Logic-based Argumentation Systems: An overview

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Use of Arguments

- Humans use argumentation in their daily life in order to evaluate information when trying to make some decision
  - Which film should I watch tonight?
  - What are the pros and cons of becoming an architect when I grow up?
- Or in order to present information and support an opinion
  - You should watch *'The Artist'* because it won the best picture award
  - If you become an architect you will have a creative job

Argumentation as a cognitive process

Argument definition

- *'A reason or set of reasons given in support of an idea, action or theory'* [a]

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[a] The Oxford Dictionary of English
[b] Internet Encyclopaedia of Philosophy `http://www.iep.utm.edu`

Argumentation as a cognitive process

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Argumentation as a cognitive process

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- *'The statement a person makes in the attempt to convince someone of something, or present reasons for accepting a given conclusion'* [b]

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Argumentation as a cognitive process

Use of arguments

- *'A reason or set of reasons given in support of an idea, action or theory'*
  - Evaluate information for decision support

Argumentation as a cognitive process

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Argumentation as a cognitive process

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  - Evaluate information for decision support
- *'An exchange of diverging or opposite views'*
  - Debate
- *'The statement a person makes in the attempt to convince someone of something, or present reasons for accepting a given conclusion'*
  - Persuasion

Argumentation as a cognitive process

Types of Argumentation

- **Monological argumentation** for individual analysis or presentation of information e.g. a political speech before the elections
- **Dialogical argumentation** for exchange of information between agents e.g. a debate between the leaders of two political parties before the elections

Argumentation as a cognitive process

Use of arguments

- Typically we start with an argument that supports a case of interest, then counter arguments to this argument are presented, counter-counter arguments and so on
- We can analyze series of arguments and counter arguments in order to draw conclusions
- Some arguments are refutable while some other are winning

Argumentation as a cognitive process

Example

- Is the use of CCTV for surveillance good for the citizens?

Argumentation as a cognitive process

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Example

- Is the use of CCTV for surveillance good for the citizens?
  - CCTV surveillance provides security and security is good for the citizens, therefore CCTV surveillance is good for the citizens
  - CCTV surveillance invades privacy and privacy invasion is not good for the citizens therefore CCTV surveillance is not good for the citizens
  - Security is more vital than privacy therefore CCTV surveillance is good for the citizens
  - ...

Motivation for automating argumentation

Why would we need to automate argumentation?

- It simulates human reasoning when dealing with conflicting information
- It provides a way of handling uncertainty
- Useful for decision support systems

Computational argumentation

Modelling Argumentation

- Define structures that represent arguments
- Formalize counter argument relations between arguments
- Define formal criteria for comparing arguments and identify which are the winning ones
- Automate all the above

Modelling Argumentation

- Various formalisations exist for modelling argumentation.
- Based on different theories (e.g. classical logic/graphs based approaches)
- They vary in terms of expressivity, the way they define attack relations and evaluation criteria

Abstract argumentation

Abstract argumentation is a simple, yet illustrative way for formalising the mechanism of argumentation. [1]

[1] P. Dung. On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming, and n-person games. *Artificial Intelligence*, 77:321–357, 1995.

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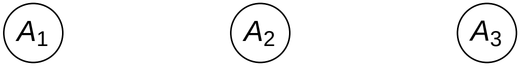
- Arguments are depicted as nodes in a directed graph $(\mathcal{A}, \rightarrow)$



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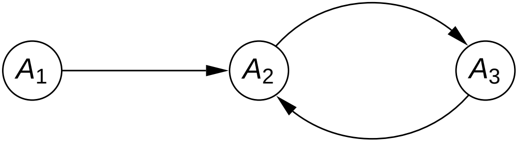
- Arcs linking pairs of nodes denote the attack relation between the nodes of the pair



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Evaluation of information

- Apart from the binary attack relation between pairs of nodes in $(\mathcal{A}, \rightarrow)$, further relations are defined according to the interrelated attacks in the graph
- More composite notions provide the means for analysing the overall information depicted in the graph

Abstract argumentation

- For instance, a set of arguments $S \subseteq \mathcal{A}$ is said to **defend** an argument $B \in \mathcal{A}$ iff for each argument $B' \in \mathcal{A}$, if B' attacks B then each of the elements of S attacks B'.

