Lecture 10

Structured Argumentation & Applications of Argumentation

INST0074

Lecture Outline

- Structured Argumentation Frameworks
  - Rule-based Argumentation (ASPIC+) (Modgil and Prakken, 2014)
  - Deductive Argumentation (Besnard and Hunter, 2014)
  - Assumption Based Argumentation (Toni, 2014)
  - Defeasible Logic Programming (Garcia and Simari, 2014)
- Applications of Argumentation

Structured Argumentation

- A more detailed formalization of arguments concerned with how arguments are constructed and when an argument attacks another argument.
- Features of structured argumentation frameworks
    - Formal language for representing knowledge
    - Arguments constructed from the available knowledge
    - The premises and claim of the argument are made explicit
    - Relationship between premises and claim is formally defined
    - Attacks among arguments are formally defined
    - Defeat = Attack + Preference

ASPIC+: Main Ideas

- Arguments are **inference graphs** where
  - **Nodes** are well founded formulae of a logical language $\mathcal{L}$
  - **Links** are applications of **inference rules**
    - $\mathcal{R}_s$ = **Strict** rules (ϕ_1, ..., $\phi_n \rightarrow \phi$); or
    - $\mathcal{R}_d$= **Defeasible** rules (ϕ_1, ..., $\phi_n \Rightarrow \phi$)
  - Reasoning starts from a knowledge base $\mathcal{K} \subseteq \mathcal{L}$
- **Defeat**
  - Attack on conclusion, premise or inference rule
  - Takes into account preferences over arguments
- Acceptability of arguments: based on the semantics of AAFs

Argumentation System

- An **argumentation system** is a triple $AS = (\mathcal{L}, \mathcal{R}, n)$ where:
  - $\mathcal{L}$ is a **logical language** with negation (¬)
  - $\mathcal{R} = \mathcal{R}_s \cup \mathcal{R}_d$ is a set of **strict** ($\phi_1, \ldots, \phi_n \rightarrow \phi$) and **defeasible** ($\phi_1, \ldots, \phi_n \Rightarrow \phi$) inference rules
  - n: $\mathcal{R}_d \rightarrow \mathcal{L}$ is a **naming convention** for defeasible rules

- Notation:
  - $-\phi = \neg\phi$ if ϕ does not start with a negation
  - $-\phi = \psi$ if ϕ is of the form $\neg\psi$

Argumentation Theory

- A **knowledge base** in $AS = (\mathcal{L}, \mathcal{R}, n)$ is a set $\mathcal{K} \subseteq \mathcal{L}$
- $\mathcal{K}$ is a partition $\mathcal{K}_n \cup \mathcal{K}_p$ with:
  - $\mathcal{K}_n$ = **necessary** premises
  - $\mathcal{K}_p$ = **ordinary** premises
- An **argumentation theory** is a pair AT = (AS, $\mathcal{K}$) where AS is an argumentation system and $\mathcal{K}$ a knowledge base in AS

Structure of an argument

- An **argument** A on the basis of an argumentation theory is:
  - $\boldsymbol{\phi}$ if $\phi \in \mathcal{K}$
    - Prem(A) = $\{\phi\}$, Conc(A) = ϕ, Sub(A) = $\{\phi\}$, DefRules(A) = $\emptyset$
  - $\boldsymbol{A_1, ..., A_n \rightarrow \phi}$ if $A_1, ..., A_n$ are arguments such that there is a strict inference rule Conc(A_1), ..., Conc(A_n) $\rightarrow \phi$
    - Prem(A) = Prem(A_1) $\cup$ ... $\cup$ Prem(A_n)
    - Conc(A) = ϕ
    - Sub(A) = Sub(A_1) $\cup$ ... $\cup$ Sub(A_n) $\cup$ $\{A\}$
    - DefRules(A) = DefRules(A_1) $\cup$ ... $\cup$ DefRules(A_n)
  - $\boldsymbol{A_1, ..., A_n \Rightarrow \phi}$ if $A_1, ..., A_n$ are arguments s.t. there is a defeasible inference rule Conc(A_1), ..., Conc(A_n) $\Rightarrow \phi$
    - Prem(A) = Prem(A_1) $\cup$ ... $\cup$ Prem(A_n)
    - Conc(A) = ϕ
    - Sub(A) = Sub(A_1) $\cup$ ... $\cup$ Sub(A_n) $\cup$ $\{A\}$
    - DefRules(A) = DefRules(A_1) $\cup$ ... $\cup$ DefRules(A_n) $\cup$ $\{A_1, ..., A_n \Rightarrow \phi\}$

Types of arguments

- An argument A *is:*
  - **Strict** if DefRules(A) = $\emptyset$
  - **Defeasible** if not strict
  - **Firm** if Prem(A) $\subseteq \mathcal{K}_n$
  - **Plausible** if not firm

Examples of arguments in ASPIC+

- Consider an argumentation theory with:
  - $\mathcal{R}_s = \{s_1, s_2\}$, $\mathcal{R}_d = \{d_1, d_2, d_3, d_4, d_5\}$, where:

    $d_1: p \Rightarrow q$ $\quad$ $d_4: u \Rightarrow v$ $\quad$ $s_1: p, q \rightarrow r$

    $d_2: s \Rightarrow t$ $\quad$ $d_5: v, x \Rightarrow \neg t$ $\quad$ $s_2: v \rightarrow \neg s$

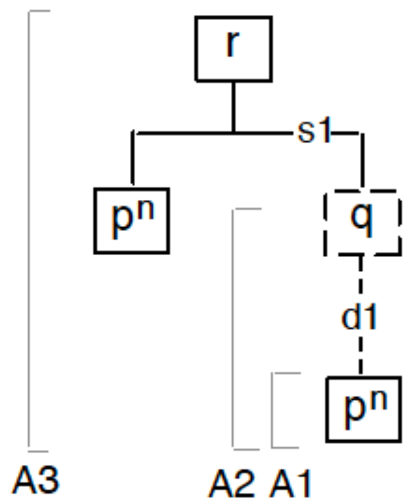
    $d_3: t \Rightarrow \neg d_1$
  - $\mathcal{K}_n = \{p\}$, $\mathcal{K}_p = \{s, u, x\}$
- Some arguments we can construct are:

  $\boldsymbol{A_1: p}$ $\quad$ $\boldsymbol{A_2: A_1 \Rightarrow q}$ $\quad$ $\boldsymbol{A_3: A_1, A_2 \Rightarrow r}$
  - A_1 is strict and firm while A_2 and A_3 are defeasible and firm
  - We can also construct

  $\boldsymbol{B_1: s}$ $\quad$ $\boldsymbol{B_2: B_1 \Rightarrow t}$ $\quad$ $\boldsymbol{B_3: B_2 \Rightarrow \neg d_1}$

