Introduction to Computational Models of Argumentation

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Computational models of argument

Overview of tutorial

- Argumentation as a cognitive process
- Computational models of argument
  - Abstract argumentation
  - Logical argumentation
  - Dialogical argumentation
- Pragmatics in argumentation
- Argumentation technology in applications

Argumentation as a cognitive process

Monological argumentation: Argumentation by a single agent

- e.g. A newspaper article by a journalist
- e.g. A political speech by a politician
- e.g. A review article by a scientist
- e.g. A problem analysis prior to making a decision

Dialogical argumentation: Argumentation between multiple agents

- e.g. Lawyers arguing in a court
- e.g. Traders negotiating in a marketplace
- e.g. Politician debating about new legislation
- e.g. Child arguing with parent for rise in pocket money

Argumentation as a cognitive process

Arguments are normally based on imperfect information

Arguments are normally constructed from information that is incomplete, inconsistent, uncertain, possibly 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.

Argumentation as a cognitive process

Today, there are 350 people in this room, therefore there must be at least two people in the room who have the same birthday	Today, there are 367 people in this room, therefore there must be at least two people in the room who have the same birthday
A1	A2

- Most arguments are refutable (such as argument A1)
- Argument A2 appears irrefutable but even this may be refuted if for example there is doubt about the number of people in the room.

Abstract argumentation: Argument graph

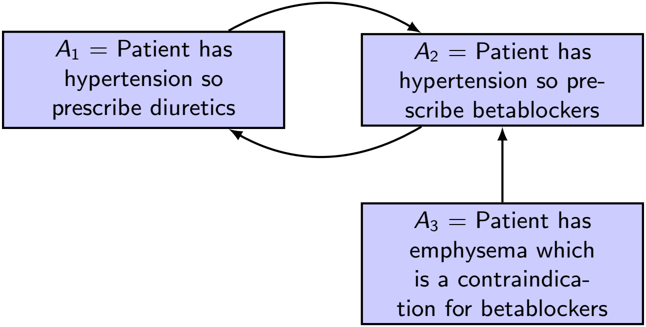
Argument graph

An **argument graph** is a pair $(\mathcal{A}, \mathcal{R})$ where $\mathcal{A}$ is a set and $\mathcal{R}$ is a binary relation over $\mathcal{A}$ (i.e., $\mathcal{R} \subseteq \mathcal{A} \times \mathcal{A}$).

- Each element $A \in \mathcal{A}$ is called an **argument**
- Each $(A, B) \in \mathcal{R}$ means that A **attacks** B (accordingly, A is said to be an **attacker** of B).
- So A is a **counterargument** for B when $(A, B) \in \mathcal{R}$ holds.

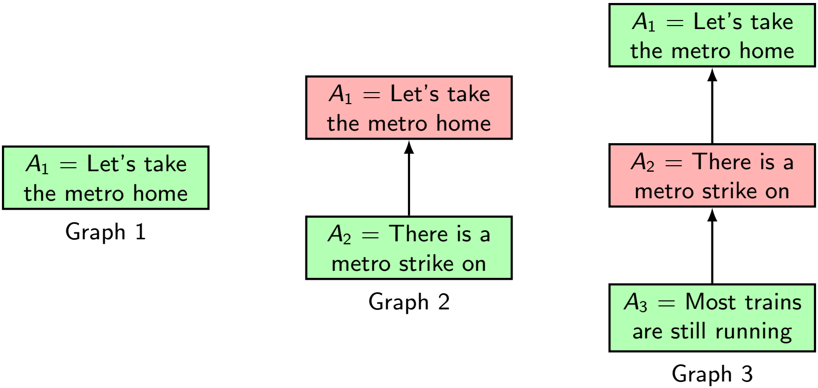
[See Dung 1995]

Abstract argumentation: Graphical representation



Abstract argumentation: Winning arguments

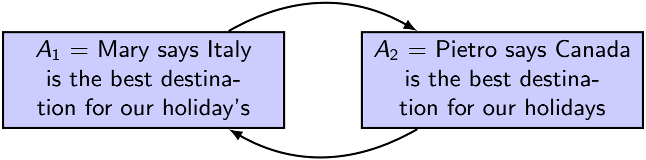
Green means the argument "wins" and red means the argument "looses".