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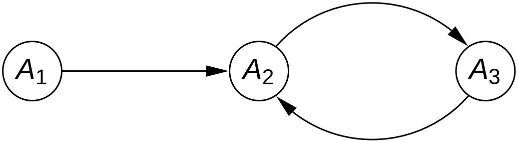
- e.g. $\{A_1, A_3\}$ defends A_3 [2]



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Abstract argumentation

Summary

- A simple structual way for representing binary attack relations in a given set of arguments
- Further definitions for an overall evaluation of a situation
- No method for deducing individual arguments from some knowledgebase
- Limited expressivity

Abstract argumentation

Implementation

A java-based implementation of Abstract argumentation [a] can be found at `http://www.argkit.org`

[a] M. South, G. Vreeswijk, and J. Fox. Dungine: a java dung reasoner. In *Proceeding of the 2008 conference on Computational Models of Argument*, pages 360–368, Amsterdam, The Netherlands, The Netherlands, 2008. IOS Press.

Assumption-based argumentation

Overview

Assumption-based argumentation [a] [b] is a more expressive formalism for modelling argumentation.

- An instantiation of Abstract argumentation
- It is based on logic and incorporates deduction
- Allows generating arguments from assumptions (facts) and rules

[a] A. Bondarenko, P. M. Dung, R. A. Kowalski, and F. Toni. An abstract, argumentation-theoretic approach to default reasoning. *Artificial Intelligence*, 93(1-2):63 – 101, 1997.

[b] P. M. Dung, R. Kowalski, and F. Toni. Dialectical proof procedures for assumption-based admissible argumentation. *Artificial Intelligence*, 170:114–159, 2006.

Assumption-based argumentation

Definition (Assumption-based argumentation framework)

An assumption-based argumentation (ABA) framework is a tuple $\langle L, R, A, \overline{\bullet} \rangle$ such that

- R is a set of rules of the form $s_1 \leftarrow s_2, ..., s_n$ each s_i is a sentence
- $A \subseteq L$ is a set of assumptions (i.e. literals assumed to hold)
- An assumption cannot be the head of any rule
- $\overline{a}$ is the contrary of assumption a

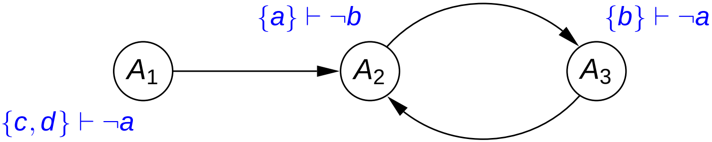
Assumption-based argumentation

Definition (Argument in an ABA framework)

- In an Assumption-based argumentation framework, an argument is a deduction supported by a set of assumptions and obtained along with the rules available.
- An argument B attacks another argument B' if the conclusion of B is the contrary of one of the assumptions supporting B'.

Assumption-based argumentation

- $L = \{a, \neg a, b, \neg b, c, \neg c, d, \neg d\}$
- $R = \{(\neg a \leftarrow c, d), (\neg b \leftarrow a), (\neg a \leftarrow b)\}$
- $A = \{a, b, c, d\}$



‘ An argument B attacks another argument B′ if the conclusion of B is the contrary of one of the assumptions supporting B′. ’

Assumption-based argumentation

Summary

- A logic-based formalisation for argumentation
- Provides methods for constructing arguments for a given knowledge by deductive inference
- More detailed and expressive knowledge representation
- Still, restricted language syntax and proof theory compared to classical logic

Assumption-based argumentation

Implementation

A Prolog-based implementation of Assumption-based argumentation exists [a] `http://www.doc.ic.ac.uk/~dg00/casapi.html`

[a] D. Gaertner and F. Toni. Casapi: a system for credulous and sceptical argumentation. In *Proc. Workshop on Argumentation for Non-monotonic Reasoning. (2007)*, pages 80–95, 2007.

Argumentation based on defeasible logic

Overview

Defeasible logic [a] incorporates two kinds of rules

- **defeasible rules:** they represent weak information (notation: $\prec$)
- **strict rules:** they represent sound information (notation: $\leftarrow$)

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$$\mathit{flies}(x) \prec \mathit{bird}(x)$$

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$$flies(x) \prec bird(x)\;, bird(tweety)$$

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but tweety is a penguin ...

