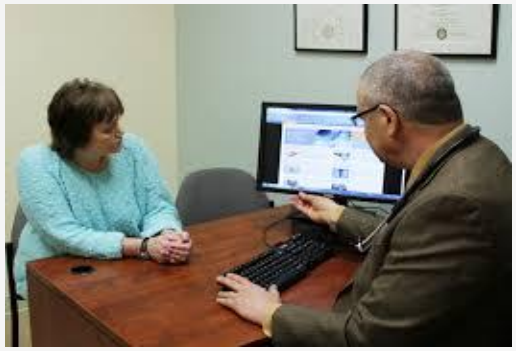
# Argumentation Technology in Medicine

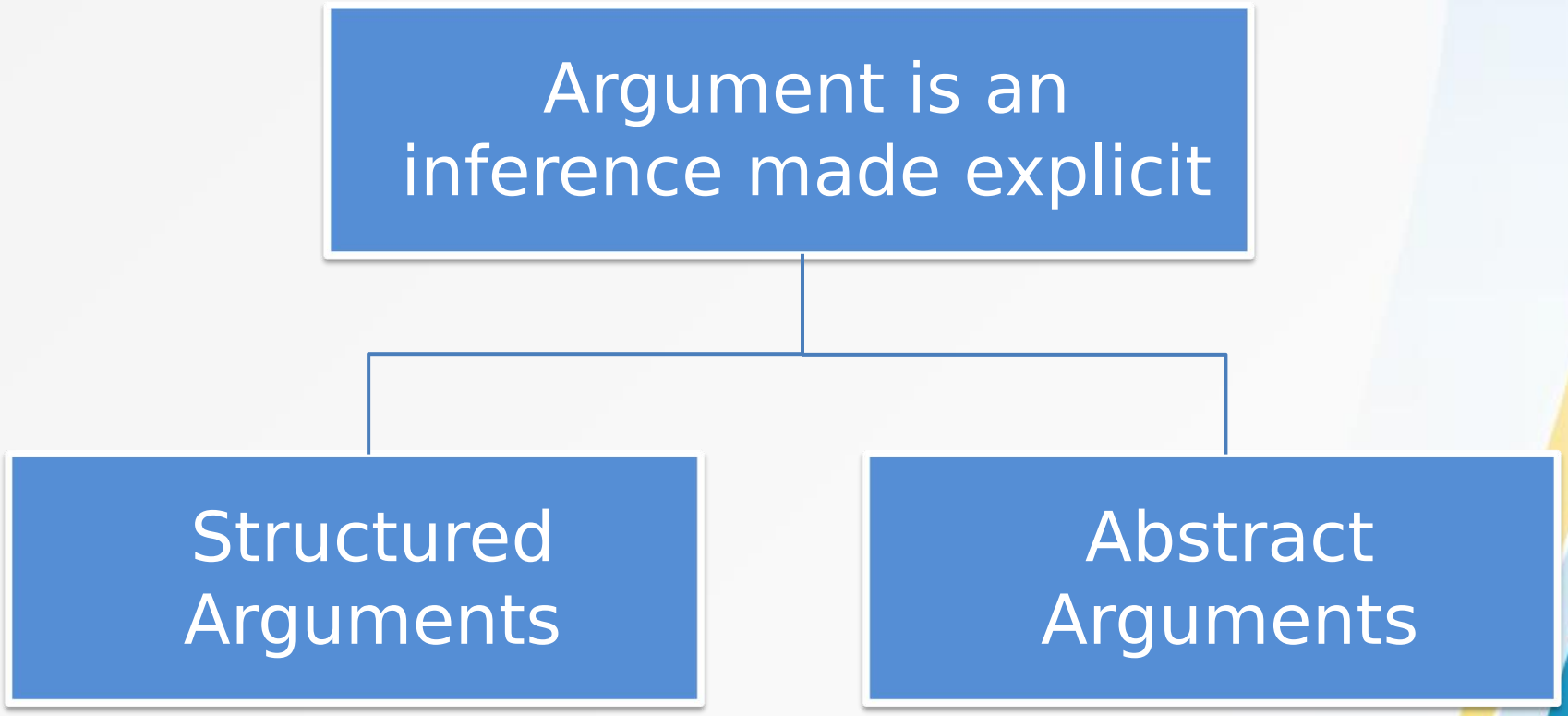


# Content

# Part I

## Introduction to argumentation

# What is an argument?



# Structured argument

It is a line of reasoning to address a specific point/problem/idea, by providing a position and the reasons/evidence that support that position.

# Parts of an argument

- One or more **premises**
- **Conclusion**

- **Premises:** try to provide the reasons/evidence why people should believe that the conclusion is true.

- **Conclusion:** is the main claim being made that follows from the premises that are suppoting it.

My Judo class was cancelled, so I can watch a movie with you tonight

Super. Great!


Premise: My Judo class was cancelled

Conclusion: I can watch a movie with you tonight

Should we watch the Lego movie?

This is not a good argument!

No please. Let's not watch that movie!

