Analysis of Conflicting Information Using Argumentation

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Inconsistency is not all bad!

- Often inconsistency is unwanted
  - Specification for a plan
  - Sensor fusion in robotics
- Sometimes inconsistency is useful
  - Lawyers look for it in an opposition case
  - Tax inspectors look for it in tax returns
- For many situations, inconsistency is a driver for further investigation
  - Biomedical knowledge
- In general, *inconsistency implies action* (Gabbay)

Inconsistency in classical logic

Classical logic (and sub-systems) are the basis of many data + knowledge engineering formalisms

- But when information is inconsistent, it is trivialised

$$\frac{\alpha \wedge \neg\alpha}{\beta}$$

- And there is no model of inconsistent information

To handle inconsistency, techniques on top of logic can be used (e.g. query techniques for inconsistent databases, paraconsistent reasoning, belief revision, conflict resolution, knowledge/belief merging, measuring/analysing inconsistency, argumentation, etc).

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 drawing conclusions (e.g. A parent answering the question "Are mobile phones safe for my children?").
- Argumentation may involve convincing an audience (e.g. A politician making the case that mobile phones should be banned for children because the risk of radiation damage is too great)

Abstract argumentation

An **abstract argument system** is a graph $(\mathcal{A}, \longrightarrow)$ where each node is an argument and each arc $A_i \longrightarrow A_j$ denotes A_i attacks A_j (Dung).

A_1	= Patient has emphysema - a contraindication for betablockers
A_2	= Patient has hypertension so prescribe betablockers
A_3	= Patient has hypertension so prescribe diuretics
IC	= Only give one prescription per disorder

$$A_1 \longrightarrow A_2 \leftrightarrow A_3$$

Abstract argumentation

A set $S \subseteq \mathcal{A}$ of arguments is **conflict-free** iff there are no a and b in S such that a attacks b.

For $A_1 \rightarrow A_2 \leftrightarrow A_3$, conflict free subsets of $\mathcal{A} = \{A_1, A_2, A_3\}$ are

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

A set of arguments $S \subseteq \mathcal{A}$ **defends** an argument $a \in \mathcal{A}$ iff for each argument $b \in \mathcal{A}$, if b attacks a then S attacks b.

$\{\}$ defends A_1

$\{A_1\}$ defends A_1

$\{A_1\}$ defends A_3

$\{A_3\}$ defends A_3

$\{A_1, A_3\}$ defends A_1

$\{A_1, A_3\}$ defends A_3

Abstract argumentation

Let Γ be a conflict-free set of arguments,

Γ is **admissible** iff $\Gamma = \{A \in \Gamma \mid \Gamma \text{ defends } A\}$

Γ is **complete** iff $\Gamma = \{A \in \mathcal{A} \mid \Gamma \text{ defends } A\}$

Γ is **grounded** iff it is the minimal (w.r.t. set inclusion) complete extension.

Γ is **preferred** iff it is a maximal (w.r.t. set inclusion) complete extension.

E.g. For $A_1 \leftrightarrow A_2$, we have the following extensions:

	admissible	complete	grounded	preferred
$\{\}$	$\times$	$\times$	$\times$	
$\{A_1\}$	$\times$	$\times$		$\times$
$\{A_2\}$	$\times$	$\times$		$\times$

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$\{A_3\}$	$\times$			
$\{A_1, A_3\}$	$\times$	$\times$	$\times$	$\times$

Abstract argumentation

- There is a range of definitions for extensions (semantics) with inter-relationships (e.g. Dung, Dung+Mancarella+Toni, Caminada, Baroni + Giacomin, Coste-Marquis+Devred+Marquis)
- The complexity class for numerous decision questions identified (Dunne).
- Implementated systems for computing extensions include Dungine (www.argkit.org) by South et al
- Enriched abstract argument systems

  - with value of each argument (Bench-Capon)

  - with logical constraints (Coste-Marquis et al)

  - with supporting arguments (Amgoud, Cayrol, Lagasquie-Schiex)

  - with conditional priorities over attacks (Modgil)

From abstract to logical argumentation

- Abstract argumentation lacks ways to

  - to construct arguments or attacks relation

  - to divide arguments

  - to combine arguments

- Logical argumentation offers a solution

  - arguments constructed from knowledge via deduction

  - attacks identified via counterarguments

Logical arguments

Let Δ be set of formulas in classical logic

An **argument** is a pair $\langle \Phi, \alpha \rangle$ such that

1. $\Phi \nvdash \bot$
2. $\Phi \vdash \alpha$
3. Φ is a minimal subset of Δ satisfying 2