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$$flies(x) \prec bird(x)\ , bird(tweety) \qquad flies(tweety)$$

but tweety is a penguin ...

$$bird(x) \leftarrow penguin(x)$$
$$\sim flies(x) \leftarrow penguin(x)$$

The statement $flies(tweety)$ cannot be used further as an assumption because it is inconsistent with this definite piece of information (*'Defeasibility'*)

[a] D. Nute. *Defeasible logics*, volume 3: Nonmonotonic Reasoning and Uncertainty Reasoning. Oxford University Press, 1994

Argumentation based on Defeasible logic

Definition (Defeasible logic Program (DeLP))

- A Defeasible Logic Program [a] $\mathcal{P} = (\Pi, \Delta)$

  Π set of strict rules and facts (literals)

  Δ set of Defeasible rules.

- An Argument in a DeLP (Π, Δ) is a pair $\langle \mathcal{A}, h \rangle$ such that h is a literal and $\mathcal{A}$ is a set of defeasible rules s.t. :
  1. There exists a derivation of h from $\Pi \cup \mathcal{A}$
  2. $\Pi \cup \mathcal{A}$ is a non-contradictory set
  3. $\mathcal{A}$ is minimal: There exists no proper subset of $\mathcal{A}$ satisfying the above conditions

---

[a] A. García and G. Simari. Defeasible logic programming: An argumentative approach. *Theory and Practice of Logic Programming*, 4(1):95–138, 2004.

Argumentation based on defeasible logic

Example

$$\Pi = \left\{ \begin{array}{l} bird(x) \leftarrow chicken(x) \\ chicken(tina) \\ scared(tina) \end{array} \right\}$$

$$\Delta = \left\{ \begin{array}{l} flies(x) \prec bird(x) \\ \sim flies(x) \prec chicken(x) \\ flies(x) \prec chicken(x), scared(x) \end{array} \right\}$$

One argument for $\sim flies(tina)$:

$$\langle \{\sim flies(tina) \prec chicken(tina)\}, \sim flies(tina) \rangle$$

Two arguments for $flies(tina)$:

$$\langle \{flies(tina) \prec bird(tina)\}, flies(tina) \rangle$$
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$$\langle \{flies(tina) \prec chicken(tina), scared(tina)\}, flies(tina) \rangle$$

Argumentation based on defeasible logic

Example (Who flies and who doesn't?)

- Although we have contradictory information inferred ($flies(tina)$ and $\sim flies(tina)$) both the inferred literals are valid in the related DeLP. Both are consistent with the strict knowledge available

$$\Pi_{tina} = \left\{ \begin{array}{l} bird(x) \leftarrow chicken(x) \\ chicken(tina) \\ scared(tina) \end{array} \right\}$$

- The difference with tweety: $flies(tweety)$ contradicts the set of the related strict rules.

$$\Pi_{tweety} = \left\{ \begin{array}{c} bird(x) \leftarrow penguin(x) \\ \sim flies(x) \leftarrow penguin(x) \\ penguin(tweety) \end{array} \right\}$$

Argumentation based on defeasible logic

Since we do not withdraw the information about tina's flying or non-flying status we use other ways for evaluating the situation

Attack between arguments

- $\langle \mathcal{A}_1, h_1 \rangle$ attacks $\langle \mathcal{A}_2, h_2 \rangle$ at literal h iff there exists a sub-argument $\langle \mathcal{A}, h \rangle$ of $\langle \mathcal{A}_2, h_2 \rangle$ such that $\Pi \cup \{h, h_1\}$ is a contradictory set.