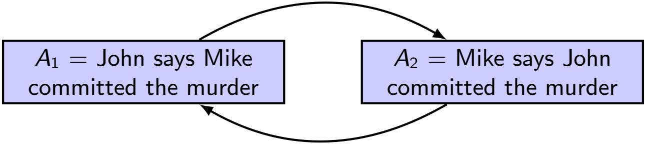
[See Simari+Loui (1992); Pollock (1995); etc.]

Abstract argumentation: Skeptical and credulous views

(Credulous) It seems reasonable to accept either argument in the following argument graph.



(Skeptical) It seems reasonable to accept neither argument in the following argument graph.

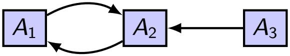


Abstract argumentation: Coalitions

Arguments can work together as a coalition by attacking other arguments.

Let $\Gamma \subseteq \mathcal{A}$ be a set of arguments.

- Γ **attacks** $B \in \mathcal{A}$ iff there is an argument $A \in \Gamma$ such that A attacks B.



	A_1	A_2	A_3
$\{\}$			
$\{A_1\}$		✓	
$\{A_2\}$	✓		
$\{A_3\}$		✓	
$\{A_1, A_2\}$	✓	✓	
$\{A_1, A_3\}$		✓	
$\{A_2, A_3\}$	✓	✓	
$\{A_1, A_2, A_3\}$	✓	✓	

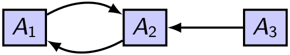
[See Dung 1995]

Abstract argumentation: Conflictfree

The following gives a requirement that should hold for a coalition of arguments to make sense. If it holds, it means that the arguments in the set offer a consistent view on the topic of the argument graph.

Conflictfree sets of arguments

A set $\Gamma \subseteq \mathcal{A}$ of arguments is **conflictfree** iff there are no A, B in Γ such that A attacks B.



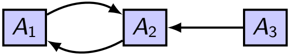
$\{\}$	$\{A_1\}$	$\{A_2\}$	$\{A_3\}$	$\{A_1, A_2\}$	$\{A_1, A_3\}$	$\{A_2, A_3\}$	$\{A_1, A_2, A_3\}$
✓	✓	✓	✓		✓		

Abstract argumentation: Defends

Arguments can defend other arguments from attack

Let $\Gamma \subseteq \mathcal{A}$ be a conflictfree set of arguments.

- Γ **defends** $A \in \mathcal{A}$ iff for each argument $B \in \mathcal{A}$, if B attacks A then Γ attacks B.



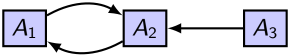
	A_1	A_2	A_3
$\{\}$			✓
$\{A_1\}$	✓		✓
$\{A_2\}$			
$\{A_3\}$	✓		✓
$\{A_1, A_3\}$	✓		✓

Abstract argumentation: Acceptability

The intuition here is that for a set of arguments to be accepted, we require that, if any one of them is challenged by a counterargument, then they offer grounds to challenge, in turn, the counterargument. There always exists at least one admissible set: The empty set is always admissible.

Acceptable sets of arguments

A set $\Gamma \subseteq \mathcal{A}$ of arguments is **admissible** iff Γ is conflictfree and defends all its elements.



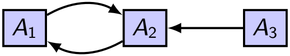
$\{\}$	$\{A_1\}$	$\{A_2\}$	$\{A_3\}$	$\{A_1, A_2\}$	$\{A_1, A_3\}$	$\{A_2, A_3\}$	$\{A_1, A_2, A_3\}$
✓	✓		✓		✓		

Abstract argumentation: Defended

The function Defended(Γ) returns all arguments defended by Γ

Let Γ be a conflictfree set of arguments,

- $\text{Defended}(\Gamma) = \{A \mid \Gamma \text{ defends } A\}$.



