Introduction to Computational Argumentation

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Overview

1. What is argumentation?
2. Key dimensions of computational argumentation
   - Abstract argumentation
   - Structured argumentation
   - Dialogical argumentation
3. Some current research areas
4. Some application areas
5. Conclusions

Argumentation as a cognitive process

Argumentation is a key way humans deal with conflicting information

- Argumentation involves identifying arguments and counterarguments relevant to an issue. (e.g. What are the pros and cons for the safety of mobile phones for children?)
- Argumentation involves weighing, comparing, or evaluating arguments. (e.g. What sense can we make of the arguments concerning mobile phones for children?)
- Argumentation may involve making decisions. (e.g. A parent answering the question "Are mobile phones safe for my children?").

Argumentation as a cognitive process

Arguments are normally based on imperfect information

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.

Argumentation as a cognitive process

Argumentation may involve convincing an audience

Argumentation as a cognitive process

Discussions where agents collaborate to understand a topic.

Negotiations where agents try to find an agreed solution.

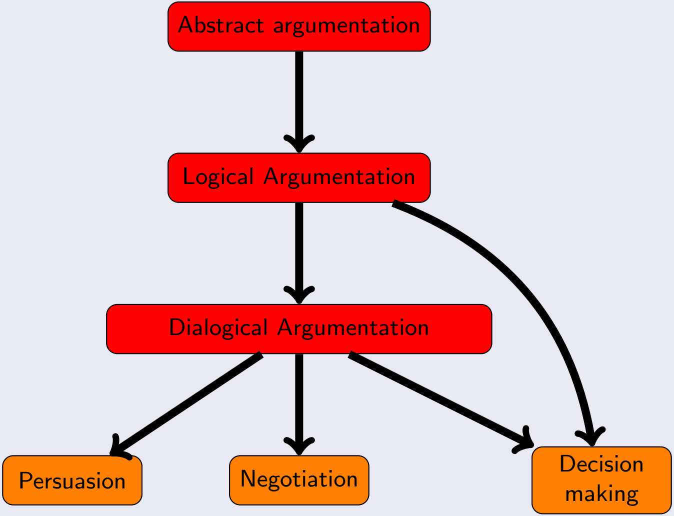
Debates where agents try to persuade each other.

Court cases where advocates try to defeat the opposition case.

Argumentation may involve exchanges of arguments in a dialogue

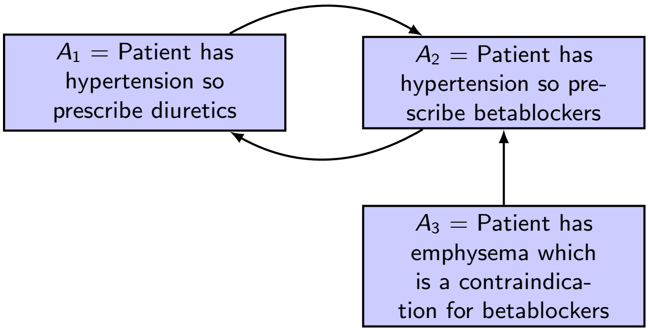
Overview of the talk

Levels of complexity in computational models



Abstract argumentation: Graphical representation

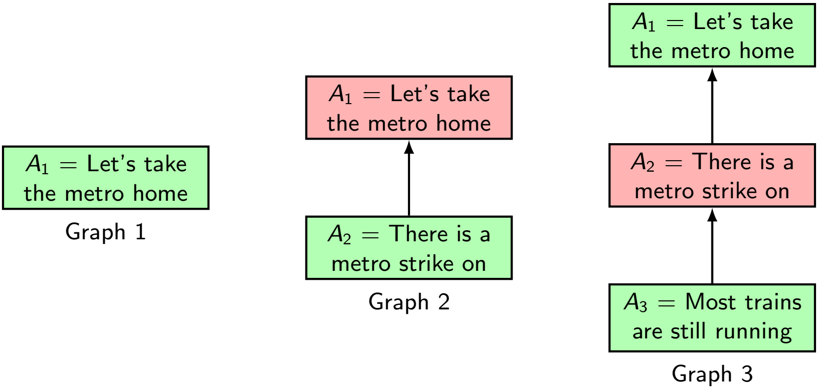
Graphical representations of argumentation have a long history (see for example Wigmore, Toulmin, etc.)