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Example

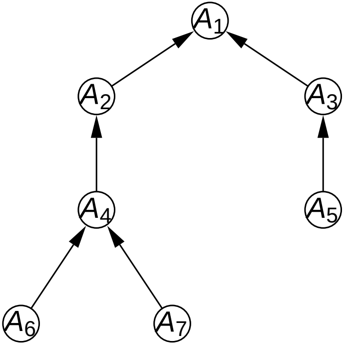
$\langle \{ \mathit{flies}(\mathit{tina}) \prec \mathit{bird}(\mathit{tina}) \}, \mathit{flies}(\mathit{tina}) \rangle$

$\langle \{ \sim \mathit{flies}(\mathit{tina}) \prec \mathit{chicken}(\mathit{tina}) \}, \sim \mathit{flies}(\mathit{tina}) \rangle$

Both arguments attack each other (in this case the sub-argument is the argument itself)

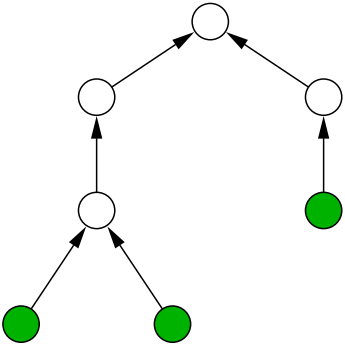
Argumentation based on defeasible logic

- In order to evaluate an argument A_1 we draw a tree with A_1 in its root, arguments that attack A_1 as its children, counter arguments to these at the next level and so on exhaustively.



Argumentation based on defeasible logic

- Leaves are marked as *'undefeated'* (no argument attacking them). Then, recursively, all the nodes that have at least one child which is marked as undeafeated are marked as *'defeated'*



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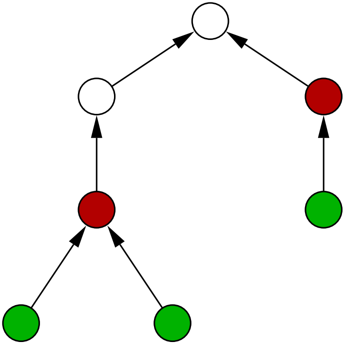

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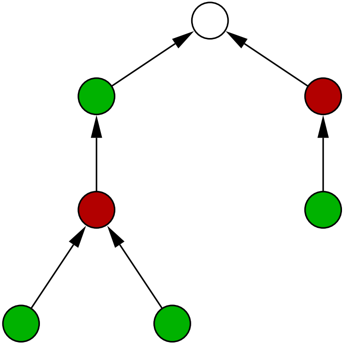

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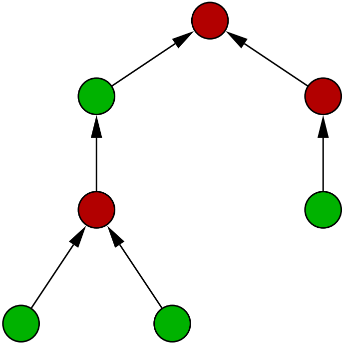

Summary

- Another logic-based approach that provides mechanisms for deducing arguments
- Defeasible rules capture the way humans tend to make inferences through observations and withdraw some conclusions in the presence of new information
- Allows for priorities on rules to be defined
- Expressivity is limited compared to classical logic approaches

Argumentation based on defeasible logic

Implementation

A Prolog-based implementation of DeLP exists [a]
`http://lidia.cs.uns.edu.ar/delp_client/index.php`

[a] A. García and G. Simari. Delp client.

Argumentation based on classical logic

Overview

- Classical logic is very expressive
- Detailed knowledge representation and inference mechanisms
- An approach introducing a sophisticated way for defining counter arguments [a] [b]

[a] Ph. Besnard and A.Hunter.Argumentation based on classical logic. *Argumentation in Artificial Intelligence*, pages 133–152, 2009

[b] Ph. Besnard and A. Hunter. A logic-based theory of deductive arguments. *Artificial Intelligence*, 128:203–235, 2001.

Argumentation based on classical logic

Definition (Argument (Classical logic argumentation))

An **argument** (for α) is a pair $\langle \Phi, \alpha \rangle$ such that Φ is a set of formulas and α is a formula in classical logic s.t.[a]

1. Φ is consistent
2. $\Phi \vdash \alpha$
3. there is no $\Phi' \subset \Phi$ such that $\Phi' \vdash \alpha$

[a] Ph. Besnard and A. Hunter. A logic-based theory of deductive arguments. *Artificial Intelligence*, 128:203–235, 2001.

