked argument to be disbelieved) [Hunter 2014, Hunter & Thimm 2017]

Epistemic approach

Advantages of epistemic approach

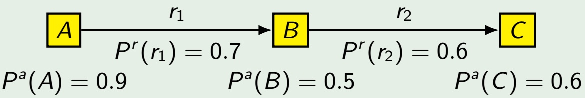
- It provides insights into the meaning of an argument being believed.
  - Using probabilistic logic provides further insights
- It can be compared with Dung's dialectical semantics
  - It can represent Dung's dialectical semantics.
  - It can provide a valuable alternative to Dung's dialectical semantics.
- It can be used to model other agents in dialogical argumentation.
  - For example, it can model beliefs by subpopulations

Overview

Extended epistemic approach

Example

Consider the graph with an epistemic bidistribution (P^a, P^r) (partially) defined through the following constraints.



Then (P^a, P^r) is (among others) rational* and weakly unified*, but not unified*.

Some postulates for the extended epistemic approach

- **rational*** if for all $A, B \in \mathcal{A}$ s.t. $(A, B) \in \mathcal{R}$ and $P^r(A, B) > 0.5$, $P^a(A) > 0.5$ implies $P^a(B) \leq 0.5$.
- **weakly unified*** if for all $(A, B) \in \mathcal{R}$, either both $P^r(A, B) \geq 0.5$ and $P^a(A) \geq 0.5$ or both $P^r(A, B) \leq 0.5$ and $P^a(A) \leq 0.5$.
- **unified*** if for all $(A, B) \in \mathcal{R}$, $P^r(A, B) = P^a(A)$

[Polberg, Hunter and Thimm 2017]

Extended epistemic approach

Independent family of postulates

Assumes no dependence between belief in attacks and belief in attackers, i.e. assignments to an attack α and its source are not necessarily related.

- Imagine two people witnessing a robbery, one claiming that the criminal ran away in a car, the other that he used a bike.
- The statements are clearly conflicting and we can believe the attacks between them independently of the belief we have in the witnesses.

Dependent family of postulates

Motivated by situations in which it is natural to expect dependency (e. g. when argument graphs are obtained from logical knowledge bases).

- Moreover, in many approaches that explicitly include the attacks in extensions and labelings, the conflicts need to conform to the same semantics as the arguments.

[Polberg, Hunter and Thimm 2017]

Overview

Epistemic approach with logical arguments

Logical arguments

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 $\Phi' \vdash \alpha$.

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

$\langle \{\neg\gamma, \beta \rightarrow \gamma\}, \neg\beta \rangle$ is a direct undercut for $\langle \{\alpha, \beta\}, \alpha \wedge \beta \rangle$

[Cayrol 1995, Besnard and Hunter 2001]

Epistemic approach with logical arguments

Probability distribution over models of the language $\mathcal{M}$

A function $P : \mathcal{M} \rightarrow [0,1]$ such that

$$\sum_{m \in \mathcal{M}} P(m) = 1$$

Probability of a formula ϕ

$$P(\phi) = \sum_{m \in \text{Models}(\phi)} P(m)$$

Example

Model	a	b	P
m_1	true	true	0.8
m_2	true	false	0.2
m_3	false	true	0.0
m_4	false	false	0.0

- $P(a) = 1$
- $P(a \wedge b) = 0.8$
- $P(b \vee \neg b) = 1$
- $P(\neg a \vee \neg b) = 0.2$

Epistemic approach with logical arguments

Probability of an argument

The probability of an argument $\langle \Phi, \alpha \rangle$, denoted $P(\langle \Phi, \alpha \rangle)$, is $P(\phi_1 \wedge \ldots \wedge \phi_n)$, where $\Phi = \{\phi, \ldots, \phi_n\}$.

Example

Consider the following probability distributions over models

Model	a	b	Agent 1	Agent 2
m_1	true	true	0.5	0.0
m_2	true	false	0.5	0.0
m_3	false	true	0.0	0.6
m_4	false	false	0.0	0.4

Below is the probability of each argument according to each participant.