  $\boldsymbol{C_1: u}$ $\quad$ $\boldsymbol{C_2: C_1 \Rightarrow v}$ $\quad$ $\boldsymbol{C_3: C_2 \Rightarrow \neg s}$

  $\boldsymbol{D_3: x}$ $\quad$ $\boldsymbol{D_4: C_2, D_3 \Rightarrow \neg t}$

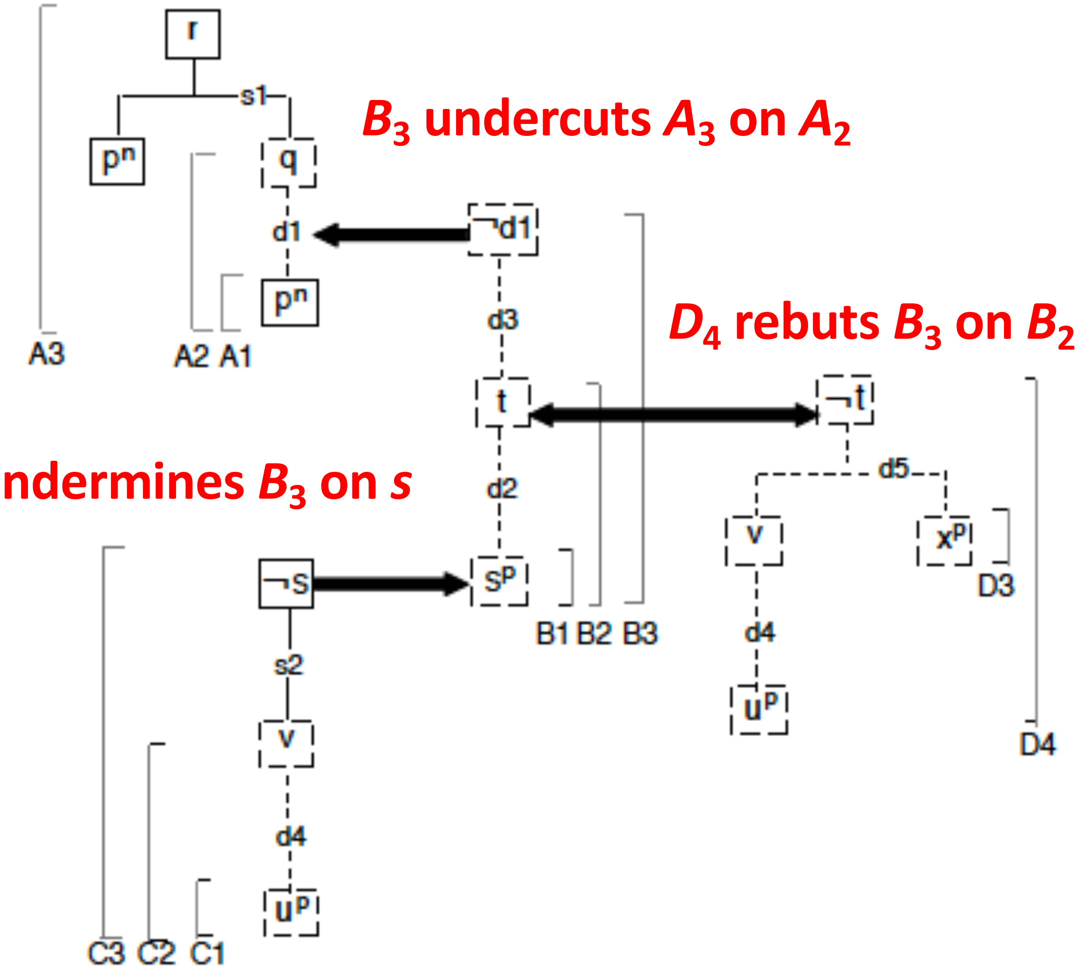


Attack

- A **undermines** B (on ϕ) if
  - Conc(A) = -ϕ for some $\phi \in$ Prem(B)/ $\mathcal{K}_n$;
- A **rebuts** B (on B') if
  - Conc(A) = -Conc(B') for some $B' \in$ Sub(B) with a defeasible top rule
- A **undercuts** B (on B') if
  - Conc(A) = -n(r) for some $B' \in$ Sub(B) with defeasible top rule r

- A **attacks** B iff A undermines or rebuts or undercuts B.

Examples of attacks in ASPIC+



B_3* undercuts *A_3* on *A_2

D_4* rebuts *B_3* on *B_2

C_3* undermines *B_3* on *s

Structured Argumentation Framework

- A **structured argumentation framework** (*SAF*) defined by an argumentation theory *AT* is a triple $(Args, C, \leq_a)$ where
  - $Args = \{A \mid A$ is an argument on the basis of $AT\}$
  - *C* is the attack relation on *Args*
  - $\leq_a$ is a preference ordering on *Args*
- A ***c-SAF*** is a *SAF* in which all arguments have consistent premises