Φ is the **support** and α is the **claim** of the argument

Example: Let $\Delta = \{\alpha, \alpha \rightarrow \beta, \gamma \rightarrow \neg\beta, \gamma, \delta, \delta \rightarrow \beta, \neg\alpha, \neg\gamma\}$

Some arguments are:

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

$\langle \{\delta, \delta \rightarrow \beta\}, \beta \rangle \quad \langle \{\alpha, \neg\gamma\}, \alpha \wedge \neg\gamma \rangle$

Logical counterarguments

A **rebuttal** for $\langle \Phi, \alpha \rangle$ is an argument $\langle \Psi, \beta \rangle$
where $\beta \vdash \neg\alpha$

An **undercut** for $\langle \Phi, \alpha \rangle$ is an argument $\langle \Psi, \neg(\phi_1 \wedge \ldots \wedge \phi_n) \rangle$
where $\{\phi_1, \ldots, \phi_n\} \subseteq \Phi$

Example: Let $\Delta = \{\alpha, \alpha \rightarrow \beta, \gamma, \gamma \rightarrow \neg\alpha\}$

$\langle \{\alpha\}, \alpha \rangle$ is a rebut for $\langle \{\gamma, \gamma \rightarrow \neg\alpha\}, \neg\alpha \rangle$

$\langle \{\gamma, \gamma \rightarrow \neg\alpha\}, \neg\alpha \rangle$ is an undercut for $\langle \{\alpha, \alpha \rightarrow \beta\}, \beta \rangle$

$\langle \{\gamma, \gamma \rightarrow \neg\alpha\}, \neg(\alpha \wedge (\alpha \rightarrow \beta)) \rangle$ is a more conservative undercut

Canonical undercuts

A **canonical undercut** for an argument $\langle \Phi, \alpha \rangle$, where $\Phi = \{\phi_1, .., \phi_n\}$, is an argument of the following form

$$\langle \Psi, \neg(\phi_1 \wedge ... \wedge \phi_n) \rangle$$

Example

$\langle \{\neg\alpha \vee \neg\beta\}, \neg(\alpha \wedge \beta) \rangle$ is a canonical undercut for $\langle \{\alpha, \beta\}, \alpha \wedge \beta \rangle$

- A canonical undercut is a "maximally conservative" undercut in the sense that the support and claim are the weakest possible for an undercut.
- Because they are maximally conservative, they subsume many other undercuts, thereby removing much redundancy.

An example of an argument tree

$$\langle\{\neg q_2, \neg q_2 \rightarrow q_1\}, q_1\rangle$$

$$\uparrow$$

$$\langle\{q_4, q_4 \rightarrow q_3, q_3 \rightarrow q_2\}, \Diamond\rangle$$

$$\nearrow \qquad \uparrow \qquad \nwarrow$$

$$\langle\{q_5, q_5 \rightarrow \neg q_4\}, \Diamond\rangle \quad \langle\{q_6, q_6 \rightarrow \neg q_3\}, \Diamond\rangle \quad \langle\{q_7, q_7 \rightarrow \neg(q_3 \rightarrow q_2)\}, \Diamond\rangle$$

q_1 Mobile phones are safe for children

q_2 Mobile phones have a health risk

q_3 Mobile phones heat the brain

q_4 Mobile phones emit strong em radiation

q_5 There is a high density of phone masts

q_6 Mobile phones can be used hands-free

q_7 Hot baths heat the brain

Another example of an argument tree

$$\langle\{\forall x.Q(x), \forall x.Q(x) \rightarrow \exists y,z.S(y,z)\}, \exists y,z.S(y,z)\rangle$$

$$\uparrow$$

$$\langle\{Pa, \forall x.(P(x) \rightarrow \neg Q(x) \vee R(x)), \neg\exists x.R(x)\}, \diamond\rangle$$

$$\nearrow \qquad\qquad \nwarrow$$

$$\langle\{\exists x.\neg(P(x) \rightarrow \neg Q(x) \vee R(x))\}, \diamond\rangle \qquad \langle\{\forall x.\neg(P(x) \wedge \neg R(x))\}, \diamond\rangle$$

Argument trees

An **argument tree** for α is a tree where the nodes are arguments such that

1. The root is an argument for α
2. For no node $\langle \Phi, \beta \rangle$ with ancestor nodes $\langle \Phi_1, \beta_1 \rangle, \ldots, \langle \Phi_n, \beta_n \rangle$ is Φ a subset of $\Phi_1 \cup \cdots \cup \Phi_n$
3. The children nodes of a node N consist of canonical undercuts for N that obey 2.