Argument	Agent 1	Agent 2
$A_1 = \langle \{a\}, a \rangle$	1.0	0.0
$A_2 = \langle \{b, b \rightarrow \neg a\}, \neg a \rangle$	0.0	0.6
$A_3 = \langle \{\neg b\}, \neg b \rangle$	0.5	0.4

[Hunter 2013]

Epistemic approach with logical arguments

Quality ranking of information in knowledgebase

Ranking	Knowledgebase	Probability distribution over language
1	Logically consistent	Consistent (i.e. sums to 1)
2	Logically inconsistent	Consistent (i.e. sums to 1)
3	Logically inconsistent	Inconsistent (i.e. does not sum to 1)
4	Logically inconsistent	No distribution

[Hunter 2013]

Overview

Studies with participants: Dialogue study

Motivation

- Most proposals for computational models of argument are motivated by a few made-up examples.
- There has been little evaluation of computational models of argument with participants.
  - Exceptions are studies by Rahwan *et al.*, Cerutti *et al.*, Rosenfeld & Kraus, and Cramer *et al.*
- In this study, we undertake a study with participants involving two dialogues.

[Polberg and Hunter, IJAR 2017]

Studies with participants: Dialogue study

Recruitment of participants

- The recruitment was done using Amazon Mechanical Turk.
- The survey was run on SurveyMonkey
- The participants were subjected to an additional language exercise (intermediate level), two attention checks and a comprehension test in order to ensure their skills and honesty of their work.
- We also requested the participants not to use Google or Wikipedia in order to verify the statements in the dialogues.
- We ran the survey until 80 answers (40 per dialogue) that had a sufficiently high score in the language, attention and comprehension tests were found.

[Polberg and Hunter, IJAR 2017]

Studies with participants: Dialogue study

Dialogue 1

Steps	Person	Statement	Content
1 to 5	P1	A	Hospital staff members do not need to receive flu shots.
1 to 5	P2	B	Hospital staff members are exposed to the flu virus a lot. Therefore, it would be good for them to receive flu shots in order to stay healthy.
2 to 5	P1	C	The virus is only airborne and it is sufficient to wear a mask in order to protect yourself. Therefore, a vaccination is not necessary.
3 to 5	P2	D	The flu virus is not just airborne, it can be transmitted through touch as well. Hence, a mask is insufficient to protect yourself against the virus.
4 to 5	P1	E	The flu vaccine causes flu in order to gain immunity. Making people sick, who otherwise might have stayed healthy, is unreasonable.
5	P2	F	The flu vaccine does not cause flu. It only has some side effects, such as headaches, that can be mistaken for flu symptoms.

Studies with participants: Dialogue study

Dialogue 2

Steps	Person	Statement	Content
1 to 5	P1	A	The flu vaccine is not safe to use by children.
1 to 5	P2	B	The flu vaccine does not contain poisonous components and is safe to use.
2 to 5	P1	C D	The vaccine contains some mercury compounds. The mercury compounds are poisonous and therefore the vaccine is not safe to use.
3 to 5	P2	E F	The child vaccine does not contain any mercury compounds. The virus is only accompanied by stabilizers and possibly trace amounts of antibiotics used in its production.
4 to 5	P1	G	The vaccine contains a preservative called thimerosal which is a mercury-based compound.
5	P2	H	Children receive the nasal spray vaccine and thimerosal has been removed from it over 15 years ago.

Studies with participants: Dialogue study

Agreement The participants were asked to state how much they agree or disagree with a given statement. They were allowed to choose one of the seven options (*Strongly Agree*, *Agree*, *Somewhat Agree*, *Neither Agree nor Disagree*, *Somewhat Disagree*, *Disagree*, *Strongly Disagree*) or select the answer *Don't Know*.

Explanation The participants were then asked to explain the chosen level of agreement for every statement, and provide reasons for disagreement not mentioned in the dialogue.

Relation The participants were asked to state how they viewed the relation between the statements. For every listed pair, they could say whether one statement was *A good reason against*, *A somewhat good reason against*, *Somewhat related, but can't say how*, *A somewhat good reason for*, *A good reason for* the other statement or select the answer *N/A* (i.e. that the statements were unrelated).