It is too long

I do not like long films

Besides, long movies are not good

# Structured argument

Prompt: “*Should plastic water bottles be banned?*”

| Argument 1 | Argument 2 |
| --- | --- |
| Water bottles can easily be made into long term fiber materials, like clothing or carpet. It is easy to just fill cup with water and re use it. | The growth in bottled water production has increased water extraction in areas near bottling plants, leading to water shortages that affect nearby consumers and farmers. In addition to the millions of gallons of water used in the plastic-making process, two gallons of water are wasted in the purification process for every gallon that goes into the bottles. |

Wachsmuth et al., 2017

idebate idea
international debate education association

NEWS | DEBATABASE | EVENTS | COMMUNITY | MEDIA

# This House believes university education should be free

## POINTS FOR

## POINTS AGAINST

### Individuals have a right to the experience of higher education

**POINT**

University offers personal, intellectual, and often spiritual, exploration. In secondary school and in professional life, no such opportunities exist as they are about instruction and following orders, not about questioning norms and conventions in the same way university so often is.[1] A life without the critical thinking skills provided by university will be less useful to society, as citizens will be unable to engage with political debate effectively – citizens need to be critical of what politicians tell them. The state has a responsibility to provide citizens with the skillset to take partake in the democratic process.[2] Free universities benefit both the citizen, as an exploration for his/her own development, and to society, for an educated and active populace.

[1] Key Degree. 2010. "How to Reap the Benefits of College". Keydegree.com. Available: http://www.keydegree.com/articles/benefitsofcollege.html

[2] Swift, Adam. 2001. Political Philosophy: A Beginner's Guide for Students and Politicians. Cambridge: Polity.

**COUNTERPOINT**

There is no right to the university experience. University life is not used as the previous argument would suggest. University life is often about alcohol first, education second. Selfknowledge and genuine wisdom come from study and reflection. This can be done anywhere, not just in a university. There is no fundamental right of individuals to be allowed to take four years free of charge to learn new skills that will benefit them or teach them how to be better citizens. The state's duty is to provide a baseline of care, which in the case of education secondary school more than provides. If individuals want more they should pay for it themselves.

https://uk.idebate.org/debatabase/education-university/house-believes-university-education-should-be-free

# Arguments according to inference type

All humans are mortal
Socrates is human
Therefore, Socrates is mortal

Most greeks like tomatoes
Socrates is greek
Socrates likes tomatoes

If A = B
C=B
Then C=A

The proportion of the sample of G has attribute T.
Therefore:
The proportion S of the population G has attribute T.

$$\frac{P \rightarrow Q \quad P}{Q}$$

| Deductive arguments | Inductive arguments |
| --- | --- |
| • If the premises are true, then the conclusion must be true<br>• The conclusion follows necessarily from the premises<br>• The premises provide conclusive evidence for the truth of the conclusion<br>• It is impossible for the premises to be true and the conclusion false | • If the premises are true, then the conclusion is *probably* true<br>• The conclusion follows *probably* from the premises<br>• The premises provide good (but not *conclusive*) evidence for the truth of the conclusion<br>• It is unlikely for the premises to be true and the conclusion false<br>• Types: statistical syllogisms, causal inference, predictions, etc. |

# Abstract argument

"An abstract argument is not assumed to have any specific structure but, roughly speaking, an argument is anything that may attack or be attacked by another argument."

(Baroni and Giacomin, 2009)

Baroni P., Giacomin M. (2009) Semantics of Abstract Argument Systems. In: Simari G., Rahwan I. (eds) Argumentation in Artificial Intelligence. Springer, Boston, MA

# Abstract arguments

a:
Tomorrow will rain because the national weather forecast says so.

b:
Tomorrow will not rain because the regional weather forecast says so

b ⟶ a

AF = {{a,b},{(b,a)}}

# Part II

## Argumentation theory in the medical context

# Why to use argumentation in medicine?

Expected utility approaches to decision theory: "... there is essentially only one way to reach a decision sensibly:

1. the uncertainties present in the situation must be quantified in terms of values, i.e., probabilities.

2. the consequences of the courses of actions must be described in terms of utilities.

3. decision-making on the basis of the the calculated probabilities that give the greatest utility" (Lindley, 1985, p.vii).

In Fox, J. et al., 2009

# Why to use argumentation in medicine?

- Acquiring or estimating the numbers required to model decisions in the way clinicials demand may be difficult.
- Existing knowledge may not provide a sufficient basis for a calculated mathematical expectation.
- Is the exception rather than the rule to model a clinical decision in the way that Lindley recommends.

# Why to use argumentation in medicine?

- Clinicians often solve problems by reasoning, rather than by calculation: using more domain-specific knowledge:
  - E.g. a clinician can deduce diagnosis and treatment planning from detailed knowledge of disease processes and their effects.

- When knowledge is abstracted to statistical relationships, the information about the processes underlying the data is lost, and cannot be included in the decision-making.

# Argumentation Theory (AT)

- AT offers a way to understand and model human reasoning by:
  - defining argument interrelations and their dialectical reasoning processes (argumentation)
  - attempting to imitate the way humans make inferences and utilize conflicting information
- From its origins in classical philosophy, AT has evolved to become an important research field in AI.

# Overview of Argument Formalisms

| Argument formalisms | Description | Argument formalisms |
|---|---|---|
| Logic-based representations | Variants of first order logic and combination of logic programming and other types of formalisms. | • Logic of argument (LA) (Fox, J. et al. 1993)<br>• Defeasible Logic Programming (DeLP) (Garcia et al., 2004) |
| Argument structures theories | Aim to represent the inner structure of arguments and model the relation between the expressed propositions. | • Toulmin model (2003) and its adaptations like Freeman's (2008), Peldszus and Stede's models (2013) |
| Argument schemes | Represent common, stereotypical patterns of reasoning used in everyday conversational argumentation or specialised contexts. | • Perelman and and Olbrechts-Tyteca (1969)<br>• Kienpointer (1992)<br>• Walton et al. (2008)<br>• Wagemans (2016) |
| Dialog games for argumentation | Formalises the employed language and its effect on the listener. Consists on turns performed by the participants to achieve a goal and a set of rules that structure the interaction. | • Prakken (2005)<br>• Dialogue Game Description Language (DGDL) (Wells and Reed, 2012) |