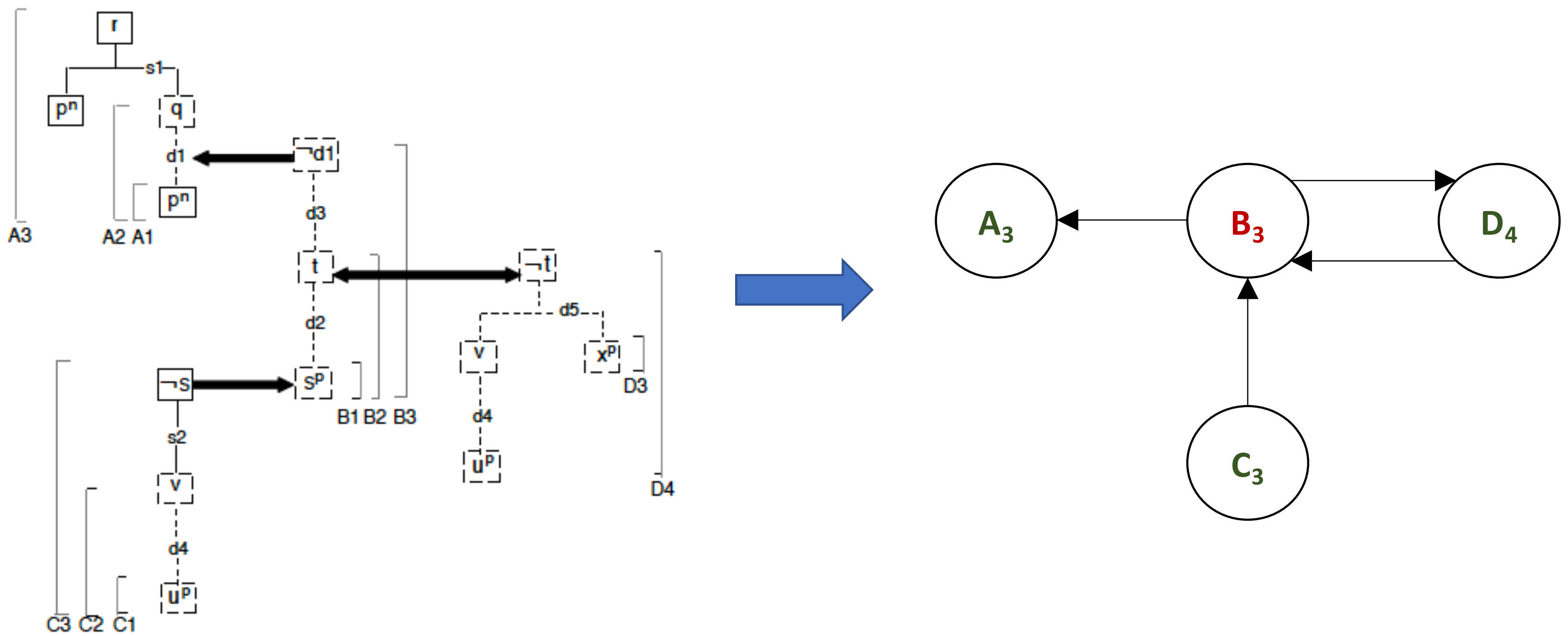
Defeat

- Given a SAF = ($Args, C, \leq_a$) and arguments A, $B \in Args$:
- A **defeats** B iff for some $B' \in$ Sub(B)
  - A undermines or rebuts B on B' **and not $A <_a B'$**
    - (*$A <_a B'$ iff $A \leq_a B'$ and not $B' \leq_a A$*)
  - A undercuts B on B'

- General constraint: A $<_a$ B if B is strict and firm and A is defeasible or plausible.

Generating AAFs from SAFs

- An AAF corresponding to a *SAF* = $(Args, C, \leq_a)$ a pair $(Args, R)$ where
  - R is the defeat relation on *Args* defined by C and $\leq_a$.



Deductive Argumentation

Argumentation Graph	Defines how arguments and counter-arguments are composed into a graph
Counterarguments	Defines when an argument attacks another argument
Arguments	Defines how an argument is constructed from the base logic
Base Logic	Defines the logical language and the consequence or entailment relation

Base Logic

- A logic is defined by a language $\mathcal{L}$ and a consequence relation $\vdash_i$
- Examples of base logic:
  - Simple logic
  - Classical logic
  - Non-monotonic logics
  - Temporal logics
  - Description logics
  - Paraconsistent logics

Deductive arguments

- Given a base logic (a language $\mathcal{L}$ and a consequence relation $\vdash_i$), a **deductive argument** is a pair **⟨Φ, α⟩** where $\boldsymbol{\Phi \vdash_i \alpha}$
  - **Φ** is the support or premises or assumptions of the argument
  - **α** is the claim or conclusion of the argument
- For an argument *A* = ⟨Φ, α⟩:
  - Support(*A*) = Φ
  - Claim(*A*) = α
- An argument ⟨Φ, α⟩
  - satisfies the **consistency constraint** when Φ is consistent
  - satisfies the **minimality constraint** when there is no $\Psi \subset \Phi$, such that $\Psi \vdash_i \alpha$

Arguments based on classical logic

- For a set of classical logic formulae **Φ** and a classical logic formula **α**, **$\langle\Phi, \alpha\rangle$** is a **classical logic argument** iff
  - **$\Phi \vdash \alpha$**
    - $\vdash$ is the standard consequence relation of classical logic
  - **$\Phi \nvdash \bot$**
    - Φ is consistent
  - **there is no $\Psi \subset \Phi$, such that $\Psi \vdash \alpha$**
    - Φ is minimal
- An example:

`⟨{∀X.multipleOfTen(X)→even(X), ¬even(77)}, ¬multipleOfTen(77)}⟩`

Classical logic attacks

- Let A and B two classical logic arguments:
  - A is a **classical defeater** of B if **Claim(A)** $\vdash \neg\bigwedge \boldsymbol{\varphi_i} \mid \boldsymbol{\varphi_i} \in$ **Support(B)**
    - e.g. $\langle \{a \vee b, c\}, (a \vee b) \wedge c \rangle$ is a classical defeater of $\langle \{\neg a, \neg b\}, \neg a \wedge \neg b \rangle$
  - A is a **classical direct defeater** of B if $\exists\ \boldsymbol{\varphi_i} \in$ **Support(B) s.t. Claim(A)** $\vdash \neg\boldsymbol{\varphi_i}$
    - e.g. $\langle \{a \vee b, c\}, (a \vee b) \wedge c \rangle$ is a classical direct defeater of $\langle \{\neg a \wedge \neg b\}, \neg a \wedge \neg b \rangle$
  - A is a **classical undercut** of B if $\exists\ \boldsymbol{\varphi_1, \ldots, \varphi_n} \in$ **Support(B) s.t. Claim(A)** $\vdash \neg\bigwedge_{1\ldots n} \boldsymbol{\varphi_i}$
    - e.g. $\langle \{\neg a \wedge \neg b\}, \neg(a \wedge b) \rangle$ is a classical undercut of $\langle \{a, b, c\}, a \wedge b \wedge c \rangle$
  - A is a **classical direct undercut** of B if $\exists\ \boldsymbol{\varphi_i} \in$ **Support(B) s.t. Claim(A)** $\equiv \neg\boldsymbol{\varphi_i}$
    - e.g. $\langle \{\neg a \wedge \neg b\}, \neg a \rangle$ is a classical direct undercut of $\langle \{a, b, c\}, a \wedge b \wedge c \rangle$
  - A is a **classical canonical undercut** of B if **Claim(A)** $\equiv \neg\bigwedge \boldsymbol{\varphi_i} \mid \boldsymbol{\varphi_i} \in$ **Support(B)**
    - e.g. $\langle \{\neg a \wedge \neg b\}, \neg(a \wedge b \wedge c) \rangle$ is a classical canonical undercut of $\langle \{a, b, c\}, a \wedge b \wedge c \rangle$

Classical logic attacks (cont'd)

- Let *A* and *B* two classical logic arguments:
  - *A* is a **classical rebuttal** of *B* if **Claim(*A*) ≡ ¬ Claim(*B*)**
    - e.g. $\langle \{a, a \rightarrow b\}, (b \vee c) \rangle$ is a classical rebuttal of $\langle \{\neg a \wedge \neg b, \neg c\}, \neg (b \vee c) \rangle$
  - *A* is a **classical defeating rebuttal** of *B* if **Claim(*A*) ⊢ ¬ Claim(*B*)**
    - e.g. $\langle \{a, a \rightarrow b\}, b \rangle$ is a classical defeating rebuttal of $\langle \{\neg a \wedge \neg b, \neg c\}, \neg (b \vee c) \rangle$