[See Dung (AIJ 1995)]

Abstract argumentation: Winning arguments

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



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

Abstract argumentation: Extensions

Types of extension for a set of arguments

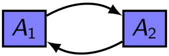
Admissible iff it is conflictfree and defends all its members

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

[See Dung (AIJ 1995)]

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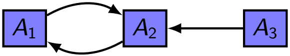

	admissible	complete	grounded	preferred	stable
$\{\}$	✓				
$\{A_1\}$	✓				
$\{A_3\}$	✓				
$\{A_1, A_3\}$	✓	✓	✓	✓	✓

[See Dung (AIJ 1995)]

Abstract argumentation: Extensions

Types of extension for a set of arguments

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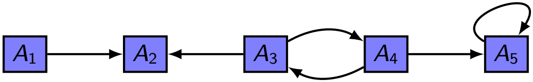


	admissible	complete	grounded	preferred	stable
$\{A_1\}$	✓	✓	✓		
$\{A_1, A_3\}$	✓	✓		✓	
$\{A_1, A_4\}$	✓	✓		✓	✓

[See Dung (AIJ 1995)]

Abstract argumentation: Probabilistic approaches

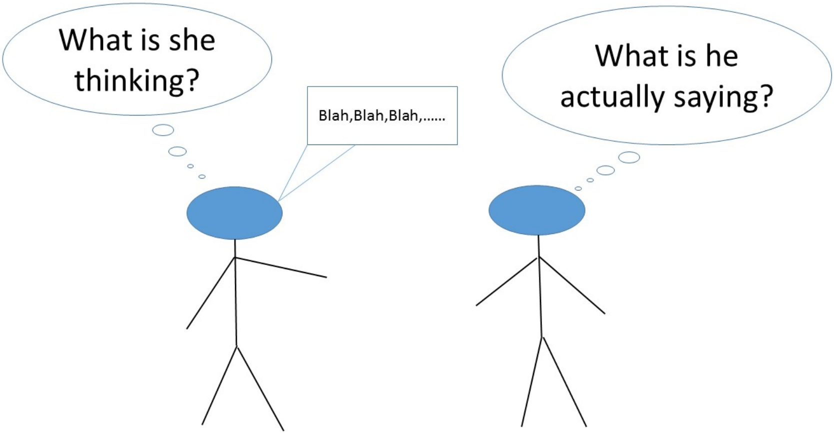
Strength of an argument

- 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** [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

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

Abstract argumentation: Constellations approach

Example

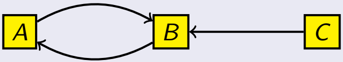
	Subgraph	Probability
G_1	$A \leftrightarrow B$	0.09
G_2	A	0.81
G_3	B	0.01
G_4		0.09

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

[Li, Oren and Norman 2011]

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	$A \quad\quad C$	0.25	$\{A, C\}$
G_3	$A \leftrightarrow B$	0.25	$\{\}$
G_4	A	0.25	$\{A\}$

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

[Hunter 2012, Rienstra 2012]

Abstract argumentation: Epistemic approach

Epistemic approach for handling uncertainty in the belief in the arguments

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

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

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,

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

Abstract argumentation: Epistemic approach

Epistemic approach for handling uncertainty in the belief in the arguments

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

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

The belief in an argument α is

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

Example

Consider

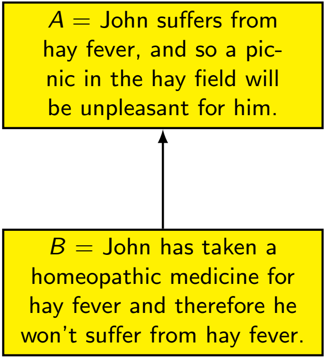
$$P(\{A, B\}) = 0.6 \quad P(\{A\}) = 0.3 \quad P(\{B\}) = 0 \quad P(\{\}) = 0.1$$

Hence,

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

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

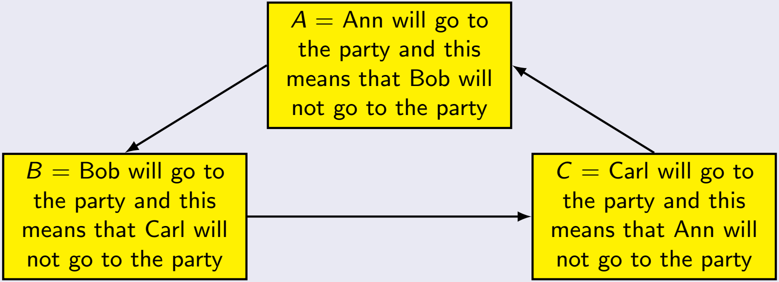
Definition

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 $\{A\}$.