# Argument Frameworks (AF)

- Graphs that capture the interaction of arguments. It can be grouped in three categories:
  - Abstract argumentation
  - Structured argumentation
  - Representational argumentation

# Argument Frameworks (AF)

| AFs | Description | Examples |
|---|---|---|
| Abstract argumentation | Arguments as abstract entities only defined by their relations. Built on the seminal work by Dung (1995). There have been several extensions of the original concept of AAF. | • Bipolar AF (BAF) (Cayrol et al., 2005)<br>• Value-based AF (VAF) (Bench-Capon, 2002)<br>• Extended AF (EAF) (Modgil, 2009)<br>• Recursive AF (RAF) (Baroni et al., 2011)<br>• AF with Sets of Attacks (SETAF) (Nielsen and Parsons, 2007) |
| Structured argumentation | The structure at the nodes describes the reasoning of an argument: the logic formulas represent the propositions and the reasoning patterns can be attached as a structure to the nodes. | • Argumentation Service Platform with Integrated Components (ASPIC) (Prakken, 2010) and ASPIC+ (Modgil, 2014)<br>• Assumption Based Argumentation (ABA) and ABA+ (Čyras, K., and Toni,2016) |
| Representational argumentation | Argument representation for storage and communication with a more informal structure. | • Argument Interchange Format (AIF) (Rahwan, 2007) and AIF+ (Reed et al., 2008)<br>• Inference Anchoring Theory (IAT) (Budzynska et al., 2016) and S-IAT (Lawrence, 2017) |

# Challenges for tools in the medical domain

- **Conflicts**: conflicting information obtained from multiple sources is common.
- **Inconsistencies**: knowledge may be inconsistent since different doctors may have different perspectives.
- **Incremental evidence:** new evidence may challenge previously accepted decisions.
- **Alternatives**: in practical medicine, all the alternatives should be evaluated.
- **Rationalisation**: knowing the reason behind the alternative conclusions for a given problem.
- **Convincingness**: physicians need to give good reasons to the patients for following a treatment.

# Application of argumentation in the medical domain

- Interest in developing tools/applications that require a reasoning mechanism over the available evidence:
  - Decision-making for prognosis (i.e. treatment planning)
  - Risk assessment (e.g. risk of disease)
  - Identification of anomalous patient responses to treatments
  - Advising patients on treatment regimes
  - Supporting the elaboration of clinical guidelines and meta-analyses

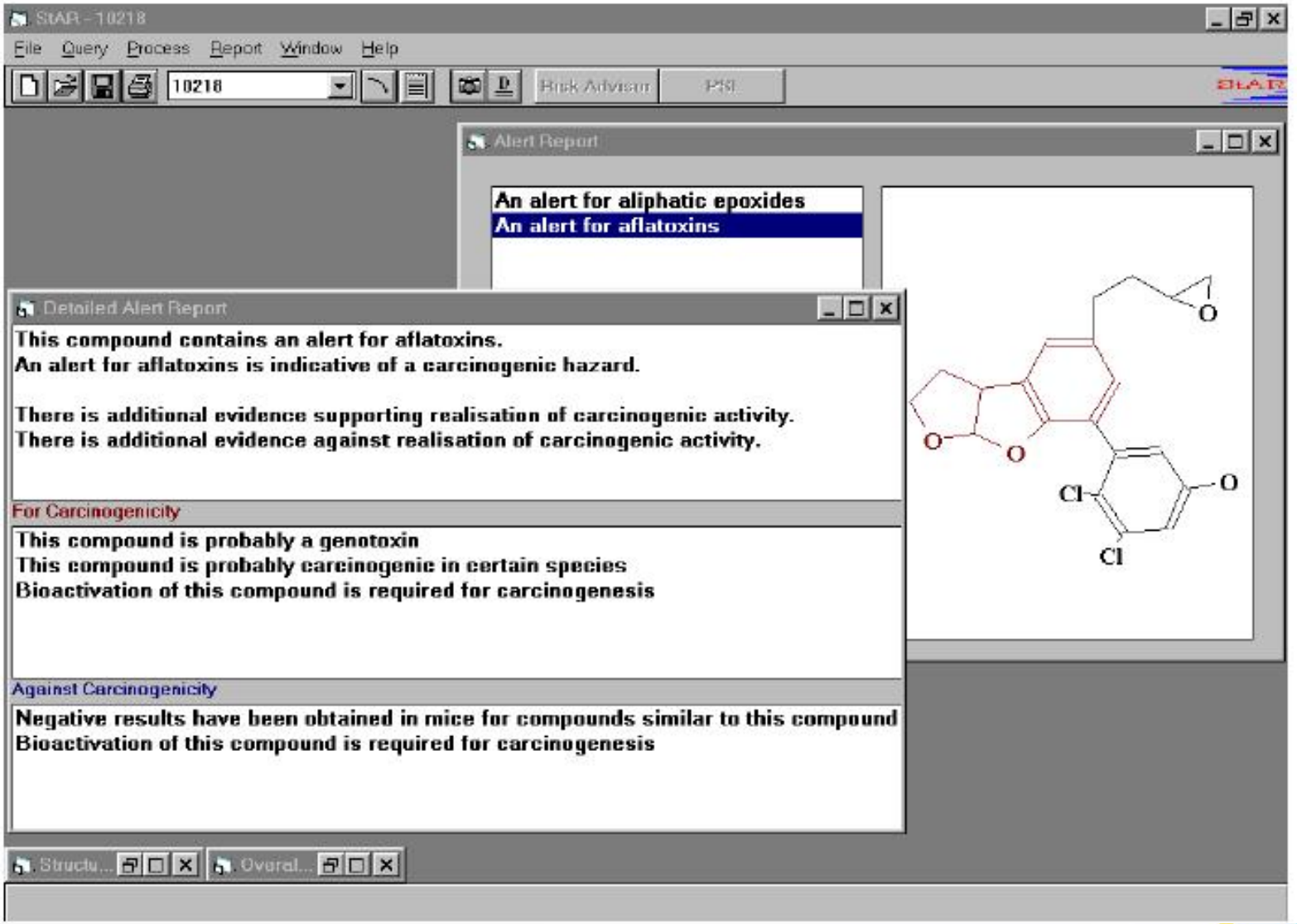
# Requirements of argumentation representations for the medical domain