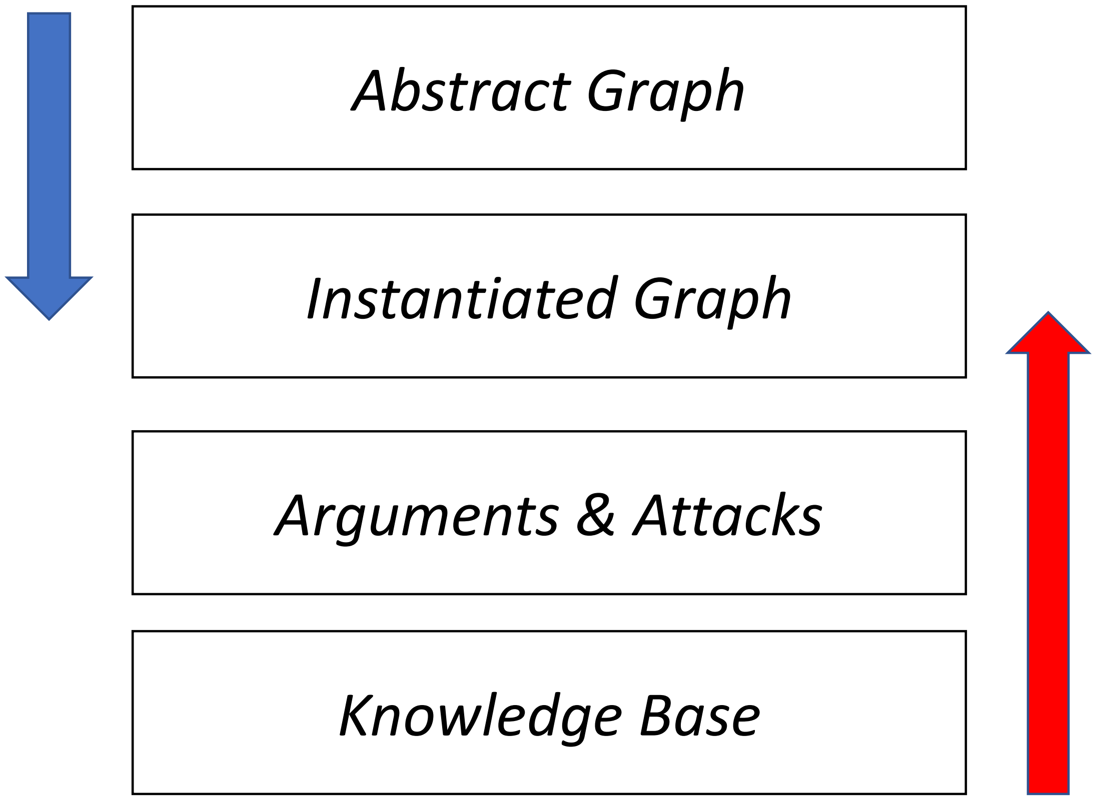
Examples of classical logic arguments & attacks

- Propositional logic arguments
  - A = $\langle$`{lowCostFly, luxFly, lowCostFly,luxFly→goodFly}, goodFly`$\rangle$
  - B = $\langle$`{¬lowCostFly ∨ ¬luxFly}, ¬lowCostFly ∨ ¬luxFly`$\rangle$
  - B is a classical undercut of A
- First-order logic arguments
  - A = $\langle$`{bird(Tweety), ∀X.bird(X)→flies(X)}, flies(Tweety)`$\rangle$
  - B = $\langle$`{∃X. bird(X)∧¬flies(X)}, ¬∀X.bird(X)→flies(X)`$\rangle$
  - B is a classical direct undercut of A

Approaches to constructing argument graphs

Descriptive approach:

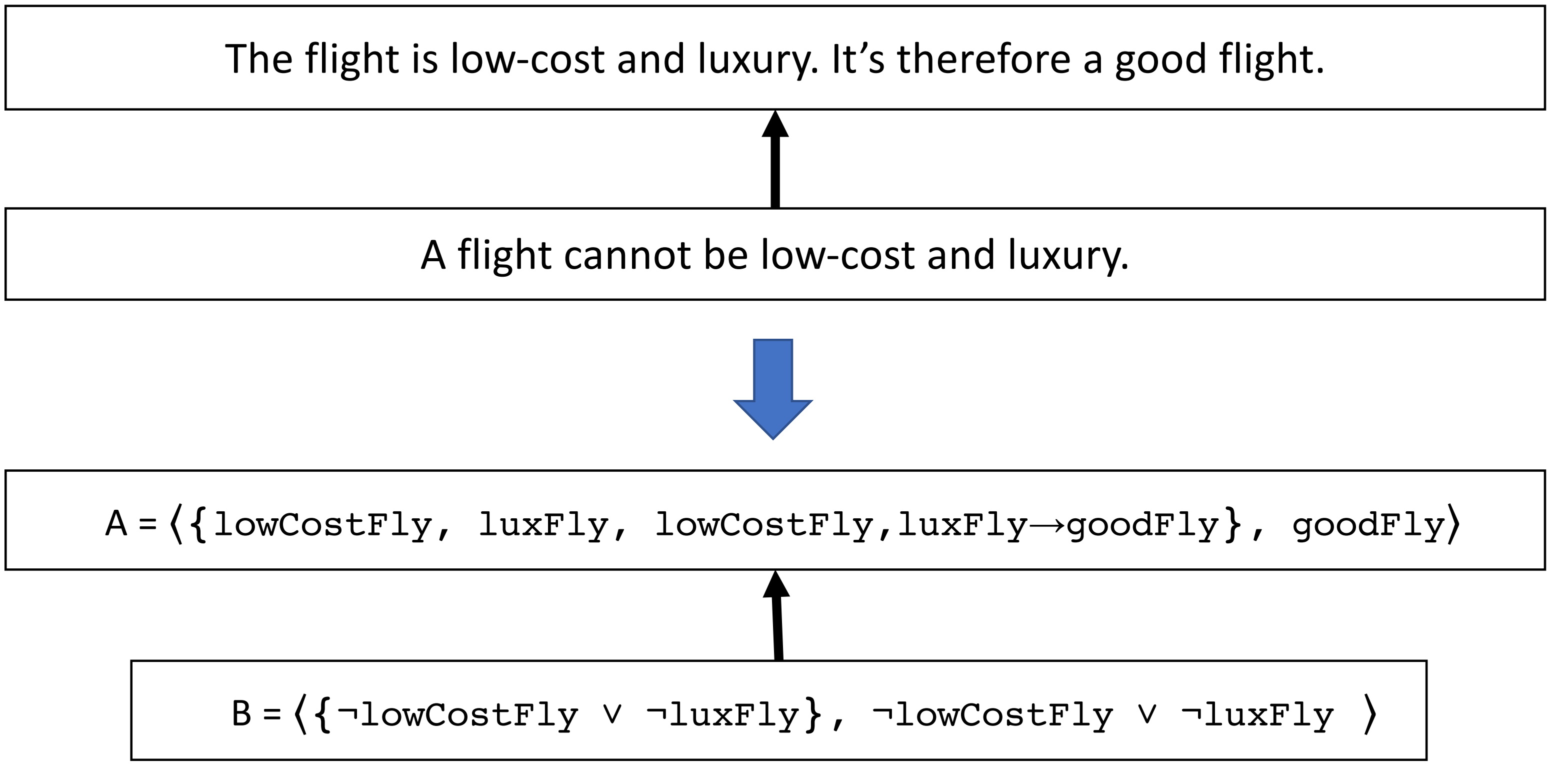
- **Input**: an abstract argument graph
- **Output**: an instantiated argument graph