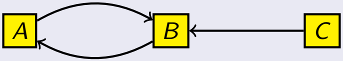


Abstract argumentation: Epistemic approach

Definition

A probability function 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



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

Abstract argumentation: Conclusions

Pros

- Abstract argumentation has formalized the notion of dialectics that is important in argumentation (see Dung AIJ 1995).
- 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).

Pros

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

$$\langle \{\alpha\}, \alpha \rangle \qquad \langle \{\alpha, \alpha \rightarrow \beta\}, \beta \rangle$$
$$\langle \{\alpha, \alpha \rightarrow \beta, \beta \rightarrow \gamma\}, \gamma \rangle \qquad \langle \{\alpha \rightarrow \beta\}, \alpha \rightarrow \beta \rangle$$
$$\langle \{\alpha \rightarrow \beta\}, \neg\alpha \vee \beta \rangle \qquad \langle \{\}, \neg\alpha \vee \alpha \rangle$$

[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 $\alpha \vdash \neg \bigwedge \Psi$

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

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

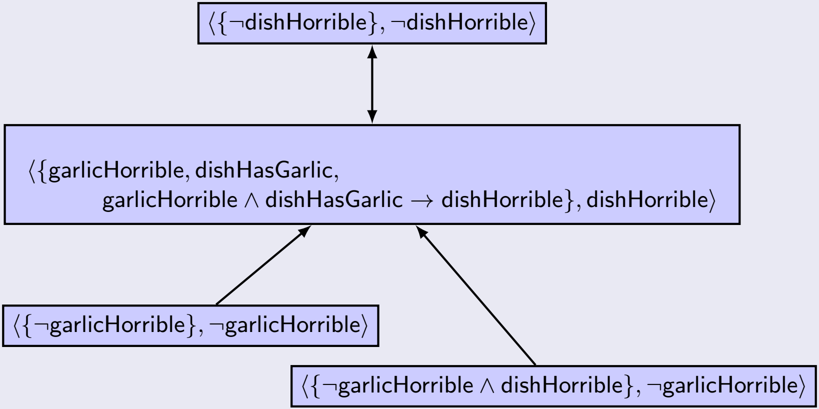
$\langle \{\gamma, \gamma \rightarrow \neg \beta\}, \neg(\beta \wedge (\beta \rightarrow \alpha)) \rangle$ undercuts $\langle \{\beta, \beta \rightarrow \alpha\}, \alpha \rangle$

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

Logical argumentation: Attacks by counterarguments

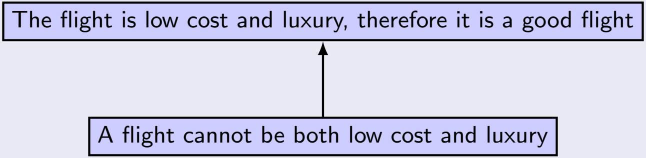
A rebut denotes a disagreement with the claim, whereas an undercut denotes a disagreement with the support (i.e. a the explanation or justification).

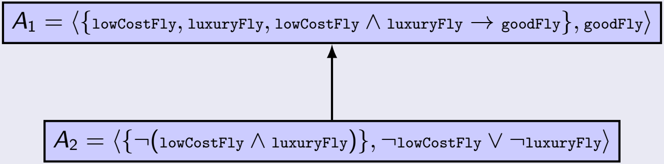
Example



Logical argumentation: Argument graphs

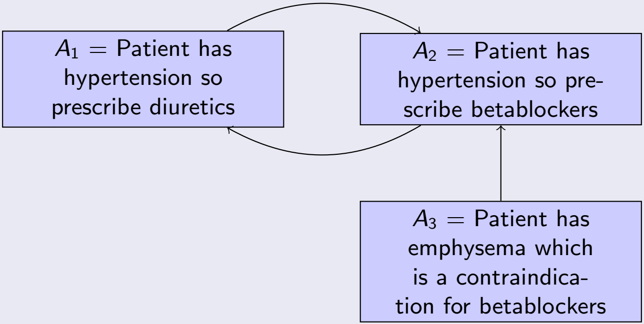
Example of abstract graph and descriptive graph