- **Defeasibility:** The AR should allow defeasible reasoning.
- **Argument schemes:** imitate the way humans make inferences in the presence of missing information, and resolve conflicts. AS can challenge stable conclusions through critical questions.
- **Meta-arguments:** about the reliability of the evidence used by other arguments.
- **Dialogue:** interactions between medical practitioners and patients can be represented in a dialog framework in which convincing the patient through good arguments is the goal.

# Examples of medical tools using argumentation

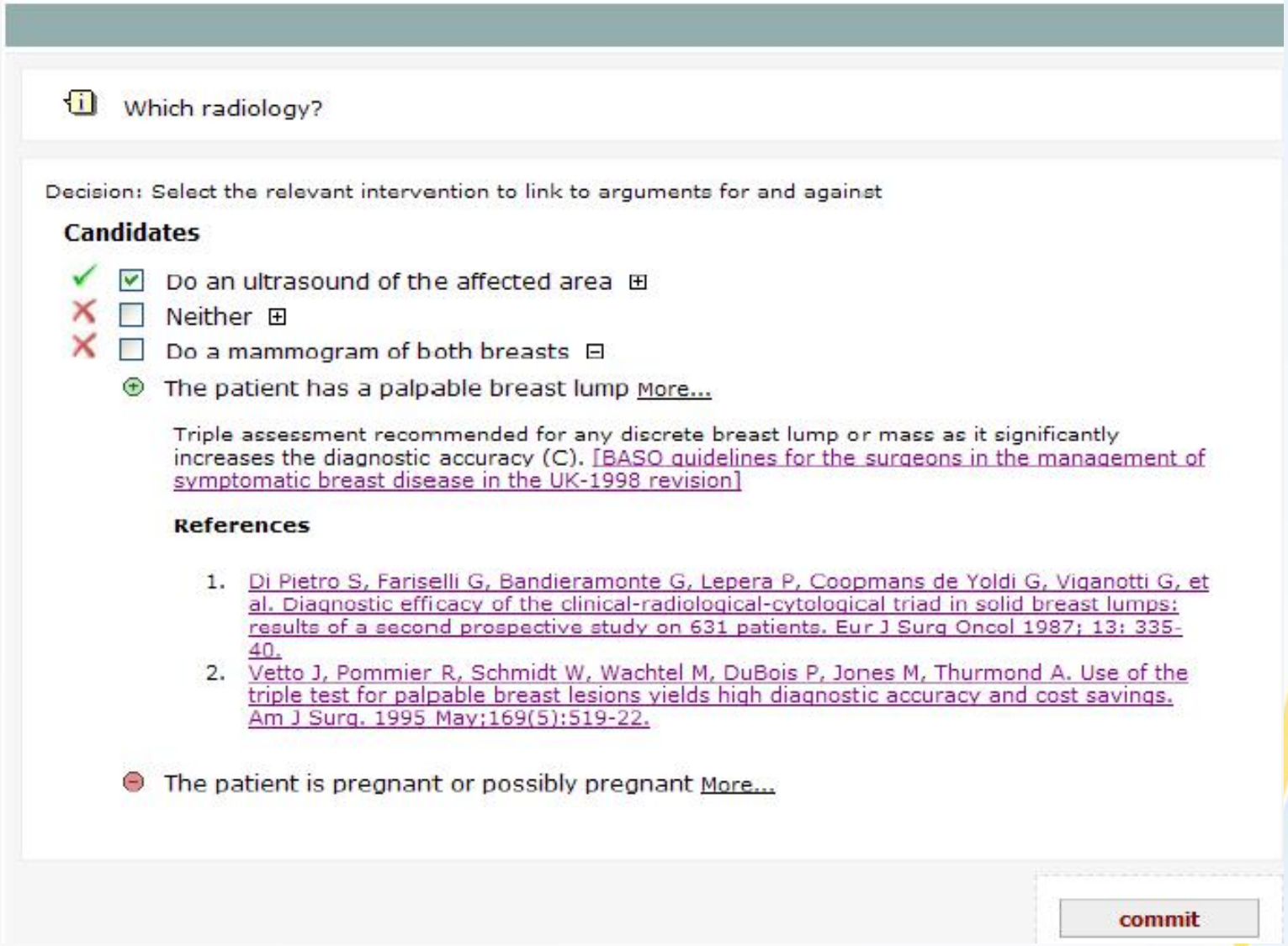
| Application | Authors | Description | AF used |
|---|---|---|---|
| Aggregation of clinical trial evidence<br><br>*http://www0.cs.ucl.ac.uk/staff/a.hunter/projects/argmed/* | Hunter and Williams, 2012 | Inductive arguments are generated from a set of evidence. Superiority of the interventions is determined according to preference criteria across the arguments. | AF based on Dung's model |
| *arguEIRA* | Grando et al., 2013 | Generation of rules derived from AS and their critical questions for explaining anomalous patient responses to treatments | Dung's model and ASPIC platform |
| *StAR*: qualitative reasoning in toxicology | Krause, Fox, and Judson, 1995 | Generation of arguments for and against the compound being carcinogenic for each toxic alert. | Logic Argumentation |
| Imaging decision-making | Patkar et al., 2006 | Weighing up pro and con arguments for each decision candidate in radiology. | Toulmin's model |