- $\text{Defended}(\{\}) = \{A_3\}$
- $\text{Defended}(\{A_1\}) = \{A_1, A_3\}$
- $\text{Defended}(\{A_3\}) = \{A_1, A_3\}$
- $\text{Defended}(\{A_1, A_3\}) = \{A_1, A_3\}$

[See Dung 1995]

Abstract argumentation: Maximal and minimal sets

Maximal and minimal sets w.r.t. set inclusion

Let Φ be a set of sets

- $X \in \Phi$ is minimal iff there is no $Y \in \Phi$ such that $Y \subset X$
- $X \in \Phi$ is maximal iff there is no $Y \in \Phi$ such that $X \subset Y$

For example,

- Let $\Phi = \{\{5\}, \{1,2\}, \{1,3\}, \{1,2,4\}, \{1,2,3\}, \{1,3,5\}, \{1,2,3,5\}\}$
- The minimal sets are $\{5\}$, $\{1,2\}$, and $\{1,3\}$.
- The maximal sets are $\{1,2,4\}$ and $\{1,2,3,5\}$

Abstract argumentation: Extensions

The notion of admissible sets of arguments can be regarded as the minimum requirement for a set of arguments to be accepted.

Extensions of an argument graph

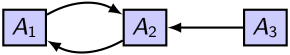
Let Γ be a conflictfree set of arguments, and let Defended : $\wp(\mathcal{A}) \mapsto \wp(\mathcal{A})$ be a function such that $\text{Defended}(\Gamma) = \{A \mid \Gamma \text{ defends } A\}$.

1. Γ is a **complete extension** iff $\Gamma = \text{Defended}(\Gamma)$
2. Γ is a **grounded extension** iff it is the minimal (w.r.t. set inclusion) complete extension.
3. Γ is a **preferred extension** iff it is a maximal (w.r.t. set inclusion) complete extension.
4. Γ is a **stable extension** iff it is a preferred extension that attacks all arguments in $\mathcal{A} \setminus \Gamma$.

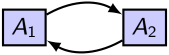
In general, the grounded extension provides a skeptical view on which arguments can be accepted, whereas each preferred extension take a credulous view on which arguments can be accepted.

[See Dung 1995]

Abstract argumentation: Examples

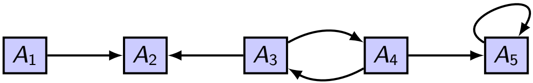


	admissible	complete	grounded	preferred	stable
$\{\}$	✓				
$\{A_1\}$	✓				
$\{A_3\}$	✓				
$\{A_1, A_3\}$	✓	✓	✓	✓	✓

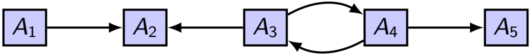


	admissible	complete	grounded	preferred	stable
$\{\}$	✓	✓	✓		
$\{A_1\}$	✓	✓		✓	✓
$\{A_2\}$	✓	✓		✓	✓

Abstract argumentation: Examples



	admissible	complete	grounded	preferred	stable
$\{A_1\}$	✓	✓	✓		
$\{A_1, A_3\}$	✓	✓		✓	
$\{A_1, A_4\}$	✓	✓		✓	✓



	admissible	complete	grounded	preferred	stable
$\{A_1\}$	✓	✓	✓		
$\{A_1, A_3, A_5\}$	✓	✓		✓	✓
$\{A_1, A_4\}$	✓	✓		✓	✓

Abstract argumentation: Some results

Some theorems from Dung (1995) include:

- The empty set is always admissible.
- There is always a preferred extension.
- Every preferred extension is complete
- Every stable extension is preferred
- The grounded extension is the intersection of all complete extensions.
- No stable extension is empty but there are argument frameworks for which there is no stable extension.
- If an argument graph has no cycle then there is a single extension that is stable, preferred, complete and grounded.

Abstract argumentation: Taking values into account

Example involving ethical values

Consider the following arguments concerning the theft by Hal of insulin from Carla's House because he has lost his through no fault of his own.

- A_1 Hal is justified because a person can use other people's property to save a life *(Life)*
- A_2 It is wrong to infringe the property rights of others *(Property)*
- A_3 If Hal compensates Carla, then property rights have not been infringed *(Property)*

So $\{A_1, A_3\}$ is the preferred extension, but it may appear unjust to accept A_1 based on the value of *(Life)* using the argument A_3 which is based on the value of *(Property)*.

[See Bench-Capon 2003]

Abstract argumentation: Taking values into account

Refinement of attack

- For a set of values V, let $\preceq$ be a pre-order relation over V.
- $v_1 \prec v_2$ means v_1 is strictly less preferred to v_2
- A *attacks*$_\preceq$ B iff A *attacks* B and $A \not\prec B$

Example involving ethical values (cont'd)

Suppose the value *Property* $\prec$ *Life*, the argument graph becomes, and so A_1 is now unattacked.