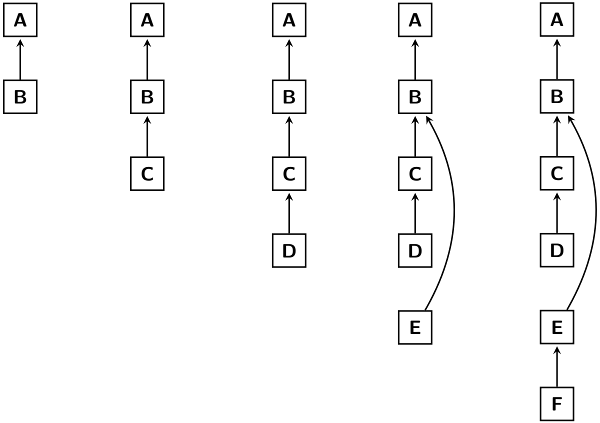
Awareness The participants were asked which of the presented statements they were familiar with prior to the experiment.

Studies with participants: Dialogue study

- the **intended graph** is meant to depict the minimal set of relations we consider reasonable for a given set of arguments.
- the **augmented graph** is obtained by adding to the intended graph indirect relations from the prudent/careful or bipolar argumentation approach.
- the **participant–sourced graphs**:
  - the **declared graph** is constructed from the answers given us by the participants in the Agreement and Relation tasks.
  - the **expanded graph** is constructed from the declared graph, extended with the statements extracted from the answers that the participants have provided in the Explanation task
  - the **common graph** which is a declared graph created by the highest number of participants at a given step in the dialogue .

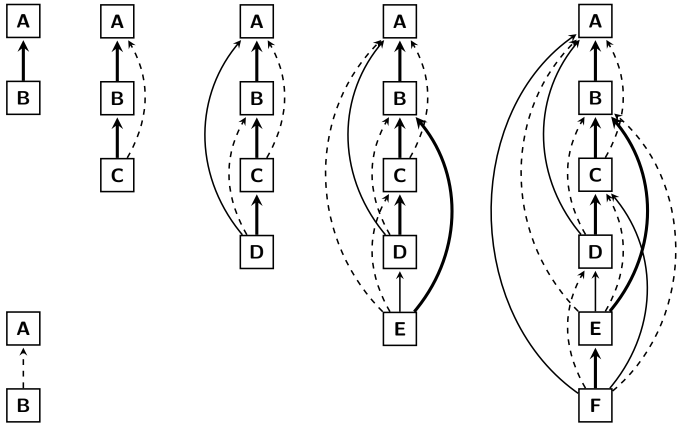
[Polberg and Hunter, IJAR 2017]

Studies with participants: Dialogue study



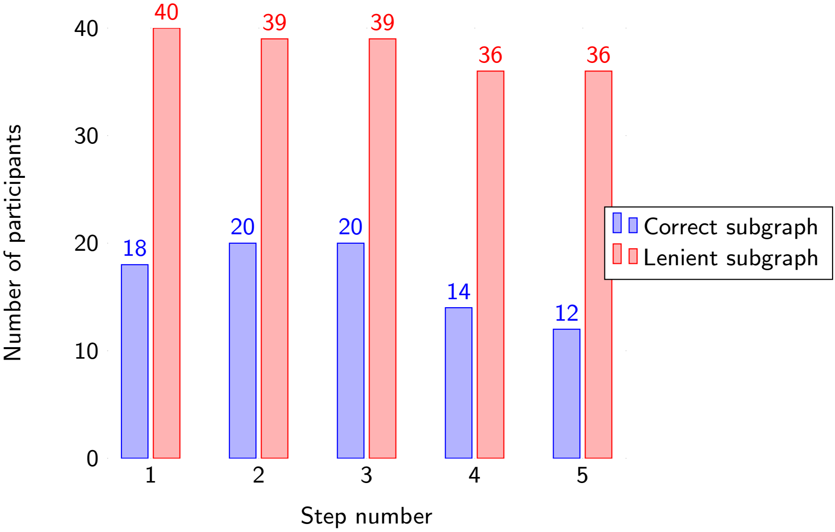
The intended argument graphs for dialogue 1. Solid edges represent the attack relation.

