Representing and Reasoning about Arguments Mined from Texts and Dialogues

Leila Amgoud[1], Philippe Besnard[1] and Anthony Hunter[2]

[1]CNRS, IRIT, Université de Toulouse, Toulouse, France
[2]University College London, London, U.K.

July 13, 2015

Overview

Issues

In this paper, we are concerned with two interrelated issues.

1. An appropriate target language for representing arguments mined from natural language.
2. Methods to combine, deconstruct, and analyse (for instance to check whether the set is inconsistent) with arguments mined from text.

Proposal

- A formal language for representing some of the structure of arguments.
- A framework for inferencing with the arguments in this formal language.
- This framework is flexible so different sets of inference rules can be used.

Arguments in natural language

Red denotes outer reason-claim coupling, and blue denotes inner reason-claim coupling. Note, outer reason-claim coupling has two reasons for the claim.

⟨claim⟩Heathrow needs more capacity⟨\claim⟩

⟨reason⟩ Heathrow runs at close to 100% capacity. With demand for air travel predicted to double in a generation, Heathrow will not be able to cope without a third runway, say those in favour of the plan. ⟨\reason⟩

⟨reason⟩ ⟨reason⟩ Because the airport is over-stretched, any problems which arise cause knock-on delays. ⟨\reason⟩ ⟨claim⟩ Heathrow, the argument goes, needs extra capacity if it is to reach the levels of service found at competitors elsewhere in Europe, or it will be overtaken by its rivals. ⟨\claim⟩ ⟨\reason⟩

`http://news.bbc.co.uk/1/hi/uk/7828694.stm`

Syntax

Formula

A *formula* is of the following form where each of x and y is *either* a formula of $\mathbb{L}$ *or* a formula of the form

$$(-)\mathcal{R}(y) : (-)\mathcal{C}(x)$$

The set of formulas is denoted $\texttt{Arg}(\mathbb{L})$.

Argument

An *argument* is a formula of $\texttt{Arg}(\mathbb{L})$ of the form

$$\mathcal{R}(y) : (-)\mathcal{C}(x)$$

Syntax

Two types of argument

$$\mathcal{R}(y) : \mathcal{C}(x) \text{ means that } \text{“}y \text{ is a reason for concluding } x\text{”}$$
$$\mathcal{R}(y) : -\mathcal{C}(x) \text{ means that } \text{“}y \text{ is a reason for not concluding } x\text{”}$$

Examples of arguments

1. Paul: Carl will fail his exams (*fe*). He did not work hard ($\neg wh$).
   $\mathcal{R}(\neg wh) : \mathcal{C}(fe)$
2. Mary: No, he will not fail. The exams will be easy this semester (*ee*).
   $\mathcal{R}(ee) : \mathcal{C}(\neg fe)$
3. John: Carl is very smart! (*sm*).
   $\mathcal{R}(sm) : -\mathcal{C}(fe)$

Syntax

Rejection (anti-argument)

A *rejection of an argument* is a formula of $\texttt{Arg}(\mathbb{L})$ of the form

$$-\mathcal{R}(y) : (-)\mathcal{C}(x)$$

Two types of rejection

$-\mathcal{R}(y) : \mathcal{C}(x)$ means that "y is not a reason for concluding x"
$-\mathcal{R}(y) : -\mathcal{C}(x)$ means that "y is not a reason for not concluding x"

Examples of rejections

1. Paul: The fact that Carl is smart is not a reason to stop concluding that he will fail his exams. $-\mathcal{R}(sm) : -\mathcal{C}(fe)$
2. John: Anyway, the fact that Carl did not work hard is not a reason to conclude that he will fail his exams.
$-\mathcal{R}(\neg wh) : \mathcal{C}(fe)$
3. Mary: Stress is the reason that Carl will fail his exams, hence it is not the fact that he did not work hard (st).
$\mathcal{R}(\mathcal{R}(st) : \mathcal{C}(fe)) : \mathcal{C}(-\mathcal{R}(\neg wh) : \mathcal{C}(fe))$
4. Sara: He is not stressed at all.
$\mathcal{R}(\neg st) : \mathcal{C}(-\mathcal{R}(st) : \mathcal{C}(fe))$

Syntax

Levels of counterargument

Therefore, for an argument $\mathcal{R}(y) : \mathcal{C}(x)$, there are various levels of counterargument.