[See Bench-Capon 2003]

Abstract argumentation: Conclusions

- Abstract argumentation has formalized the notion of dialectics that is important in argumentation
- Implementated systems for computing extensions include
  - Dungine (www.argkit.org)
  - Aspartix (www.dbai.tuwien.ac.at/proj/argumentation/systempage/)
- Abstract argumentation has been extended in various ways (e.g. preferences, weights, probabilities, etc.)
- There is some work on using technology from natural language processing for building argument graphs (e.g. information extraction, sentiment analysis, text entailment, etc).
- 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

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 $\Delta = \{\alpha, \alpha \rightarrow \beta, \beta \rightarrow \gamma, \delta \rightarrow \neg\beta\}$, then arguments from Δ include:

$$\begin{array}{cc} \langle \{\alpha\}, \alpha \rangle & \langle \{\alpha, \alpha \rightarrow \beta\}, \beta \rangle \\ \langle \{\alpha, \alpha \rightarrow \beta, \beta \rightarrow \gamma\}, \gamma \rangle & \langle \{\alpha \rightarrow \beta\}, \alpha \rightarrow \beta \rangle \\ \langle \{\alpha \rightarrow \beta\}, \neg\alpha \vee \beta \rangle & \langle \{\}, \neg\alpha \vee \alpha \rangle \end{array}$$

[See Besnard and Hunter (2008); etc.]

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

$\langle \{\beta, \beta \to \alpha\}, \alpha \rangle$ rebuts $\langle \{\gamma, \gamma \to \neg\alpha\}, \neg\alpha \rangle$

$\langle \{\gamma, \gamma \to \neg\beta\}, \neg(\beta \wedge (\beta \to \alpha)) \rangle$ undercuts $\langle \{\beta, \beta \to \alpha\}, \alpha \rangle$

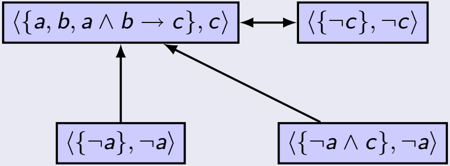
$\langle \{\delta \to \neg\beta\}, \neg\beta \rangle$ is a direct undercut for $\langle \{\alpha, \beta\}, \alpha \wedge \beta \rangle$

Logical argumentation: Attacks by counterarguments

A rebut denotes a disagreement with the claim, whereas an undercut denotes a disagreement with the support (i.e. a disagreement of the explanation or justification).

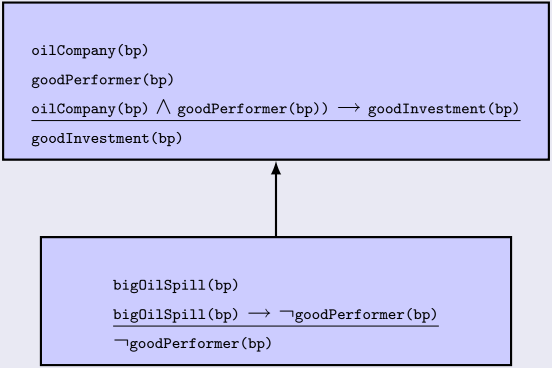
Example

- a = "garlic is horrible"
- b = "this dish contains garlic"
- c = "this dish is horrible"



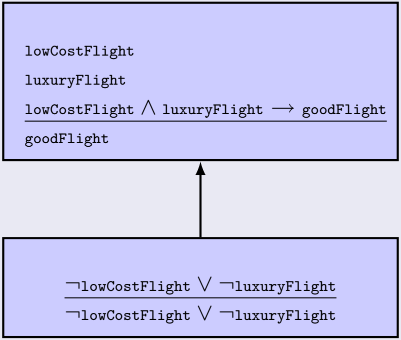
Logical argumentation: Attacking assumptions