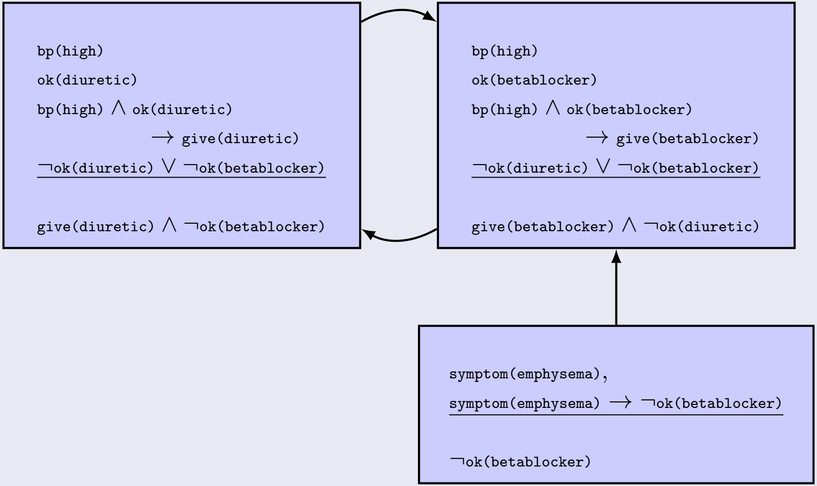
Logical argumentation: Argument graphs

Example of abstract graph



Logical argumentation: Argument graphs

Example of descriptive graph using classical logic with integrity constraint



Logical argumentation: Need for meta-level information

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

Examples of meta-level information

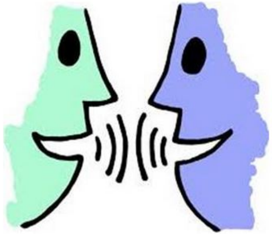
- Preferences over formulae to give a preference over arguments [e.g. Amgoud and Cayrol 2002].
  - Preference for premises that are based on more reliable sources
  - Preference for claims that meet more important goals
- Probability theory to quantify uncertainty of each argument (e.g. probability that premises are true, or probability that the argument comes from a reliable source, etc) [e.g. Hunter IJAR 2013].
- 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).

Logical argumentation

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-monotonitc 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)
- A variety of application areas are being developed (e.g. law, medicine, egovernment, engineering design, & semantic web).

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. $\mathtt{why}(\phi)$, $\mathtt{claim}(\psi)$, $\mathtt{posit}(A)$, 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).

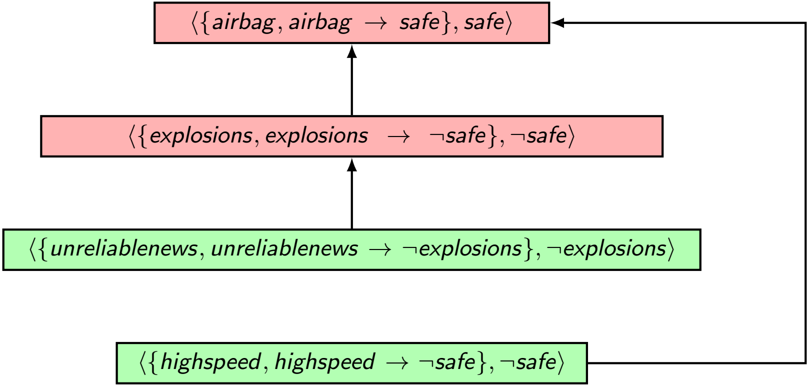
[See Hamblin (Theoria 1971); MacKenzie (JPL 1979)]

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

Current situation

Most research to date has focused on simple strategies such as being exhaustive in presenting arguments and/or being co-operative in presenting knowledge that may be useful to the other agents

New research directions

Now interest is turning to more sophisticated strategies which allow an agent to choose which moves to make in order to optimize its outcome from the dialogue.

- From 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.