1. $\mathcal{R}(z) : \mathcal{C}(\neg x)$ = "y is a reason for concluding $\neg x$"
2. $\mathcal{R}(z) : -\mathcal{C}(x)$ = "y is a reason for not concluding x"
3. $-\mathcal{R}(z) : \mathcal{C}(x)$ = "y is not a reason for concluding x"

Examples

- $\mathcal{R}(bird) : \mathcal{C}(fly)$
- $\mathcal{R}(dead) : \mathcal{C}(\neg fly)$
- $\mathcal{R}(penguin) : -\mathcal{C}(fly)$
- $-\mathcal{R}(egglaying) : \mathcal{C}(fly)$

Syntax: Use as a target language

$\langle x_1 \rangle$*Heathrow needs more capacity*$\langle \backslash x_1 \rangle$

$\langle y_1 \rangle$*Heathrow runs at close to 100% capacity. With demand for air travel predicted to double in a generation, Heathrow will not be able to cope without a third runway*$\langle \backslash y_1 \rangle$*, say those in favour of the plan.*

$\langle z_1 \rangle$*Because the airport is over-stretched*$\langle \backslash z_1 \rangle$*,* $\langle z_2 \rangle$*any problems which arise cause knock-on delays*$\langle \backslash z_2 \rangle$*.* $\langle z_3 \rangle$*Heathrow, the argument goes, needs extra capacity if it is to reach the levels of service found at competitors elsewhere in Europe, or it will be overtaken by its rivals*$\langle \backslash z_3 \rangle$*.*

1. $\mathcal{R}(y_1) : \mathcal{C}(x_1)$
2. $\mathcal{R}(\mathcal{R}(\mathcal{R}(z_1) : \mathcal{C}(z_2)) : \mathcal{C}(z_3)) : \mathcal{C}(x_1)$

Advantages over logical argumentation

Our approach

- CFCs (*cfc*) cause damage to the ozone layer of the atmosphere (*do*). Man-made pollution (*mp*) causes global warming (*gw*).

$$\mathcal{R}(\mathcal{R}(cfc) : \mathcal{C}(do)) : \mathcal{C}(\mathcal{R}(mp) : \mathcal{C}(gw))$$

Logical approach

We could represent as follows

$$\langle\{(cfc \to do) \to (mp \to gw)\}, (cfc \to do) \to (mp \to gw)\rangle$$

- But the reasons and claims are not clearly delineated.
- And we are forced to use inference rules and semantics of $\to$ (whereas we want to decouple the Boolean connectives from the $\mathcal{R}(.) : \mathcal{C}(.)$ formulae).

Advantages over logical argumentation

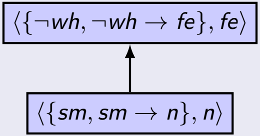
Our approach

- We cannot conclude that Carl will fail his exams (*fe*) because he is very smart (*sm*).

$$\mathcal{R}(sm) : -\mathcal{C}(fe)$$

Logical approach

Let *wh* denote Carl worked hard, and *n* denote the non-application of the defeasible rule $\neg wh \rightarrow fe$



Our solution (i.e., using argument of the form $\mathcal{R}(sm) : -\mathcal{C}(fe)$) makes the connection between *sm* and *fe* explicit in one formula.

Advantages over logical argumentation

No other logic-based approach to modelling argumentation provides a language for expressing rejection of arguments in the object language.

Example

- We can differentiate between the following where cr denotes *"The car is red"* and bc denotes *"We should buy the car"*.
  - $-\mathcal{R}(cr) : \mathcal{C}(bc)$ could counter $\mathcal{R}(cr) : \mathcal{C}(bc)$ because we need to consider more than the colour of the car when buying.
  - $\mathcal{R}(cr) : -\mathcal{C}(bc)$ could counter $\mathcal{R}(cr) : \mathcal{C}(bc)$ because we do not like the colour red for a car.
- Even if we identify the rejection $-\mathcal{R}(cr) : \mathcal{C}(bc)$, it is possible that we could identify another argument for buying the car using other criteria such as $\mathcal{R}(ec \wedge sp) : \mathcal{C}(bc)$ where ec denotes *"The car is economical"* and sp denotes *"The car is spacious"*.