Example using defeasible logic with direct undercut



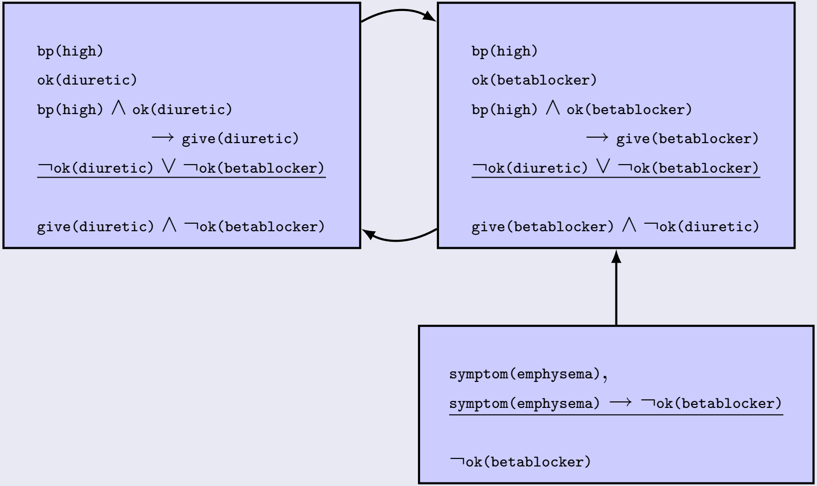
Logical argumentation: Disjunctive attack

Example using classical logic with a disjunctive attack



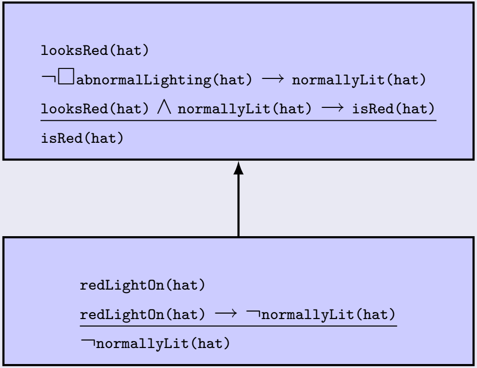
Logical argumentation

Example using classical logic with integrity constraint



Logical argumentation: Attacking defeasible rules

Example using autoepistemic logic



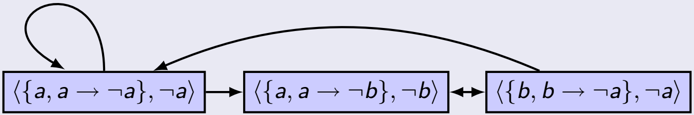
Logical argumentation: Structural properties

Covers

A logical argumentation system S is covers a class of graphs $\mathcal{G}$ iff for each $G \in \mathcal{G}$, there is a knowledgebase Δ such that the argument graph constructed from Δ is G.

Example using defeasible logic

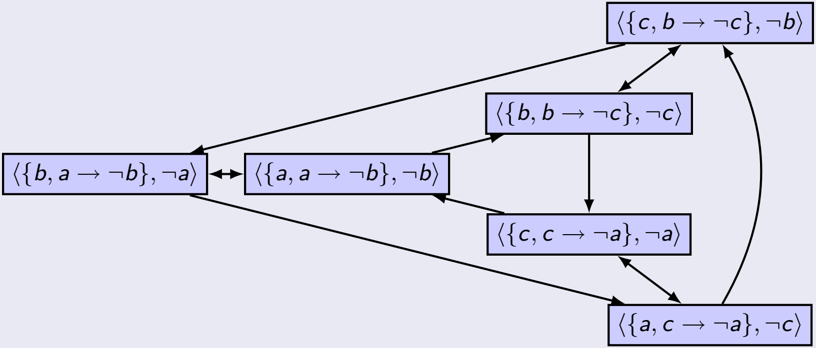
Consider $\Delta = \{a, b, a \rightarrow \neg a, b \rightarrow \neg a, a \rightarrow \neg b\}$, let the arguments be those that involves one or more rules.



With the proof theory having just modus ponens, this logical argumentation system does cover all directed graphs.

Example using classical logic

Consider $\Delta = \{a, b, a \rightarrow \neg a, b \rightarrow \neg a, a \rightarrow \neg b\}$, let the arguments be those that involves one or more rules.



Because the proof theory has modus ponens and modus tollens, this logical argumentation system does not cover all directed graphs.