[See for example Black & Hunter JAAMAS 2009; Fan & Toni ECAI 2012; Fan & Toni COMMA 2012; Rienstra et al IJCAI 2013; Hadjinikolis IJCAI 2013; Hadoux et al IJCAI 2015; Hadoux & Hunter AAAI 2017; etc.]

Dialogical argumentation: Strategies for persuasion

Example where initial argument is not believed by other person

- Him "The car is a nice red colour, and that is the only criterion to consider, therefore we should buy it."
- Her "It is a nice red colour, but I don't agree that that is the only criterion to consider."

[See Hunter & Thimm Int J. Approx. Reasoning 2017]

Dialogical argumentation: Strategies for persuasion

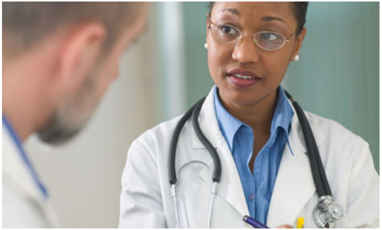
Example where initial argument is believed by other person

- Him "The car is the most economical and easy car to drive out of the options available to us, and those are the criteria we want to satisfy, so we should buy the car."

Dialogical argumentation: Strategies for persuasion

Some criteria for the persuadee being convinced by a persuasion argument

- Acceptability of persuasion argument (against counterarguments)
- Believing the premises of the persuasion argument
- Fit of persuasion argument with agenda, goals, preferences, etc
- Quality of arguments (balanced, depth, breadth, understandable, etc)
- Quality of proponent (authority, expert, attractive, witty, celebrity, etc)



[See Hunter Argument & Computation 2018]

Computational argumentation

Some research lines

- Dialectical semantics: Criteria for identifying acceptable arguments.
- Probabilistic argumentation: Enhancing models with probabilistic information (e.g. belief in arguments, awareness of arguments, etc).
- Strategic argumentation: Using information about other participant(s) to make strategic choices of move.
- Argument mining: Identifying arguments (premises and claims) in text.
- Argument analytics: Measuring features of sets of arguments (e.g. degree of inconsistency).
- Argument dynamics: How to minimally change a set of arguments in order to make specified arguments acceptable.
- Argument solvers: Software for determining acceptable arguments in an argument graph.
- Automated reasoning for structured argumentation: Software for constructing arguments and counterarguments from logical knowledgebases.

Computational argumentation: Applications

Applications in sense-making & decision-support

- Law
- Healthcare
- Intelligence analysis
- Egovernment
- Debate technologies

A review of research into applications

K Atkinson, P Baroni, M Giacomin, A Hunter, H Prakken, C Reed, G Simari, M Thimm, and S Villata (2017) Towards Artificial Argumentation, *AI Magazine*, 38(3):25-36.

Computational argumentation: Applications

Some examples of applications of argumentation in healthcare

- Computer decision support for GP prescribing (by John Fox et al.)
- Computer decision support for breast multi-disciplinary meetings (by Vivek Patkar, Dionisio Acosta, John Fox, et al.)
- Aggregating evidence about the positive and negative effects of treatments (by Anthony Hunter and Matthew Williams)
- Identifying clinical trials relevant for a specific patient (by Francesca Toni and Matthew Williams)
- Supporting patient decision making using arguments mined from patient reviews of treatments (by Anthony Hunter, Astrid Mayer and Kawsar Noor)

Towards natural intelligent interactions

- Arguments and counterarguments are an important feature of intelligent interactions.
- Computational models of argument can be part of the solution for developing intelligent interactions
  - In the short term, argumentation through structured interactions (e.g. clinical decision support systems, web systems for consultations in eGovernment, etc)
  - In the longer term, argumentation will need to be integrated with natural language processing, intelligent user models, etc, to develop systems with truly intelligent interactions.

Towards natural intelligent interactions

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.

Towards robust autonomous systems

- Heterogeneous robots need to work together to survey a situation.
- Exchanging low level information wastes time and bandwidth, and may not be possible if not designed to do so.
- Exchanging high level information (e.g. knowledge-level sensor fusion) means that the robots will need to deal with incomplete and inconsistent information.
- Working together via argumentation means high level information can be exchanged.
- So argumentation offers basis for "plus and play" interactions between intelligent robots.

Computational argumentation

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.
- A range of applications is being developed.
- Many issues remain to be addressed to fully capture human argumentative abilities.