Advantages over logical argumentation

Most natural language arguments are enthymemes

- Since most arguments are enthymemes, some premises (and sometimes claim) are implicit.
- Decoding enthymemes from natural language into logic requires
  - extensive background and/or common-sense knowledge.
  - and deep parsing techniques

Our approach handles enthymemes without decoding

For example

- Paul's car is in the park (*pr*) because it is broken (*br*), hence we cannot conclude that Paul is in his office (*of*).

$$\mathcal{R}(\mathcal{R}(br) : \mathcal{C}(pr)) : -\mathcal{C}(of)$$

Reasoning

Consistency

Let x be a formula in $\mathbb{L}$

$$\frac{\mathcal{R}(y) : \mathcal{C}(x)}{-\mathcal{R}(y) : -\mathcal{C}(x)} \qquad \frac{\mathcal{R}(y) : \mathcal{C}(x)}{\mathcal{R}(y) : -\mathcal{C}(\neg x)}$$

Example

Carl works hard (*wh*), so he will pass his exams (*pe*).

$$\frac{\mathcal{R}(wh) : \mathcal{C}(pe)}{-\mathcal{R}(wh) : -\mathcal{C}(pe)} \qquad \frac{\mathcal{R}(wh) : \mathcal{C}(pe)}{\mathcal{R}(wh) : -\mathcal{C}(\neg pe)}$$

Reasoning

Consequence relation

A consequence relation $\Vdash$ is the least closure of a set of *inference rules* extended with one *meta-rule*.

Any inference rule can be reversed

$$\frac{\mathcal{R}(y) : \Phi}{-\mathcal{R}(y) : \Psi} \qquad \text{into} \qquad \frac{\mathcal{R}(y) : \Psi}{-\mathcal{R}(y) : \Phi}$$

Meta rule

Let $i, j \in \{0, 1\}$

$$\frac{-^{(i)}\mathcal{R}(y) : \Phi}{-^{(j)}\mathcal{R}(y) : \Psi} \qquad \text{can be reversed into} \qquad \frac{-^{(1-j)}\mathcal{R}(y) : \Psi}{-^{(1-i)}\mathcal{R}(y) : \Phi}$$

Reasoning

Proposition

The inference rules below are derived from (Consistency) and the meta-rule (where x is a formula in $\mathbb{L}$ in the first, third and fourth inference rules).

$$\frac{\mathcal{R}(y) : \mathcal{C}(x)}{-\mathcal{R}(y) : \mathcal{C}(\neg x)} \quad \frac{\mathcal{R}(y) : -\mathcal{C}(x)}{-\mathcal{R}(y) : \mathcal{C}(x)} \quad \frac{\mathcal{R}(y) : \mathcal{C}(\neg x)}{\mathcal{R}(y) : -\mathcal{C}(x)} \quad \frac{\mathcal{R}(y) : \mathcal{C}(\neg x)}{-\mathcal{R}(y) : \mathcal{C}(x)}$$

Examples of using the proposition

$$\frac{\mathcal{R}(bird) : \mathcal{C}(fly)}{-\mathcal{R}(bird) : \mathcal{C}(\neg fly)} \qquad \frac{\mathcal{R}(bird \wedge dead) : \mathcal{C}(\neg fly)}{\mathcal{R}(bird \wedge dead) : -\mathcal{C}(fly)}$$

$$\frac{\mathcal{R}(penguin) : -\mathcal{C}(fly)}{-\mathcal{R}(penguin) : \mathcal{C}(fly)} \qquad \frac{\mathcal{R}(bird \wedge dead) : \mathcal{C}(\neg fly)}{-\mathcal{R}(bird \wedge dead) : \mathcal{C}(fly)}$$