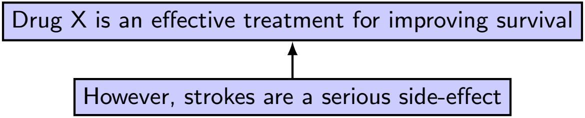
Logical argumentation: Need for meta-level information

Normally, meta-level information is also needed for logical argumentation.

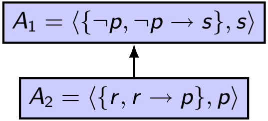
Examples of meta-level information

- Preferences over formulae to give a preference over arguments [see for example Amgoud and Cayrol 2002].
  - Preference for premises that are based on more reliable sources
  - Preference for claims that meet more important goals
- Use probability theory to quantify uncertainty of each argument (e.g. probability that premises are true [see Hunter 2012], or probability that the argument comes from a reliable source, etc).
- Use meta-level argumentation to reason about the quality of arguments (e.g. argumentation about whether proponents for arguments are qualified to argue about a topic [see Hunter 2008]).

Logical argumentation: Probabilistic logic



- p = “problematic treatment”,
- s = “effective treatment for improving survival”,
- r = “strokes are a serious side-effect”.



Model	p	s	r	P
m_1	false	true	true	0.35
m_2	false	true	false	0.35
m_3	true	true	true	0.12
m_4	true	false	true	0.18

$P(A_1) = P(m_1) + P(m_2) = 0.7$ $\quad$ $P(A_2) = P(m_3) + P(m_4) = 0.3$

Logical argumentation:Conclusions

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

Pragmatics in argumentation

How convincing an argument is $\neq$ How correct it is.

- Watching TV a lot makes children violent
- Homeopathy focuses on processes of health and illness rather than states, and therefore it is better than regular medicine
- The sheer weight of anecdotal evidence gives rise to the common-sense notion that there must be some basis for such therapies by virtue of the fact that they have lasted this long

Pragmatics in argumentation

Good arguments can fail in argumentation

- The reasoning is not appropriate for the audience

  There's no point telling a young child to take care with the vase because it is expensive

- The proponent is not credible for the audience

  A ministry official is the wrong person to tell youngsters to use a helmet when riding a motorbike

Pragmatics in argumentation

Measuring empathy and antipathy for arguments

- Model the beliefs of the intended audience by a set of propositional formulae Γ.
- Evaluate the empathy/antipathy the audience would have for each argument $\langle \Phi, \alpha \rangle$ in an argument tree based on their beliefs.
    - Empathy is the degree to which Γ entails Φ (e.g. the proportion of models of Γ that are models of Φ).
    - Antipathy is the degree to which Γ conflicts Φ (e.g. the minimum Dalal distance between the models of Γ and the models of Φ).

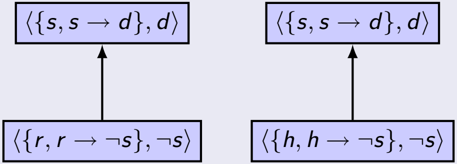
In general, arguments you want accepted should be arguments with which your audience emphise.

[See Besnard and Hunter (2008)]

Pragmatics in argumentation

Example of analysing empathy and antipathy

- s = "Cut spending in all government departments"
- d = "Reduce government deficit"
- r = "Need to invest in road and rail infrastructure"
- h = "Need to build more hospitals"



If the audience believes $\{r, \neg h\}$, then they will have an empathy for the left undercut and antipathy for the right undercut.

Argumentation technology in applications

Some technologies being developed

- Dialectical engines for identifying extensions for argument graphs
- Logical engines for generating arguments and counterarguments
- Argument interchanges formats using XML
- Use of text analysis software for identifying arguments in free text

Some domains being investigated

- Law
- eGovernment
- Medicine
- Project planning
- Engineering design
- Semantic web

Conclusions

- Argumentation is an important cognitive process for dealing with incomplete and inconsistent information.
- Computational models of argument provide a range of insights into argumentation.
  - Abstract argumentation captures the dialectical nature of argumentation.
  - Logical argumentation captures the internal structure of arguments and attacks.
  - Dialogical argumentation captures protocols and strategies for multiple agents to argue together.
- Argumentation technology offers promising solutions for a range of applications.
- Many interesting and important research questions remain.

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