# *StAR*: Qualitative Reasoning in Toxicology




Krause et al., 1995

# The Triple Assessment application




Patkar et al. (2006)

# Summarising:

- In the medical domain the most used argumentation approaches have been:
  - Abstract AF: the evidence can be treated as arguments with unspecified internal structures related by attack relations, and allows different patterns of argumentation and conflict resolution.
  - Defeasable reasoning: a previously stablished conclusion can be defeated by additional evidence.
  - Argument Schemes: represent the inferential structure of the arguments. Strict and defeasible rules can be derived from them. These rules can be used in any Dung's formalism implementations (e.g. ASPIC, TOAST).

# Defeasible reasoning and abstract argumentation

# Non-monotonic logic

- Is a logic in which the introduction of new premises can invalidate the conclusion that followed from given premises.

$\forall x\ \text{bird}(x) \rightarrow \text{fly}(x)$
$\forall y\ \text{pinguin}(y) \rightarrow \neg\text{fly}(y)$
$\text{bird}(\textit{Tweety})$

$\models \text{fly}(\textit{Tweety})$

$\text{pinguin}(\textit{Tweety})$

$\not\models \neg\text{fly}(\textit{Tweety})$

# Defeasable models

Toulmin (1958)
*The Uses of Argument*

Pollock (1987)
*Defeasable reasoning*

Dung's (1995)
*Abstract argumentation model*

# Dung's Abstract Argumentation Framework (AAF)

- Arguments are “atomic”: without an internal structure (i.e. statements)
- Argument attacks are abstract formal relations
- Semantics: abstract handling for solving conflicts between arguments by selecting acceptable subsets of statements.

***Artificial Intelligence***

“On the acceptability of arguments and its fundamental role in non-monotonic reasoning, logic programming and n-persons games”

*by Phan Minh Dung*
*1995*

# Dung's AAF

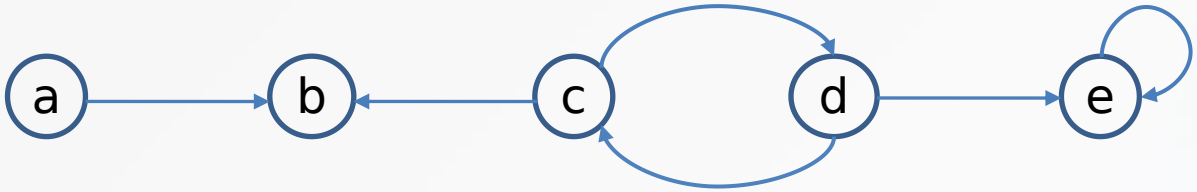
- Attack relations:
  - establish that two arguments cannot be accepted simultaneously
  - determine the role of the arguments and the semantics of the framework
- AAF is an argument attack relation in form of a directed graph in which:
  - nodes: are arguments
  - edges: are attacks to arguments

# Dung's AAF: Definition 1

***Argumentation Framework***

AF={*AR*, *Attacks*}, where:

- *AR* is a set of arguments
- *Attacks* is a binary relation on *AR*, i.e., *Attacks* ⊆ *AR* × *AR*

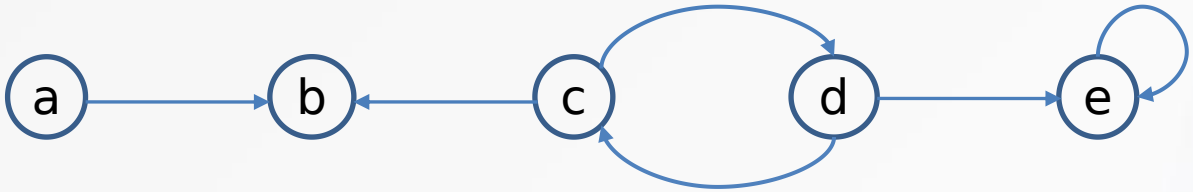



*Graph from: http://www.informatik.uni-leipzig.de/~brewka/KRlecture/Argu.pdf*

# Dung's AAF: Definition 2

***Conflict-free set***

Let AF={AR, Attacks}. A set of arguments S ⊆ AR is conflict-free in AF if for each a, b ∈ S, (a, b) ∉ Attacks



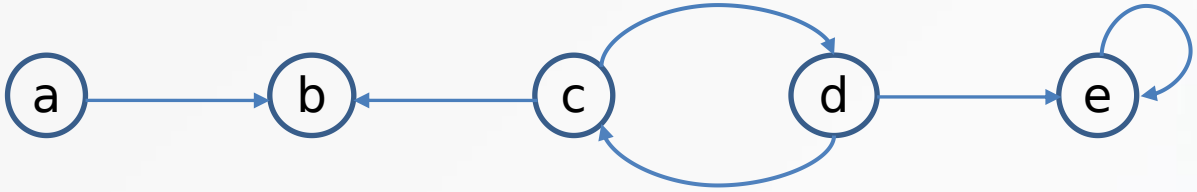

*cf(AF)={(a, c)*, (*a*, d), (b, d), (a), (b), (c), (d), ∅ }

# Dung's AAF: Definition 3

***Admissible Set***

Let AF = {AR, Attacks}. A set S ⊆ AR is *admissible* in AF if:

- S is *conflict-free* in AF
- Each a ∈ S is *acceptable* with respect to S:
  - S ⊆ AR if for each b ∈ AR with (b, a) ∈ Attack, there exists c ∈ S, such that (c, b) ∈ Attack.