Studies with participants: Dialogue study



The most common declared argument graphs for dialogue 1 based on the total sample. The thicker edges represent the relations appearing in the intended graph. Solid edges stand for attack and dashed for support.

Studies with participants: Dialogue study



Number of participants whose declared graphs contain the intended graph

Studies with participants: Dialogue study

Let n be the number of participants and $\{G_1, \ldots, G_n\}$ the frameworks they have declared. The average distance from a framework G_i, where $1 \leq i \leq n$, to other frameworks is defined as:

$$avg\_dist(G_i) = \frac{\sum_{j=1}^{n} d(G_j, G_i)}{n-1} \quad (1)$$

	Common Framework	Minimum	Maximum	Average	Median
Step 1	0.33	0.33	1.80	0.52	0.33
Step 2	0.40	0.40	3.87	0.72	0.40
Step 3	1.33	1.33	7.60	2.22	1.33
Step 4	2.07	2.07	11.93	3.44	2.07
Step 5	5.13	5.13	13.13	7.17	6.87

We include the average distance from the most common framework to other frameworks, minimum and maximum average distances amongst all the averages, median, and overall average.

Studies with participants: Dialogue study

Relation	Attack	Support	Dependent
(B, A)	85	1.25	13.75
(C, A)	12.50	84.38	3.13
(C, B)	89.06	3.13	7.81
(D, A)	81.25	6.25	12.50
(D, B)	2.08	97.92	0
(D, C)	91.67	0	8.33
(E, A)	21.88	62.50	15.63
(E, B)	81.25	3.13	15.63
(E, C)	12.50	71.88	15.63
(E, D)	68.75	3.13	28.13
(F, A)	50	6.25	43.75
(F, B)	12.50	68.75	18.75
(F, C)	62.50	6.25	31.25
(F, D)	0	68.75	31.25
(F, E)	81.25	0	18.75

Occurrences of the declared relations in dialogue 1 (as % of participants)

Studies with participants: Dialogue study

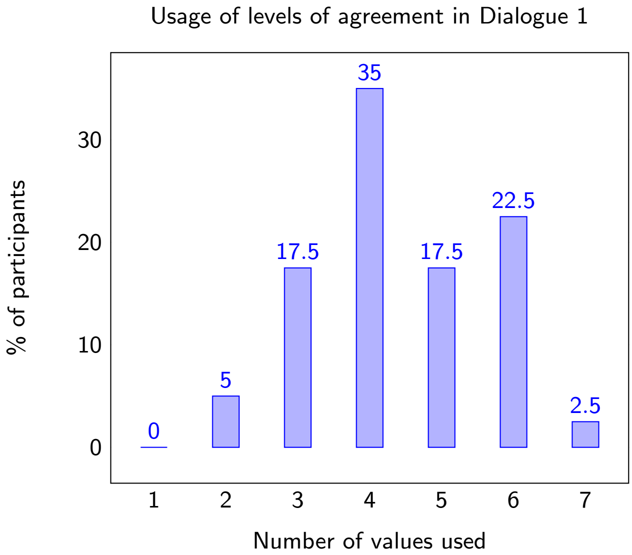
By analysing the common graphs (i.e. the declared graph created by the highest number of participants at a given step in the dialogue),

- most support relation can be explained as defence relations
- some support relation cannot be explained as defence relation but can be explained as support relations using bipolar argumentation

So participants do behave in a way that is largely consistent with the notions of defence as used in dialectical semantics, but they also use notions of support as used in bipolar argumentation.

[Polberg and Hunter, IJAR 2017]

Studies with participants: Dialogue study



Studies with participants: Dialogue study

Postulate	Definition	Dialogue 1	Dialogue 2
Rational	if A attacks B and $P(A) > 0.5$, then $P(B) \leq 0.5$.	74%	81%
Coherent	if A attacks B, then $P(A) \leq 1 - P(B)$	38%	39%
Semi-founded	if A is unattacked, then $P(A) > 0.5$.	43%	53%
Discharging	if $P(B) < 0.5$, then there is a C s.t. C attacks B and $P(C) > 0.5$.	42%	45%
Semi-optimistic	$P(A) \geq 1 - \sum_{B \text{ attacks } A} P(B)$ for every argument A with at least one attacker.	80%	80%