Argumentation based on classical logic

Example

$finishHW(Rachel) \rightarrow party(Rachel)$

If Rachel finishes her homework she'll go to the party

$rainsOutside \rightarrow getUmbrella(Rachel)$

If it rains outside Rachel will get an umbrella

$finishHW(Rachel)$

Rachel finished her homework

Rachel has an argument for going to the party

$\langle\{finishHW(Rachel), finishHW(Rachel) \rightarrow party(Rachel)\}, party(Rachel)\rangle$

Argumentation based on classical logic

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Rachel has an argument for going to the party

$\langle\{finishHW(Rachel), finishHW(Rachel) \rightarrow party(Rachel)\}, party(Rachel)\rangle$

Whether she'll get an umbrella or not is not of our interest - not included in our syllogism (minimality)

Argumentation based on classical logic

Comparing arguments

- Some arguments are more general while others are more specific
- Some arguments may encompass others.
- A **more conservative argument** is more general: it is less demanding on the support and less specific about the consequent

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- A **more conservative argument** is more general: it is less demanding on the support and less specific about the consequent

Definition

An argument $\langle \Phi, \alpha \rangle$ is **more conservative** than an argument $\langle \Psi, \beta \rangle$ iff $\Phi \subseteq \Psi$ and $\beta \vdash \alpha$.

Argumentation based on classical logic

Example

Consider the following knowledge about who is going to the party. [a]

- $party(Rachel)$ *Rachel goes to the party*
- $party(Rachel) \rightarrow \neg party(Paul) \wedge \neg party(Quincy)$
  If Rachel goes to the party, neither Paul nor Quincy go

[a] Ph. Besnard and A.Hunter.Argumentation based on classical logic. *Argumentation in Artificial Intelligence*, pages 133–152, 2009

Argumentation based on classical logic

Example

The following are arguments from the given knowledge

$\langle\{party(Rachel), party(Rachel) \rightarrow \neg party(Paul) \wedge \neg party(Quincy)\}, \neg party(Paul)\rangle$

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Example

The following are arguments from the given knowledge

$$\langle\{party(Rachel), party(Rachel) \rightarrow \neg party(Paul) \wedge \neg party(Quincy)\}, \neg party(Paul)\rangle$$

$$\langle\{party(Rachel), party(Rachel) \rightarrow \neg party(Paul) \wedge \neg party(Quincy)\}, \neg party(Quincy)\rangle$$

This is a more conservative argument, encompassed in both

$$\langle\{party(Rachel), party(Rachel) \rightarrow \neg party(Paul) \wedge \neg party(Quincy)\}, \neg(party(Paul) \wedge party(Quincy))\rangle$$

Example

So if we are told that the following hold:

$$party(Paul)$$
$$party(Quincy)$$

which support the argument that both Paul and Quincy are going:

$\langle \{party(Paul), party(Quincy)\}, party(Paul) \wedge party(Quincy) \rangle$

Argumentation based on classical logic

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1st counter argument:

$\langle\{party(Rachel), party(Rachel) \rightarrow \neg party(Paul) \wedge \neg party(Quincy)\}, \neg party(Paul)\rangle$

Argumentation based on classical logic

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1st counter argument:

$\langle\{party(Rachel), party(Rachel) \rightarrow \neg party(Paul) \wedge \neg party(Quincy)\}, \neg party(Paul)\rangle$

2nd counter argument:

$\langle\{party(Rachel), party(Rachel) \rightarrow \neg party(Paul) \wedge \neg party(Quincy)\}, \neg party(Quincy)\rangle$

Argumentation based on classical logic

Example

So if we are told that the following hold:

$$party(Paul)$$
$$party(Quincy)$$

which support the argument that both Paul and Quincy are going:

$\langle\{party(Paul), party(Quincy)\}, party(Paul) \wedge party(Quincy)\rangle$

1st counter argument:

$\langle\{party(Rachel), party(Rachel) \rightarrow \neg party(Paul) \wedge \neg party(Quincy)\}, \neg party(Paul)\rangle$

2nd counter argument:

$\langle\{party(Rachel), party(Rachel) \rightarrow \neg party(Paul) \wedge \neg party(Quincy)\}, \neg party(Quincy)\rangle$

3rd counter argument:

$\langle\{party(Rachel), party(Rachel) \rightarrow \neg party(Paul) \wedge \neg party(Quincy)\},$
$\neg(party(Paul) \wedge party(Quincy))\rangle$