*cf(AF)*={(a, c), (*a*, d), ~~(b, d)~~, (a), ~~(b)~~, (c), (d), ∅}

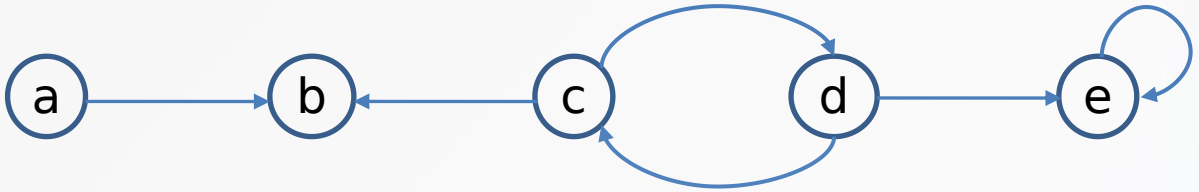
*Adm(AR)* = {(*a*, c), (a, d), (a), (c), (d), ∅}

# Dung's AAF: Definition 4

***Complete Extension Set***

Let AF = {AR, Attacks}. S ⊆ AR is a *complete extension* of AF if:

- S is *admissible* in AF
- S contains each argument that is *acceptable* with respect to S.




*Adm(AR)* = {(a, c), (a, d), (a), ~~(c)~~, ~~(d)~~, ~~∅~~}

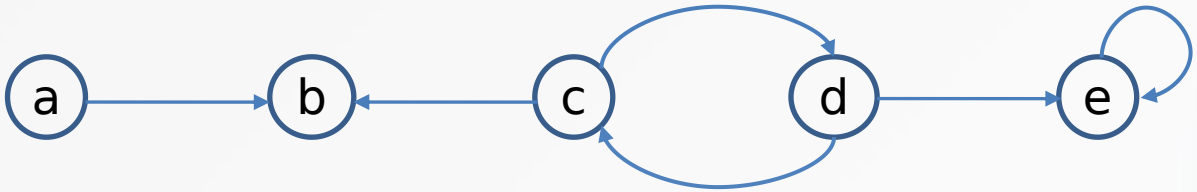
*Complete(AR)* = {(a, c), (a, d), (a)}

# Dung's AAF: Definition 5

***Grounded extension***

Let AF = {AR, Attacks}. A set S ⊆ AR is the *grounded extension* of AF if:

- S is a *complete extension* that is minimal with respect to set inclusion.




*Complete(AR)* = {~~(a, c)~~, ~~(a, d)~~, (a)}

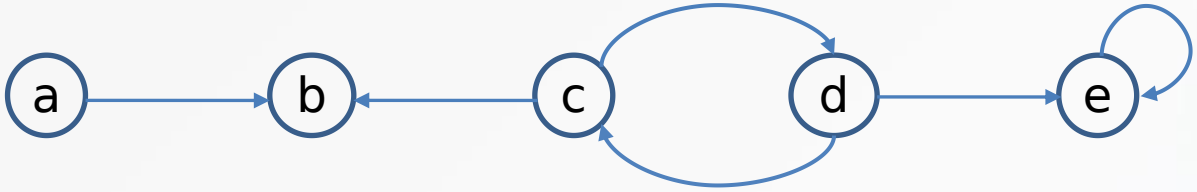
*Ground(AR)* = {(a)}

# Dung's AAF: Definition 6

***Preferred extension***

Let AF = {AR, Attacks}. A set S ⊆ AR is a *preferred extension* of AF if:

- S is a *complete extension* that is maximal with respect to set inclusion.



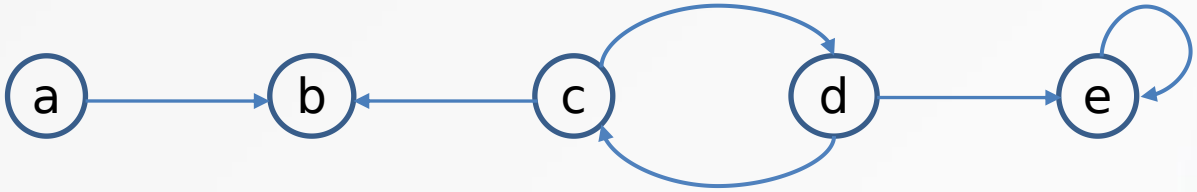

*Complete(AR)* = {(a, c), (a, d), ~~(a)~~}

*Pref(AR)* = {(a, c), (a, d)}

# Dung's AAF: Definition 7

***Stable extension***

Let AF = {AR, Attacks}. A conflict-free set S ⊆ AR is a *stable extension* iff S attacks each argument which does not belong to S.




*Stable(AR)* = {(a,d)}

# Argument Schemes

# Argumentation Schemes (AS)

- AS are historically based on Aristotle's *theory of topics*.
- AS are patterns of human reasoning.
- Inference from premises to conclusion that can be thought as rules of inference.
- The conclusion or the premises can be rejected by critical questions (defeasibility arguments).
- A collection of AS can be found in Walton et al., 2008.