Example of a reasoning system: Indicative reasoning

Inference rules of indicative reasoning

$$\frac{\mathcal{R}(y):\mathcal{C}(x) \quad \mathcal{R}(x):\mathcal{C}(y) \quad \mathcal{R}(y):\mathcal{C}(z)}{\mathcal{R}(x):\mathcal{C}(z)} \quad \textbf{(Mutual Support)}$$

$$\frac{\mathcal{R}(y):\mathcal{C}(x) \qquad \mathcal{R}(z):\mathcal{C}(x)}{\mathcal{R}(y\vee z):\mathcal{C}(x)} \quad \textbf{(Or)}$$

$$\frac{\mathcal{R}(y\wedge z):\mathcal{C}(x) \qquad \mathcal{R}(y):\mathcal{C}(z)}{\mathcal{R}(y):\mathcal{C}(x)} \quad \textbf{(Cut)}$$

$$\frac{\mathcal{R}(y):\mathcal{C}(z) \qquad \mathcal{R}(y):\mathcal{C}(x)}{\mathcal{R}(y\wedge z):\mathcal{C}(x)} \quad \textbf{(Cautious Monotonicity)}$$

$$\frac{\mathcal{R}(y):\mathcal{C}(\mathcal{R}(z):\mathcal{C}(x))}{\mathcal{R}(y\wedge z):\mathcal{C}(x)} \quad \textbf{(Exportation)}$$

$$\frac{\mathcal{R}(y):\mathcal{C}(\mathcal{R}(z):\mathcal{C}(x))}{\mathcal{R}(z):\mathcal{C}(\mathcal{R}(y):\mathcal{C}(x))} \quad \textbf{(Permutation)}$$

Example of a reasoning system: Indicative reasoning

Examples

- Let x stand for "Paul and Mary are married to each other", y for "Paul and Mary are in love with each other", z for "Paul and Mary go for a romantic dinner".

$$\frac{\mathcal{R}(y) : \mathcal{C}(x) \quad \mathcal{R}(x) : \mathcal{C}(y) \quad \mathcal{R}(y) : \mathcal{C}(z)}{\mathcal{R}(x) : \mathcal{C}(z)} \qquad \textbf{(Mutual Support)}$$

- Birds (b) with wings (w) fly (f)

$$\frac{\mathcal{R}(b \wedge w) : \mathcal{C}(f) \qquad \mathcal{R}(b) : \mathcal{C}(w)}{\mathcal{R}(b) : \mathcal{C}(f)} \qquad \textbf{(Cut)}$$

Example of a reasoning system: Indicative reasoning

Examples

John has a good idea (*gi*), so if he perseveres (*ps*), he will succeed (*su*).

$$\frac{\mathcal{R}(gi) : \mathcal{C}(\mathcal{R}(ps) : \mathcal{C}(su))}{\mathcal{R}(gi \wedge ps) : \mathcal{C}(gi)} \quad \textbf{(Exportation)}$$

$$\frac{\mathcal{R}(gi) : \mathcal{C}(\mathcal{R}(ps) : \mathcal{C}(su))}{\mathcal{R}(ps) : \mathcal{C}(\mathcal{R}(gi) : \mathcal{C}(su))} \quad \textbf{(Permutation)}$$

Example of a reasoning system: Indicative reasoning

Proposition (Coherence)

There is no $i, j \in \{0, 1\}$ such that the following is a derived inference rule.

$$\frac{-^{(i)}\mathcal{R}(y) : -^{(j)}\mathcal{C}(x)}{-^{(1-i)}\mathcal{R}(y) : -^{(j)}\mathcal{C}(x)}$$

Examples

- $-\mathcal{R}(y) : \mathcal{C}(x)$ cannot be derived from $\mathcal{R}(y) : \mathcal{C}(x)$
- $-\mathcal{R}(y) : -\mathcal{C}(x)$ cannot be derived from $\mathcal{R}(y) : -\mathcal{C}(x)$