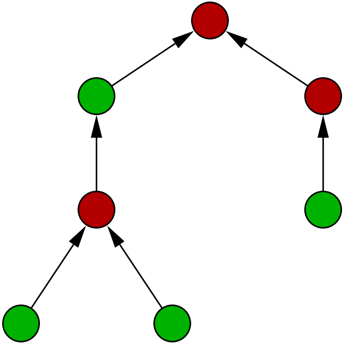
Argumentation based on classical logic

Argument trees

- We use the 'most conservative' counter arguments
- Counter arguments of this kind attack the set of assumptions of another argument altogether and not just one of its assumptions
  - $\langle \Psi, \alpha \rangle$ is a counter argument for $\langle \Phi, \beta \rangle$ when $\langle \Psi, \neg \bigwedge \Phi \rangle$ holds
- We draw trees with series of counter arguments

Argumentation based on classical logic

We mark nodes as *'undefeated'* or *'defeated'* recursively like in DeLP (but our nodes here are classical-logic 'conservative' arguments!)



Argumentation based on classical logic

Summary

- Powerful language, simple and intuitive syntax and semantics
- Well established proof theory and extensive foundational results
- Concise representation of the most meaningful counter arguments
- Propositional and First-Order logic (hence also fragments of FO logic, Modal logic, Description logics . . .)
- Expressivity vs complexity

Argumentation based on classical logic

Implementation

A java-based implementation of argumentation based on classical propositional logic exists [a]

http://www.ing.unibs.it/comma2010/demos/Efstathiou_etal.pdf

[a] V. Efstathiou and A.Hunter. JArgue: An implemented argumentation system for classical propositional logic, COMMA 2010

Applications and Research topics

- e-democracy [3]
- Medical decision support [4] [5]
- Idea visualisation and sharing [6] [7]
- Argument diagramming [8]
- Multiagent negotiation [9]
- Semantic Web [10]
- Legal reasoning [11]

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[3] http://www.csc.liv.ac.uk/~parmenides/

[4] N.Gorogiannis, A.Hunter and M.Williams. An argument-based approach to reasoning with clinical knowledge. *International Journal of Approximate Reasoning*: 51(1):1-22, 2009

[5] J. Fox, V. Patkar and R. Thomson. Decision support for health care: the PROforma evidence base. *Informatics in Primary Care*, 14 : 49Ű54, 2006

[6] http://debategraph.org

[7] http://cohere.open.ac.uk/

[8] http://araucaria.computing.dundee.ac.uk/doku.php

[9] http://www.argugrid.eu

[10] I. Rahwan, B. Banihashemi, C. Reed, D. Walton and S. Abdallah. Representing and classifying arguments on the Semantic Web. *The Knowledge Engineering Review*, 26 : pp 487-511, 2011

[11] H. Prakken and G. Sartor. Argument-based logic programming with defeasible priorities *Journal of Applied Non-classical Logics*, 7: 25-75, 1997)

Summary

Summary

- Argumentation is a cognitive process employed by humans when trying to make decisions; especially when dealing with conflicting information
- Computational argumentation can be used by decision support systems; particularly useful for conflict resolution
- Various frameworks have been proposed for modelling argumentation, based on different underlying logics
- Several theories extend these frameworks and a number of tools has been implemented to support the various applications of argumentation
- Still, many practical challenges to overcome

Challenges

Too much information.
We need to distinguinsh which is relevant to our case.

$cloudy(outside)$
It is cloudy outside
$finishHW(Rachel) \rightarrow party(Rachel)$
If Rachel finishes her homework she'll go to the party
$rain(outside) \rightarrow getUmbrella(Rachel)$
If it rains outside Rachel will get an umbrella
$likesIcecream(Rachel)$
Rachel likes ice cream
$sisters(Rachel, Anna)$
Rachel and Anna are sisters
$finishHW(Rachel)$
Rachel finished her homework

Challenges

Missing information. A human would argue

> *'It is cloudy outside, Rachel should get an umbrella'*

But the actual underlying reasoning is:

$$cloudy(outside)$$
$$cloudy(outside) \rightarrow rain(outside)$$
$$rain(outside) \rightarrow getUmbrella(Rachel)$$

Computability issues to overcome