Table: Satisfaction of postulates by the participants in the dialogues (as percentage of participant steps)

Studies with participants: Dialogue study

Key observations

1. The data supports the use of **constellation approach** to probabilistic argumentation – people may interpret statements and relations between them differently
2. The data supports the use of **epistemic approach** to probabilistic argumentation:
   - People may assign levels of agreements to statements going beyond the 3–valued Dung's approach.
   - The epistemic postulates, in contrast to the standard semantics, can be highly adhered to.
   - The extended epistemic postulates allow us to model situations where strength of argument and attack are decoupled.
3. The data supports the use of **bipolar argumentation frameworks** – the notion of defence does not account for all of the positive relations between the statements viewed by the participants
4. The data shows that **people use their own personal knowledge** in order to make judgments and might not necessarily disclose it

[Polberg and Hunter, IJAR 2017]

Overview

Studies with participants: Crowdsource study

- We created a data set consisting of 30 arguments in three categories – celebrity, scientific and society – each with a particular format.
  - **Celebrity** E.g., *Melissa Latimer, a popular health and fitness celebrity, says that coffee can disturb the natural rhythm of the body and cause sleeping issues. Therefore, you should drink less coffee and replace it with healthier options, such as green tea.*
  - **Scientific** E.g., *Extensive scientific studies carried out by the Australian Government National Health and Medical Research Council show that there is no evidence that homeopathy is an effective treatment for any health condition. Therefore, we should not use it as an alternative to traditional medicine.*
  - **Society** E,g,, *Vaccines are crucial in building herd immunity and preventing diseases from spreading, which is important for people with compromised immune systems. Therefore, we should receive vaccines for our wellbeing as well as for the people around us.*
- In each category, five are pro arguments (i.e. for something) and five are con arguments (i.e. against something).
- The topics of the arguments are medicines, recycling, electric cars, and coffee.

[Hunter & Polberg ICTAI'17]

Studies with participants: Crowdsource study

Crowd-sourcing of data for user model

- For each argument, we asked each participant to score the following on a scale from -10 to 10.
  - how believable is the argument?
  - how convincing is the argument?
  - how appealing is the argument?
- We chose these dimensions because they provide a seemingly diverse and insightful range of notions for evaluating an argument.

[Hunter & Polberg ICTAI'17]

Studies with participants: Crowdsource study

We can easily find arguments with a high score in one dimension but a low one in another.

- *Smoking causes numerous diseases. Therefore, you should quit.* Believable, but not always convincing
- *Education should be free for everyone independently of race, gender or religion. Therefore, we should abolish the tuition fees incurred on students by the universities.* Appealing, but not always convincing
- *We have a found a tumour in your brain and, if it is left untreated, you have a year left to live. You will eventually develop seizures, difficulties with speech, movement and vision and experience severe headaches. Therefore, we would advise you to undergo a surgery to remove as much of the tumour as possible and follow it up with radiotherapy.* Believable and convincing, but not appealing.

[Hunter & Polberg ICTAI'17]

Studies with participants: Crowdsource study

Requirement of participants

- We recruited 50 participants using Amazon Mechanical Turk and ran the survey on SurveyMonkey.
- Prior to the survey, participants were subjected to an additional language exercise and two attention checks to ensure their skills and honesty of their work.
- No definition was given to participants of the terms (i.e. believability, convincingness, and appeal), as we wanted to investigate empirically the diversity of ways that people may score them.
- However, we did check that they had a reasonable understanding of the general meaning of them and saw the differences between them.
- The participants were not informed of the category (i.e. celebrity, scientific, or society) to which a given argument was assigned.

Data available online
(http://www0.cs.ucl.ac.uk/staff/a.hunter/papers/empiricalappendix.zip)

For every two of the three listed attributes (i.e. believable, convincing, appealing), we have calculated the (Spearman) correlation between them for arguments belonging to the same group and for all arguments altogether.