Example of a reasoning system: Indicative reasoning

Proposition

The following inference rules do not hold for restricted reasoning

$$\frac{\forall x \in \mathbb{L}}{\mathcal{R}(x) : \mathcal{C}(x)} \qquad \textbf{(Reflexivity)}$$

$$\frac{\models y \rightarrow x}{\mathcal{R}(y) : \mathcal{C}(x)} \qquad \textbf{(Logical Consequence)}$$

$$\frac{\mathcal{R}(y) : \mathcal{C}(x) \qquad \models y \leftrightarrow z}{\mathcal{R}(z) : \mathcal{C}(x)} \qquad \textbf{(Left Logical Equivalence)}$$

$$\frac{\mathcal{R}(y) : \mathcal{C}(x) \qquad \models x \rightarrow x'}{\mathcal{R}(y) : \mathcal{C}(x')} \qquad \textbf{(Right Logical Consequence)}$$

$$\frac{\mathcal{R}(y) : \mathcal{C}(x) \qquad \mathcal{R}(y) : \mathcal{C}(z)}{\mathcal{R}(y) : \mathcal{C}(x \wedge z)} \qquad \textbf{(And)}$$

$$\frac{\mathcal{R}(z) : \mathcal{C}(y) \qquad \mathcal{R}(y) : \mathcal{C}(x)}{\mathcal{R}(z) : \mathcal{C}(x)} \qquad \textbf{(Transitivity)}$$

$$\frac{\mathcal{R}(y) : \mathcal{C}(x) \qquad z \models y}{\mathcal{R}(z) : \mathcal{C}(x)} \qquad \textbf{(Left Logical Consequence)}$$

Example of a reasoning system: Indicative reasoning

Example to motivate need for failure of reflexivity

Let x stand for "I should have a pay rise".

$$\frac{\forall x \in \mathbb{L}}{\mathcal{R}(x) : \mathcal{C}(x)}$$

Example to motivate need for failure of right logical consequence

Let x be "temp in range 39-41C" and let x' be "temp in range 36-41C"

$$\frac{\mathcal{R}(\mathit{flu}) : \mathcal{C}(x) \qquad \models x \rightarrow x'}{\mathcal{R}(\mathit{flu}) : \mathcal{C}(x')}$$

Example to motivate need for and

Let y be "Paul is standing in the middle of the road while a car is approaching", x be "Paul should move forward", and z be "Paul should move backwards".

$$\frac{\mathcal{R}(y) : \mathcal{C}(x) \qquad \mathcal{R}(y) : \mathcal{C}(z)}{\mathcal{R}(y) : \mathcal{C}(x \wedge z)}$$

Example of a reasoning system: Indicative reasoning

Proposition

Mutual Support is a special instance of transitivity.

Proposition

The following *non*-implications hold:

- $\mathcal{R}(y) : -\mathcal{C}(\mathcal{R}(z) : \mathcal{C}(x))$ does not imply $\mathcal{R}(y) : -\mathcal{C}(x)$
- $\mathcal{R}(y) : -\mathcal{C}(x)$ does not imply $\mathcal{R}(y) : -\mathcal{C}(\mathcal{R}(z) : \mathcal{C}(x))$

The above result shows that blocking a reason is different from blocking a conclusion in restricted reasoning.

Example of a reasoning system: Indicative reasoning

Proposition

The following are properties of the $\Vdash$ relation where Δ is a set of (rejections of) arguments, and α and β are (rejections of) arguments.

$$\Delta \Vdash \alpha \text{ if } \alpha \in \Delta \qquad \textbf{(Reflexivity)}$$
$$\Delta \cup \{\alpha\} \Vdash \beta \text{ if } \Delta \Vdash \beta \qquad \textbf{(Monotonicity)}$$
$$\Delta \Vdash \beta \text{ if } \Delta \cup \{\alpha\} \Vdash \beta \text{ and } \Delta \Vdash \alpha \qquad \textbf{(Cut)}$$

This result shows that the consequence relation $\Vdash$ for indicative reasoning meets the minimum requirements as argued by Tarski.

Example of a reasoning system: Indicative reasoning

Proposition

The following non-trivialization property holds for the $\Vdash$ relation:

$$\{-^{(i)}\mathcal{R}(y) : -^{(j)}\mathcal{C}(x), -^{(1-i)}\mathcal{R}(y) : -^{(j)}\mathcal{C}(x)\} \nVdash \texttt{Arg}(\mathbb{L})$$

This shows that the $\Vdash$ consequence relation is *paraconsistent* in the sense that it is not trivialized by inconsistency (i.e. not all formulae of the language $\texttt{Arg}(\mathbb{L})$ follow from inconsistency).