A **complete argument tree** is an argument tree where children nodes of a node N consist of all canonical undercuts for N that obey 2.

Judgement of an argument tree

Blue arguments are undefeated

Red arguments are defeated

Mr Jones has to have surgery to remove the heart tumour

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$\uparrow$

This is not a good plan: If we do it, there is a 50% chance he will die in the theatre

Judgement of an argument tree

Blue arguments are undefeated

Red arguments are defeated

Mr Jones has to have surgery to remove the heart tumour

$\uparrow$

This is not a good plan: If we do it, there is a 50% chance he will die in the theatre

$\uparrow$

But if we do nothing, then there is a 100% chance he will die within one month

Judgement of an argument tree

Blue arguments are undefeated

Red arguments are defeated

$$\langle\{\beta, \beta \rightarrow \alpha\}, \alpha\rangle$$

$$\uparrow$$

$$\langle\{\gamma, \delta, \delta \wedge \gamma \rightarrow \neg\beta\}, \diamond\rangle$$

$$\nearrow \qquad\qquad \nwarrow$$

$$\langle\{\phi, \phi \rightarrow \neg\gamma\}, \diamond\rangle \qquad\qquad \langle\{\psi, \psi \rightarrow \neg\delta\}, \diamond\rangle$$

$$\uparrow \qquad\qquad \uparrow$$

$$\langle\{\neg\psi\}, \diamond\rangle \qquad \langle\{\neg(\phi \rightarrow \neg\gamma)\}, \diamond\rangle$$

Logics for argumentation

Each logic-based argumentation system constructs arguments of the form $\langle \Phi, \alpha \rangle$ where $\Phi \vdash_i \alpha$ for some underlying logic $\vdash_i$ such as

- Classical logic
- Defeasible logic
- Temporal logic
- :
- Defeasible logic + Description logic

E.g. Nute, Prakken, Fox+Krause+Parsons, Simari et al, Cayrol et al, Caminada+Amgoud, Toni et al, Vreeswijk, Verheij, Pollock, Benferhat et al, Elvang et al, Amgoud+Cayrol, Besnard+Hunter, Bench-Capon, etc.

Ontology-based argumentation

- Δ is a set of rules of the form $\beta_1 \wedge \ldots \beta_j \rightarrow \beta_{j+1}$
- Γ is an ontology in classical/description logic

$\Delta \vdash_\Gamma \psi$ iff there is a sequence of literals $\alpha_1, \ldots, \alpha_n$
such that ψ is α_n and for each $\alpha_i \in \{\alpha_1, \ldots \alpha_n\}$
either there is a $\beta_1 \wedge \ldots \wedge \beta_j \rightarrow \alpha_i \in \Delta$
and $\{\beta_1, \ldots, \beta_j\} \subseteq \{\alpha_1, \ldots, \alpha_{i-1}\}$
or $\Gamma \cup \{\alpha_1, \ldots, \alpha_{i-1}\} \vdash \alpha_i$

E.g. $\{a \rightarrow b, c \rightarrow \neg d\} \vdash_{\{a, b \rightarrow c\}} \neg d$ because of the sequence $a, b, c, \neg d$.

Ontology-based argumentation

Let Δ be set of rules and let Γ be an ontology.

An **argument** is a pair $\langle \Phi, \alpha \rangle$ such that

1. Φ is consistent
2. Φ is a minimal subset of Δ s.t. $\Phi \vdash_\Gamma \alpha$

Example: Let $\Delta = \{b \wedge c \rightarrow d, d \rightarrow f, g \rightarrow \neg d, i \rightarrow \neg f\}$

and $\Gamma = \{a, a \rightarrow b, c, h, h \rightarrow g, i\}$

$\langle \{b \wedge c \rightarrow d, d \rightarrow f\}, f \rangle$

$\langle \{g \rightarrow \neg d\}, \neg d \rangle$ (undercut)

$\langle \{i \rightarrow \neg f\}, \neg f \rangle$ (rebut)

Ontology-based argumentation

- **Exploit the ontology as a repository of strict knowledge:** Use instances in ontology (ABox) as facts, and use class + relationship definitions in ontology (TBox) to infer further facts.
- **Exploit rigour of the ontology for the rule language:** Use class + relationship names of ontology as the predicate symbols in rules.
- **Exploit ontology reasoning software:** Evaluate each condition in a rule by querying the ontology.
- **Exploit argumentation system:** For generating and comparing arguments from defeasible rules (e.g. DeLP, ASPIC,CASAPI, etc).
- **Exploit the ontology to determine conflict between pairs of atoms:** Conflict is redefined in terms of inconsitency in the ontology.