Generative approach:

- **Input**: knowledge base
- **Output**: an instantiated argument graph

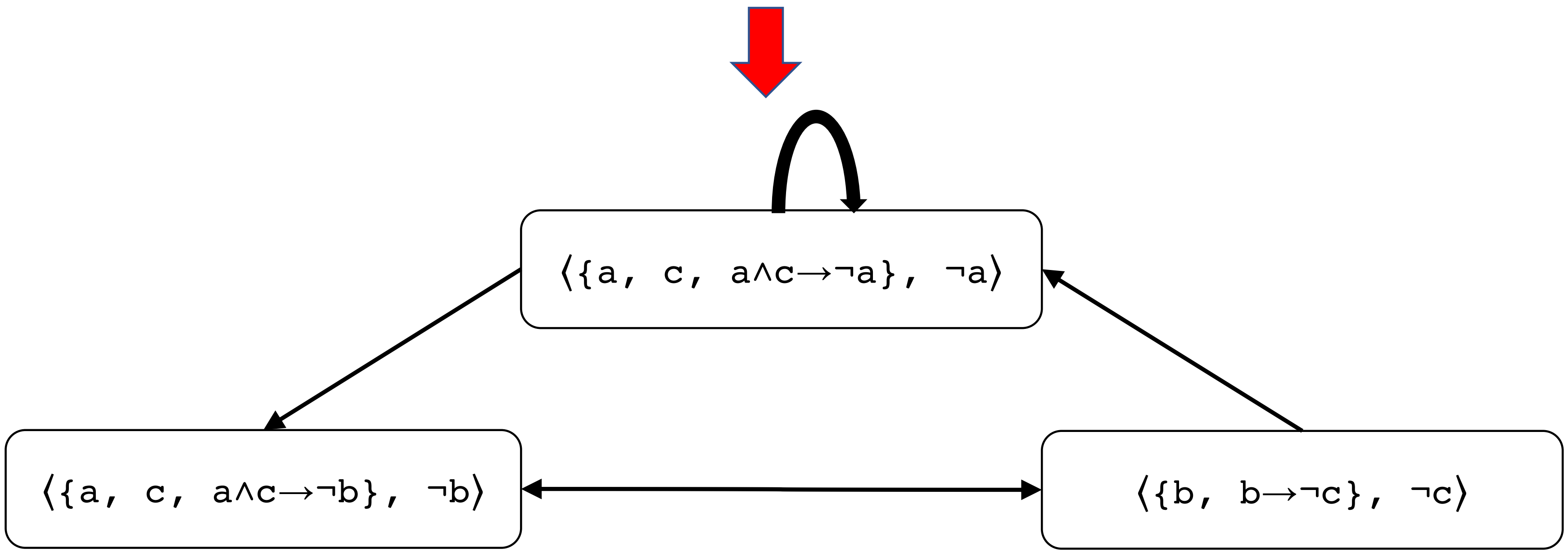
Generating an instantiated graph



Generating an abstract graph

- Consider the simple logic knowledge base:

  {a, b, c, a∧c→¬a, b→¬c, a∧c→¬b}
- And let all arguments involve one more rules



Assumption-based Argumentation

- A **deductive system** is a pair ($\mathcal{L}$, $\mathcal{R}$) where
  - $\mathcal{L}$ is a logical language
  - $\mathcal{R}$ is a set of rules (ϕ_1, ..., $\phi_n \rightarrow \phi$) over $\mathcal{L}$
- An **assumption-based argumentation framework** is a tuple ($\mathcal{L}$, $\mathcal{R}$, $\mathcal{A}$, ~)
  - ($\mathcal{L}$, $\mathcal{R}$) is a deductive system
  - $\mathcal{A} \subseteq \mathcal{L}$, $\mathcal{A} \neq \emptyset$ is a set of **assumptions**
  - No rule has an assumption as conclusion
  - ~ is a total mapping from $\mathcal{A}$ into $\mathcal{L}$. ~a is the **contrary** of a
- An **argument S ⊢ p** is a deduction of **p** from a set **S** $\subseteq \mathcal{A}$.
- Argument S ⊢ p **attacks** argument S' ⊢ p' iff p = ~q for some q $\in$ S'
- Acceptability semantics similar to the semantics of AAFs
- Read more about ABA in (Toni, 2014)

Defeasible Logic Programming (DeLP)

- An argumentation system based on logic programming
- Elements of a **Defeasible Logic Program**
  - A set of facts
  - A set of strict and defeasible rules
  - A binary argument ordering
- An **argument (*A*, *L*)** is a defeasible derivation for *L* (similar to ASPIC+)
- Argument *A* **attacks** argument *B* at sub-argument B’ iff the conclusions of *A* and *B’* are inconsistent. *A* **defeats** *B* iff *A* attacks *B* on *B' and A* $\not<$ *B’*
- Game-theoretic acceptability semantics
- Read more about DeLP in (Garcia and Simari, 2014)

Applications of Argumentation

- Argumentation on the Web
  - The Argument Web
  - Argument search on the Web
  - Online debate platforms
- Argumentation in Medicine
- Argumentation in Law

The Argument Web

- An Online Ecosystem of Tools, Systems and Services for Argumentation (Reed et al., 2017), https://arg-tech.org/index.php/research/
- The **Argument Interchange Format**
  - An ontology of arguments
  - Models arguments at different levels of abstraction
  - Aims to facilitate the exchange of data between different argumentation tools and agent-based applications.
  - Integrates elements of argumentation theories from different disciplines: formal argumentation, multi-agent systems, informal logics
  - Available in several formats (OWL, XML, JSON, Prolog, SVG, etc.)