Example

$$\{\mathcal{R}(y) : \mathcal{C}(x), \mathcal{R}(y) : -\mathcal{C}(x)\} \nVdash \texttt{Arg}(\mathbb{L})$$

Representing attacks

Inference rules for deriving attacks

$$\frac{\mathcal{R}(y):\mathcal{C}(x) \qquad \mathcal{R}(z):\mathcal{C}(\neg x)}{\mathcal{R}(\mathcal{R}(z):\mathcal{C}(\neg x)):\mathcal{C}(-\mathcal{R}(y):\mathcal{C}(x))} \quad \textbf{(Strong Rebuttal)}$$

$$\frac{\mathcal{R}(y):\mathcal{C}(x) \qquad \mathcal{R}(z):-\mathcal{C}(x)}{\mathcal{R}(\mathcal{R}(z):-\mathcal{C}(x)):\mathcal{C}(-\mathcal{R}(y):\mathcal{C}(x))} \quad \textbf{(Weak Rebuttal)}$$

$$\frac{\mathcal{R}(y):\mathcal{C}(x) \qquad \mathcal{R}(z):\mathcal{C}(\neg y)}{\mathcal{R}(\mathcal{R}(z):\mathcal{C}(\neg y)):\mathcal{C}(-\mathcal{R}(y):\mathcal{C}(x))} \quad \textbf{(Strong Premise Attack)}$$

$$\frac{\mathcal{R}(y):\mathcal{C}(x) \qquad \mathcal{R}(z):-\mathcal{C}(y)}{\mathcal{R}(\mathcal{R}(z):-\mathcal{C}(y)):\mathcal{C}(-\mathcal{R}(y):\mathcal{C}(x))} \quad \textbf{(Weak Premise Attack)}$$

$$\mathcal{R}(z):\mathcal{C}(-\mathcal{R}(y):\mathcal{C}(x)) \quad \textbf{(Strong Reason Attack)}$$

$$\mathcal{R}(z):-\mathcal{C}(\mathcal{R}(y):\mathcal{C}(x)) \quad \textbf{(Weak Reason Attack)}$$

$$-\mathcal{R}(y):\mathcal{C}(x) \quad \textbf{(Pure Reason Attack)}$$

For comparison with logical argumentation, strong rebuttal captures “rebuttal”, strong premise attack captures “assumption attack”, and weak reason attack captures Pollock’s undercutting.

Representing attacks

Example of strong rebuttal (capturing "rebuttal")

Nixon is quaker (*nq*) and Nixon is a republican (*nr*). Is Nixon a pacifist (*np*)?

$$\frac{\mathcal{R}(nq) : \mathcal{C}(np) \qquad \mathcal{R}(nr) : \mathcal{C}(\neg np)}{\mathcal{R}(\mathcal{R}(nr) : \mathcal{C}(\neg np)) : \mathcal{C}(-\mathcal{R}(nq) : \mathcal{C}(np))}$$

Example of strong premise attack (capturing "assumption attack")

The weather is good (*gw*) so the bbq will be a success (*bs*). But, the weather report predicts rain (*ra*).

$$\frac{\mathcal{R}(gw) : \mathcal{C}(bs) \qquad \mathcal{R}(ra) : \mathcal{C}(\neg gw)}{\mathcal{R}(\mathcal{R}(ra) : \mathcal{C}(\neg gw)) : \mathcal{C}(-\mathcal{R}(gw) : \mathcal{C}(bs))}$$

Example of weak reason attack (capturing Pollock's undercutting)

The object looks red (*lr*). It is illuminated by red light (*il*). Thus, we cannot conclude that looking red implies the object being indeed red (*re*).

$$\mathcal{R}(\mathcal{R}(il) : \mathcal{C}(lr)) : -\mathcal{C}(\mathcal{R}(lr) : \mathcal{C}(re))$$

Conclusions

Some advantages of our approach

- Target language for mined arguments that is between abstract and logical argumentation
- Representation of link between reason and claim
- Explicit representation of support in the object language
- Practical representation of enthymemes
- Representation of rejections (anti-arguments)
- Nesting of arguments and rejections
- Explicit representation of attacks in the object language
- Reasoning systems (inference rules and/or semantics)