# Argumentation Schemes (AS)

| Modus Ponens | AS for witness testimony |
|---|---|
| *P*<br>If *P*, then *Q*<br>Therefore: *Q*<br><br>If Tweety is a bird, then Tweety flies<br>Tweety is a bird<br>Then Tweety flies | Witness *A* has testified that P<br>Therefore: *P*<br><br>**Critical questions:**<br>Wasn't *A* mistaken?<br>Wasn't *A* lying? |

| Rules of inference | Argument schemes |
|---|---|
| Ex.: *modus ponens* | Ex. *AS for witness testimony* |
| abstract | concrete |
| strict | defeasable |
| usually of universal validity | context dependent |

# Argumentation Schemes: Walton's

- 60 schemes: E.g. AS from *Analogy*, *Example*, *Commitment*, *Cause to Effect, Position to know, Expert opinion, etc.*

**Cause to Effect**

*Major premise:* Generally, if A occurs, then B will (might) occur.
*Minor Premise:* In this case, A occurs (might occur).
*Conclusion:* Therefore, in this case, B will (might) occur.

**Critical Questions**

*CQ1:* How strong is the causal generalization?
*CQ2:* Is the evidence cited (if there is any) strong enough to warrant the causal generalizsation?
*CQ3:* Are there other causal factors that could interfere with the production of the effect in the given case?

(Walton, 2008, p.328)

# Argumentation Schemes: Challenges

- Walton and Macagno (2016) conclude that the most important aspect of any scheme classification system is:
  - How to situate an argument in relation to other arguments it is related to?
  - How to evaluate an AS or a set of AS?
  - When is an AS good, and under which circunstances?
  - When is an adaptation appropiate?

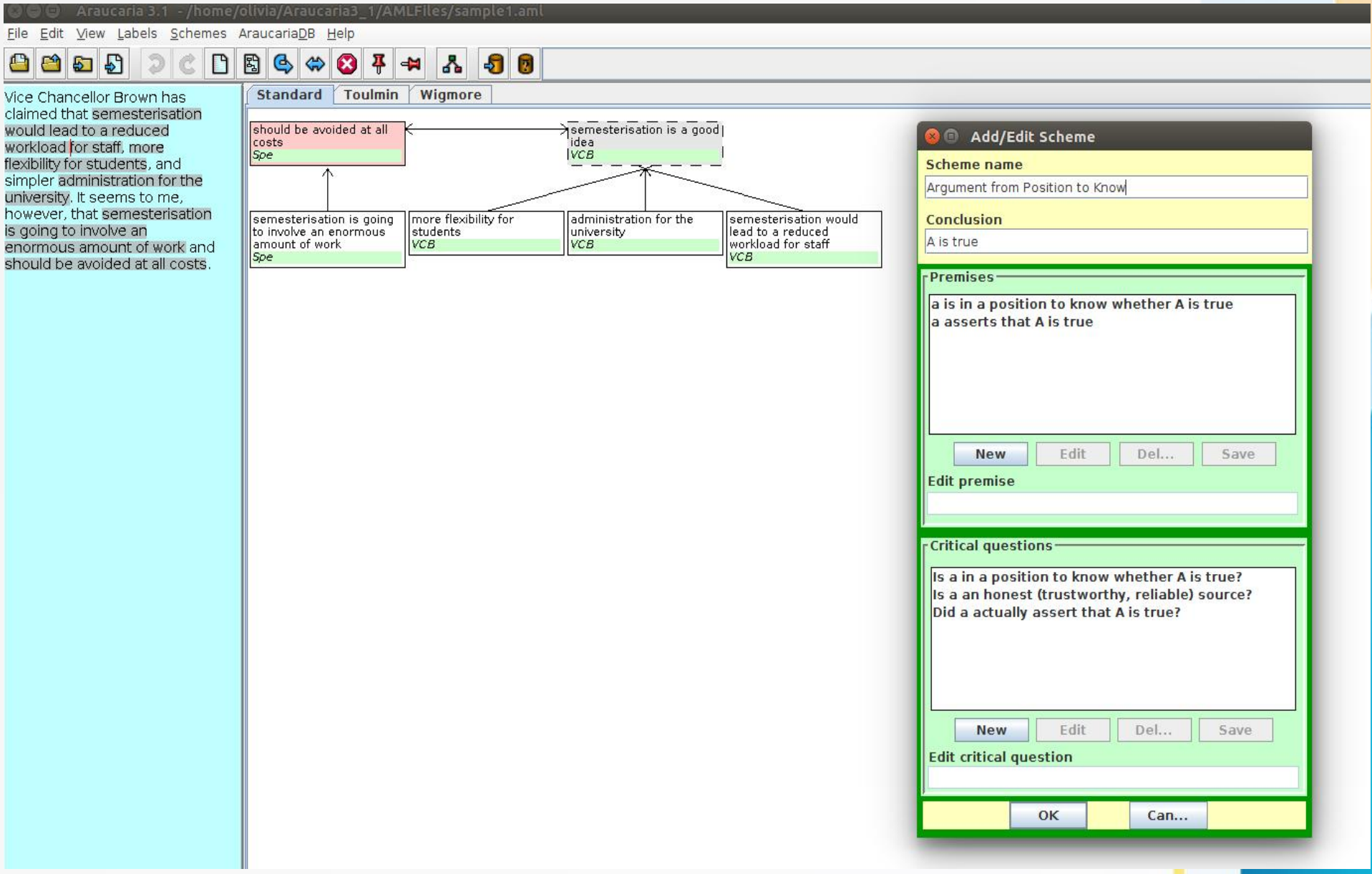
# Formalisation of AS

- The Araucaria tool (Reed and Rowe, 2001) for analysis of AS from text:
  - Allows the visual representation of AS, their relationships and inference process.
  - Stores AS in XML format.
- *Rationale, Argumed, Compendium*
- A natural way to formalise reasoning with AS is to regard them as *defeasible inference rules* and their critical questions as pointers to counterarguments.