The Argument Web

ARG-tech
Centre for Argument Technology

- **OVA** (Online Visualisation of Argument): http://ova.arg-tech.org/
  - A web drag-and-drop interface for analysing textual arguments
  - Manual annotation of the argumentative structure of natural language text
  - Based on the Argument Interchange Format
  - Arguments can be saved on the Argument Web
  - Other similar tools
    - DebateGraph, https://debategraph.org/
    - RationaleOnline, https://www.rationaleonline.com/
- Collaborative analysis of arguments
  - **OVA 2.0**: allows multiple analysts to work together on a single analysis
  - **AnalysisWall**: a large, shared workspace (high-resolution touchscreen) running bespoke argument analysis software

AnalysisWall

Source: https://arg-tech.org

The Argument Web

- **Argugrader** (Argument Pedagogy): http://www.argugrader.com/
  - Students prepare their argument analysis in OVA
  - Argugrader compares submissions over model answers using graph matching algorithms and produces a grade and textual feedback
- Dialogue applications
  - **Arvina** (web-based discussion s/w): https://arg-tech.org/index.php/arvina/
  - **Argublogging** (dialogue application for bloggers)
- **AIFdb Corpora**: http://corpora.aifdb.org/
  - Corpora of argument in several different languages from various domains as diverse as mediation, pedagogy, politics, broadcast debate, eDemocracy and financial discussion

Argument Search

- Technology that finds pro and con arguments for controversial issues
- **args.me**: https://www.args.me/
  - Indexes debate portal arguments
  - Retrieves and ranks relevant arguments in response to queries.
- **ArgumenText**: https://www.argumentsearch.com/
  - Indexes diverse web pages
  - Mines relevant arguments in response to queries
- **PerspectroScope**: https://perspectroscope.seas.upenn.edu/
  - Similar to ArgumentText for debate portals and Wikipedia texts

Searching for arguments in args.me

args | abolish the death penalty

Page 1 of 639 arguments, 326 pro, 313 con (retrieved in 0.4s)

Pro

#1 No execution of the innocent
http://www.bbc.co.uk (81 other sources...)
As long as human justice remains fallible, the risk of executing the innocent can never be eliminated.

#2 Everyone has a right to live
http://www.amnesty.org (102 other sources...)
Everyone has an inalienable human right to live, even those who commit murder.

#3 Death penalty fails to deter
http://www.procon.org (24 other sources...)
There is no scientific proof that executions have a greater deterrent effect than life imprisonment.

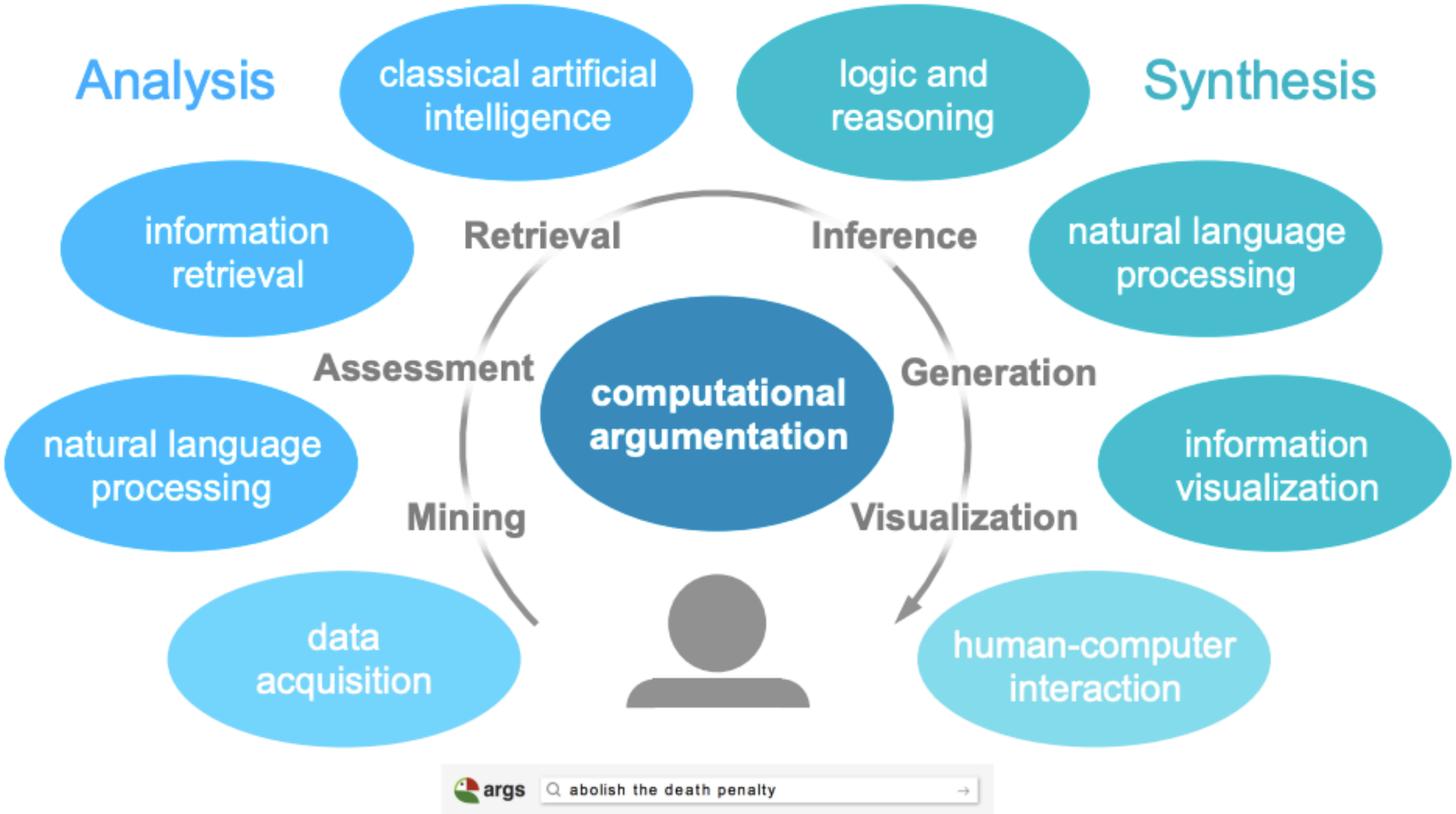
Con

#1 Retribution
http://www.bbc.co.uk (36 other sources...)
Real justice requires people to suffer for their wrongdoing in a way adequate for the crime.

#2 Death penalty deters
http://www.debate.org (15 other sources...)
By executing convicted murderers, would-be murderers are deterred from killing people.