Category	Believable - Convincing	Convincing - Appealing	Appealing - Believable
Celebrity	0.85	0.63	0.64
Scientific	0.89	0.50	0.46
Society	0.90	0.69	0.66
Total	0.89	0.61	0.59

Table: Correlations between dimensions

[Hunter & Polberg ICTAI'17]

Studies with participants: Crowdsource study

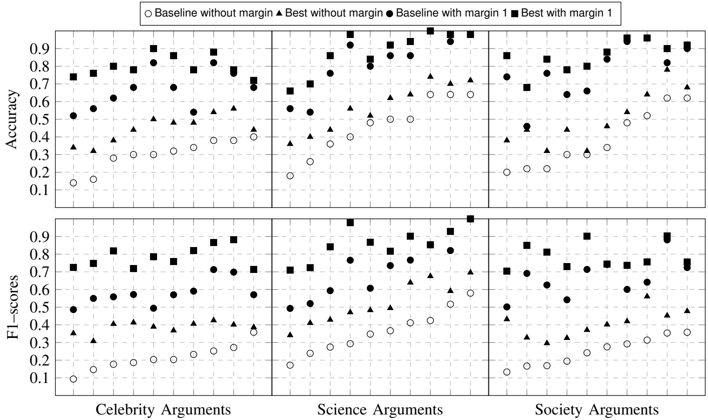


Fig. 1: Accuracy and F1–scores of predicted scores of arguments in a given category w.r.t. this category. Each point on the x–axis denotes an argument. For presentation purposes, the results have been ordered by increasing accuracy or F1–score w.r.t. the baseline without margin.

Studies with participants: Crowdsource study

	Predicting category	Celebrity		Scientific		Society	
	Predicted category	Accuracy	F1	Accuracy	F1	Accuracy	F1
Best without margin	Celebrity	0.48	0.39	0.52	0.46	0.52	0.43
	Scientific	0.59	0.53	0.58	0.53	0.57	0.48
	Society	0.58	0.46	0.59	0.46	0.53	0.41
Best with margin 1	Celebrity	0.816	0.79	0.84	0.82	0.83	0.80
	Scientific	0.90	0.86	0.90	0.86	0.90	0.86
	Society	0.89	0.85	0.88	0.83	0.86	0.80

TABLE I: Average accuracy and F1–scores for predicting with different categories

[Hunter & Polberg ICTAI'17]

Studies with participants: Crowdsource study

Conclusions on the crowd-sourcing study

- We have developed and evaluated methods for acquiring crowd-sourced opinions on arguments, and shown how they can be used for predicting opinions on arguments.
- This shows how it is viable to acquire data to construct classifiers, and that these can then be deployed to substantially decrease the number of questions that need to be asked of a user.
- In addition, we have shown how diverse dimensions can be taken into account such as belief, appeal and convincingness, and this study has shown how belief is a good proxy for convincingness.

[Hunter & Polberg ICTAI'17]

Overview

1. Brief review of abstract argumentation
2. Motivation for probabilistic argumentation
3. Constellations approach
4. Epistemic approach
   - Extended epistemic approach
   - Epistemic approach with logical arguments
5. Studies with participants
   - Dialogue study
   - Crowdsource study
6. Conclusions

Conclusions

Key points

- Different kinds of uncertainty pervade argumentation in the real world
- Two key kinds of uncertainty in abstract argumentation are
  - Constellations uncertainty (i.e. over structure of graph)
  - Epistemic uncertainty (i.e. over belief in each argument)
- Epistemic approach gives a clear meaning to notion of argument strength.
- Probabilistic argumentation is supported by studies with participants.
- Probability distributions can be generated from crowdsourced data.
- Applications for probabilistic argumentation include
  - modelling the arguments/attacks known by another agent
  - modelling the arguments believed by another agent
  - modelling the decoding of enthymemes

Conclusions

Further developments

- Uncertainty in epistemic probability distribution can be quantified:
  - Confidence distributions [Hunter, ECAI'16]
  - Beta distributions [Hadoux and Hunter, AAMAS'18]
- Epistemic probability distributions can be updated:
  - Functions that simulate human behaviour [Hunter IJCAI'15, Sum'16]
  - Minimal change that satisfy postulates [Hunter & Potyka Ecsqaru'18]
- Epistemic probability distributions can be used in strategic choice of move in dialogues [Hadoux & Hunter ICTAI'16, AAAI'17, Foiks'18].

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