# Formalisation of AS *Position to know*

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE ARG SYSTEM "argument.dtd">
<ARG>
  <?Araucaria UTF-8?>
  <SCHEMESET>
    <SCHEME>
      <NAME>Argument from Position to Know</NAME>
      <FORM>
        <PREMISE>a is in a position to know whether A is true</PREMISE>
        <PREMISE>a asserts that A is true</PREMISE>
        <CONCLUSION>A is true</CONCLUSION>
      </FORM>
      <CQ>Is a in a position to know whether A is true?</CQ>
      <CQ>Is a an honest (trustworthy, reliable) source?</CQ>
      <CQ>Did a actually assert that A is true?</CQ>
    </SCHEME>
  </SCHEMESET>
  <TEXT>Vice Chancellor Brown has claimed that semesterisation would lead to a reduced workload for staff,
more flexibility for students, and simpler administration for the university. It seems to me, however, that
semesterisation is going to involve an enormous amount of work and should be avoided at all costs. </TEXT>
 <EDATA>
    <AUTHOR>null</AUTHOR>
    <DATE>2003-05-09</DATE>
    <SOURCE />
    <COMMENTS />
  </EDATA>
  <AU>
    <PROP identifier="D" missing="yes">
      <PROPTEXT offset="-1">semesterisation is a good idea</PROPTEXT>
      <OWNER name="VCBrown" />
    </PROP>
    <REFUTATION>
      <AU>....
```

# Araucaria




http://araucaria.computing.dundee.ac.uk/doku.php

**ARGUMENT FROM POSITION TO KNOW**
A is in position to know whether P is true.
Minor Premise: A asserts that P is true.
Conclusion: P is true.

**CRITICAL QUESTIONS**
CQ1: Is A in the position to know whether P is true?
CQ2: Did *A* assert that *P* is true?
CQ3: Is *A* an honest (trustworthy, reliable) source?

*(Walton et al., 1996, p. 61-63)*

formalisation

$dw(x, \varphi)$: $PositionToKnow(x, \varphi), Says(x, \varphi) \Rightarrow \varphi$
$uw(x, \varphi)$: $\neg Credible(x) \Rightarrow \neg dw(x, \varphi)$

Modgil, Sanjay, and H. Prakken. "Abstract rule-based argumentation" (2018): 286-361.

# Argumentation Frameworks and their implementations

ASPIC (Argumentation Service Platform with Integrated Components) (Amgoud et al. 2006)

ASPIC+ (Prakken, 2010)

Toast (Snaith and Reed, 2012)

# ASPIC

- Vreeswijk's formalisation of the *structure of arguments* combined with Pollock's rebutting and undercutting defeat.
- Characterisation of a set of tree-structured arguments ordered with a binary defeat relation, that makes possible the instantiation of Dung's abstract model.
- Any Dung's semantics can be used to compute the acceptability status of the structured arguments.
- It has more expressiveness compared to Dung's abstract formalism.
- The inference engine was developed as an European project (2006). Its goal: propose rationality postulates as an option to rule-based argumentation systems.

# ASPIC Platform

- Consensus of theoretical argumentation models and services that implement such models.
- Could be used in different application fields (e.g. law, e-commerce, medicine, etc.)
- It considers the primary argumentation roles: inference, decision, dialogue and learning.
- Limitation: it considers domain-specific inference rules instead of general inference patterns, which limited its potential to be a general account of structured argumentation.

# ASPIC+

- Extends ASPIC by partitioning inferences and facts into an undeniable and defeasible part.
- ASPIC+ generalises ASPIC to accommodate a broader range of instantiations, including:
  - assumption-based argumentation
  - systems using argument schemes
- Arguments are built over a knowledge base and conflict handling is handed via preference relations.
- Under some assumptions, the reasoning postulates are satisfied when applying preferences.

# Toast: The Online Argument Structures Tool

- System that implements the ASPIC+ FW (Snaith and Reed, 2012). https://toast.arg-tech.org/

- Was used for medical reasoning (Quinlan, Thompson and Reed, 2012):
  - to establish if there was sufficient evidence to substitute missing data with data that was available.
  - to pose CQs of the completed analyses to establish the credibility and consistency of results.

# TOAST

The Online Argument Structures Tool

ARG-tech
Centre for Argument Technology

## About

The Online Argument Structures Tool (TOAST) is an implementation of the ASPIC+ theory of structured argumentation. Using the text fields below, build an argumentation theory consisting of a knowledge base, rules, contrariness and preferences. Evaluating the theory first translates it into a Dung-style abstract argumentation framework, which is subsequently evaluated for to determine the acceptability of the arguments. More information about the format of the knowledge base and rules can be found on the **help page**. A **RESTful API** is also available.

## Argumentation Theory

Axioms:

Premises:

Assumptions:

Preferences:

Rules:

Rule Preferences:

Contrariness:

Options:

Preference principle:
(•) Last link ( ) Weakest link

Evaluation engine: Dung-O-Matic ▾

Semantics: Grounded ▾

[x] Show islands in abstract framework?

**Add rule labels** | [ ] Close under transposition?

Query: [ ] Evaluate **Load an example** | **Help** | **API**

## Citation

If you find TOAST useful, and wish to reference it, please use the following citation:

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## Source code

Coming soon.

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# Part III

## Argumentation technology for explaining medical hypotheses and anomalous patient responses to treatments