#3 Prevention of re-offending
http://www.bbc.co.uk (25 other sources...)
Those executed cannot commit further crimes. Imprisonment does not protect sufficiently.

Argument Search: Tasks



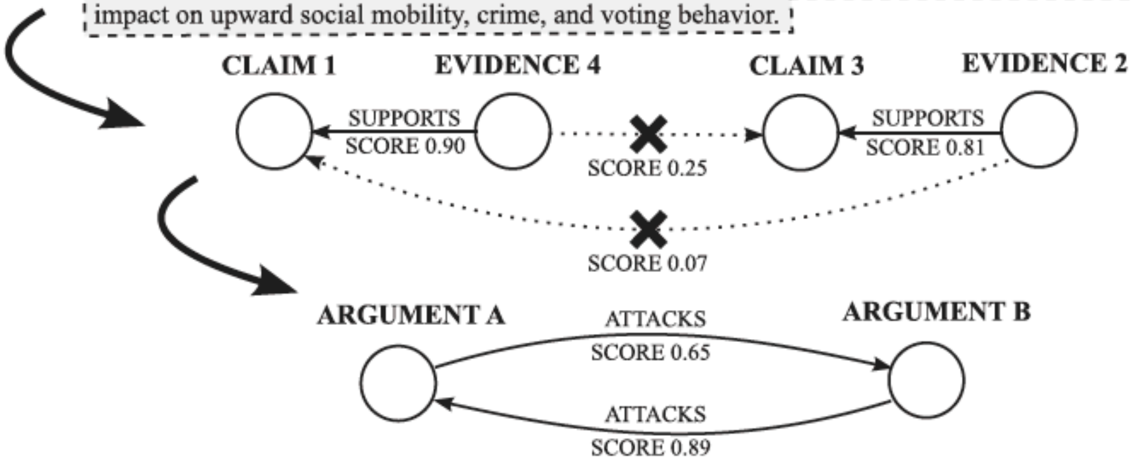
Read more about args.me in (Wachsmuth et al., 2017)

Argument mining

- Core task is many argument-based applications
- Automatic identification of arguments and their relations in natural language text
- A challenging problem involving several NLP tasks:
  - Sentence classification
  - Sentiment analysis
  - Named entity recognition
  - Link prediction
  - Discourse relation classification
  - Etc.
- See (Lippi and Torroni, 2016) for a recent survey

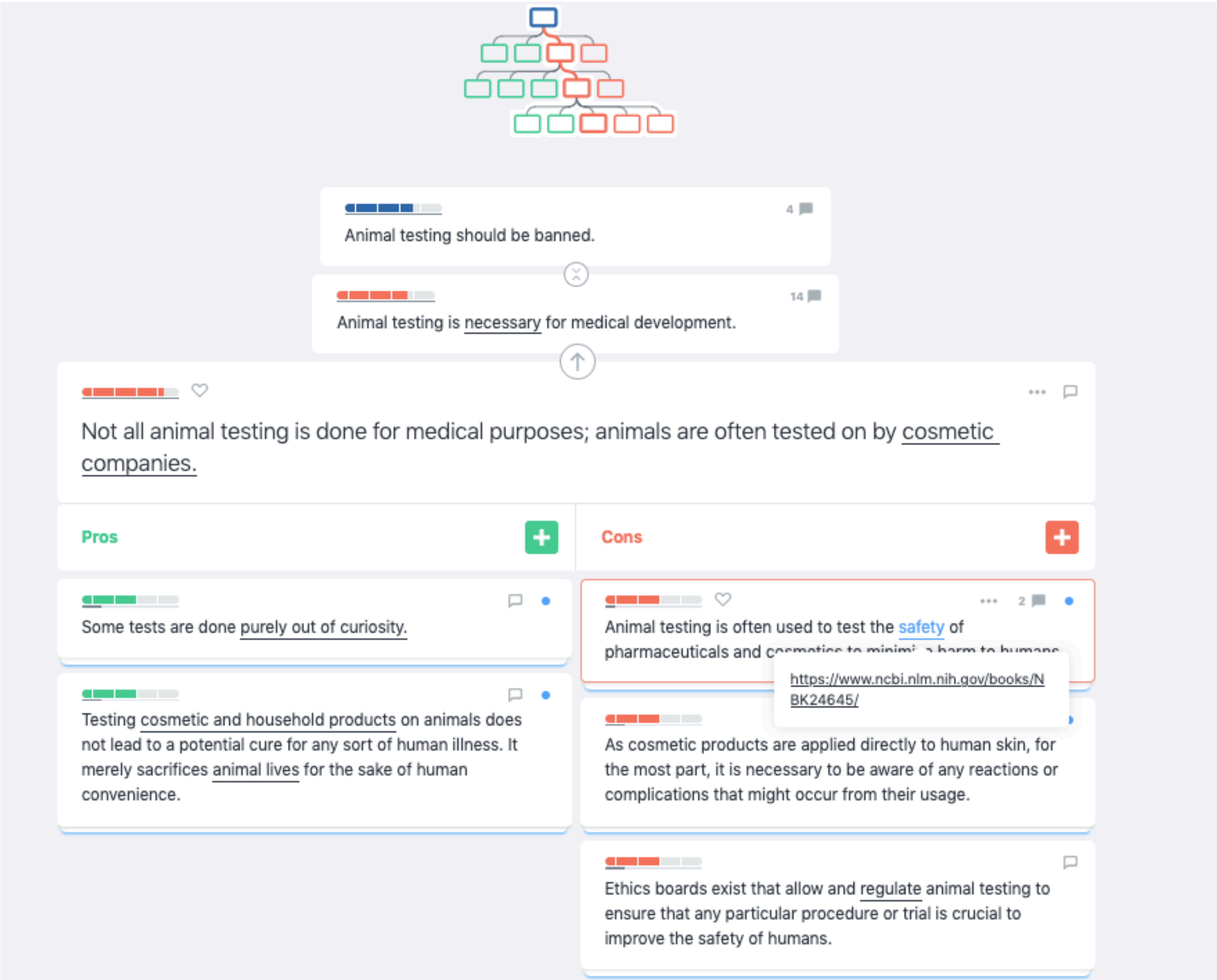
Argument mining: an example

CLAIM 1 While those on the far-right think that immigration threatens national identity, as well as cheapening labor and increasing dependence on welfare.
[...]
Proponents of immigration maintain that, according to Article 13 of the Universal Declaration of Human Rights, everyone has the right to leave or enter a country, along with movement within it [...] **EVIDENCE 2**
[...]
CLAIM 3 Some argue that the freedom of movement both within and between countries is a basic human right, and that the restrictive immigration policies, typical of nation-states, violate this human right of freedom of movement.
[...]
Immigration has been a major source of population growth and cultural change throughout much of the history of Sweden. The economic, social, and political aspects of immigration have caused controversy regarding ethnicity, economic benefits, jobs for non-immigrants, settlement patterns, impact on upward social mobility, crime, and voting behavior. **EVIDENCE 4**