Analysing knowledge in evidence-based medicine

A case study on evidence-based medicine in breast cancer

- 37 000 cases/ yr in the UK of whom $1/3^{rd}$ die
- Prognostic Factors: ER status, LN status, Bone Metastases
- Treatments: ER Blockers (Tamoxifen & Anastrazole)
- $>$ 500 new clinical trials/ year
- Trials offer evidence on *likely* outcomes for groups of patients
- Different trials address different (but often not disjoint) groups of patients, and often related types of drug (e.g. Tamoxifen & Hormone recepter antagonists)
- Different trials can conflict

Analysing knowledge in evidence-based medicine

CLASS NAMES

- DrugRegimes
  - Bisphosphonates
    - ZoledronicAcid
  - HormoneRA
    - Tamoxifen
      - Tamoxifen5Yr
      - Tamoxifen2Yr
    - Anastrazole
  - Diseases
  - Breast Cancer
    - ERPos Breast Cancer
    - ERNeg Breast Cancer
  - EndometrialCancer

PROPERTIES

hasDisease(Person, Disease)
hasTreatment(Person, Treatment)
hasAge(Person, int)

INSTANCES

Tamoxifen5Yr(TamCourseA)
Tamoxifen2Yr(TamCourseB)
Anastrazole(AnastrazoleCourseA)
ZoledronicAcid(ZolendronateA)

Analysing knowledge in evidence-based medicine

An example of a defeasible rule obtained from a clinical trial.

r_1:

Women(x)

$\wedge$ hasDisease(x,y) $\wedge$ EarlyBreastCancer(y) $\wedge$ ERPositiveDisease(y)

$\wedge$ hasTreatment(x,z) $\wedge$ Tamoxifen5Yr(z)

$\wedge$ IncreasedBrCaDFS(a)

$\Rightarrow$ hasDeltaRisk(x,a)

Note that all have a single treatment in the body & atom in the head

Analysing knowledge in evidence-based medicine

- From 39 papers on randomized clinical trials (RCTs), 68 defeasible rules obtained from the statistically significant relative risk statements in the abstracts.
- A set of such conditional formulae is normally inconsistent with an ontology and a set of integrity constraints.
- Construct arguments and counterarguments relating to the effects of different treatments involving tamoxifen on DFS and OS.
- Construct warranted arguments on toxicological effects of tamoxifen.
- Evaluation: Type I and II errors with clinical guidelines (e.g. NCI).
- Project undertaken by Matt Williams (an oncologist with CRUK funding).

Analysing knowledge in evidence-based medicine

- Rapidly growing base of results in publications forming a body of knowledge that is often incomplete and inconsistent
- Potential for systematic formal representation of such knowledge
- Potential for using information extraction technology
- With analytical tools, scientists and clinicians can compare, contrast and combine different sources of knowledge, e.g.
  - to review an area
  - to design or evaluate meta-analyses
  - to construct or evaluate clinical guidelines
  - to locate potentially interesting clinical questions
  - to see if new papers are somehow exceptional to established view

Our research in argumentation systems

- Analysis of computational complexity
- Development of algorithms and implemented systems
- Application studies in analysing scientific knowledge (including clinical trials, biochemical pathways & bioprocess design)
- Addressing pragmatics + rhetorics (since there is always an audience for argumentation)
  - Redundancy (syntactic, semantic, and enthymemes)
  - Relevancy (to an agent's informational needs)
  - Empathy or antipathy (for an argument w.r.t. an agent's beliefs)
  - Advocacy (appropriateness of an advovate for an argument)
  - Persuasiveness (of an argument to change beliefs of an agent)

Conclusions

- There is a need for inconsistency tolerance in applications
- Argumentation is an important cognitive process
- Argumentation systems offer diverse and useful approaches to using inconsistent information
- More info + papers at www.cs.ucl.ac.uk/staff/a.hunter
- For a review of argumentation systems,

Ph Besnard and A Hunter
Elements of Argumentation
MIT Press 2008