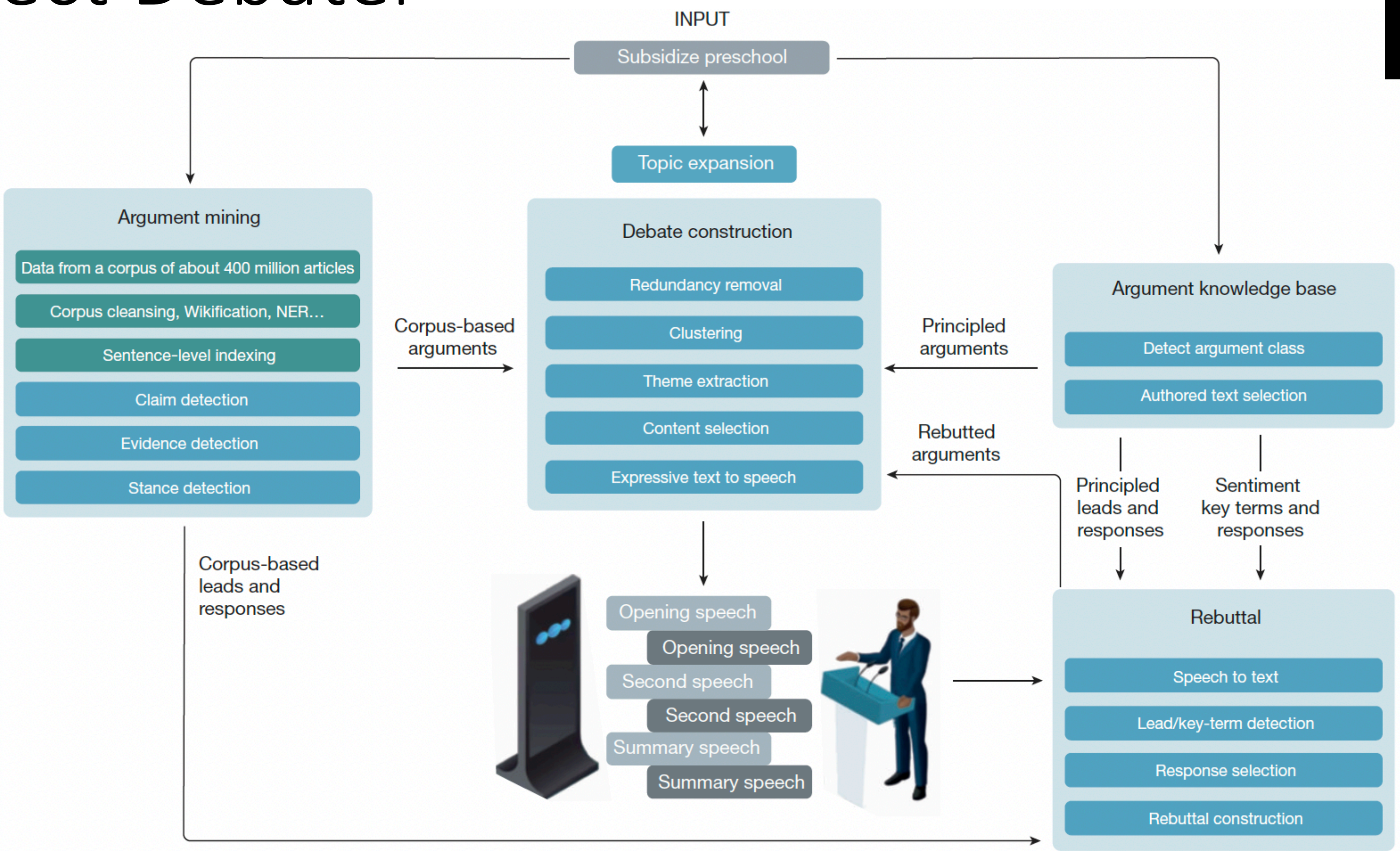
Debate platforms

- Platforms where web users can participate in debates
  - Users can create debates, post pro/con arguments and vote on other users' arguments.
  - Tools for evaluating arguments and visualising debates
  - Examples: Kialo.com, Debate.org, createdebate.com, debategraph.org
- Social Argumentation Frameworks (Leite and Martins, 2011)
  - Extension of Abstract Argumentation Frameworks
  - Evaluation of arguments in debates based on the votes they have received and the strength of the opposing arguments
  - Frameworks considering argument support
    - Quantitative Argumentation Debate Framework (Rago et al., 2016)
    - Multi-Aspect Comment Evaluation Framework (Patkos et al., 2016)



An online debate in Kialo.com

Project Debater



Read more about the Project Debater at: https://research.ibm.com/interactive/project-debater/

Argumentation in Medicine

- Medical information: complex, heterogeneous, incomplete, inconsistent
- Medical decision support
  - **Capsule** (Walton et al., 1997) helps family doctors with drug prescription. Arguments pro and con a drug based on similar past cases and patient record.
- Evidence-based research
  - Framework that produces argument-based personalised recommendations for treatment based on the results of clinical trials (Hunter and Williams, 2012).
- Behaviour change
  - Automated persuasion system that selects convincing arguments for persuading a patient to change behaviour (e.g. take more exercise) (Hunter, 2018)

Argumentation in Law

- Legal reasoning is essentially argumentative
- Case-based reasoning
  - **HYPO** (Ashley, 1990) and **CATO** (Aleven, 2003): Use of arguments to model how lawyers make use of past decisions when arguing a case.
  - Argument-based model of precedent (Horty and Bench-Capon, 2012)
- Practical reasoning
  - Modelling legal arguments using argument schemes (Atkinson et al., 2005)
- Evidential reasoning
  - Evidential Argumentation System (Oren and Norman, 2008)
  - Use of formal argumentation systems to model Wingmore charts and reason about legal evidence (Bex et al., 2003)

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Bibliographic Resources on Argumentation

- Books on Argumentation
  - Handbook of Formal Argumentation, vol.1 & 2
  - Elements of Argumentation (Besnard and Hunter, 2008)
  - Argumentation in AI (Eds: I. Rahwan and G. Simari, 2009)
- AI Journals and Conferences
- Journal: Argument & Computation
- Conferences & workshops on argumentation
  - Conference on Computational Models of Argument
  - Workshop on Argumentation in Multiagent Systems
  - Workshop Computational Models of Natural Argument
  - Workshop Theory and Applications of Formal Argumentation
  - Workshop on Argument Strength
- International Competition on Computational Models of Argumentation