On ASPIC^{+} and Defeasible Logic

Ho-Pun Lam, Guido Governatori and Régis Riveret

COMMA 2016
Potsdam, Germany
14-16 September 2016

Outlines

- Background
  - ASPIC$^+$
  - DL and its variants
- Acceptability of Arguments in ASPIC$^+$ and DL
- Mapping from ASPIC$^+$ to DL
- Conclusions

ASPIC^{+}

An *argumentation system* (AS) is a triple $AS = (\mathcal{L}, \mathcal{R}, n)$ where:

1. $\mathcal{L}$ is a logical language closed under negation ($\neg$).
2. $\mathcal{R} = \mathcal{R}_s \cup \mathcal{R}_d$ is a set of strict ($\mathcal{R}_s$) and defeasible ($\mathcal{R}_d$) inference rules of the form $\varphi_1, \ldots, \varphi_n \rightarrow \varphi$ and $\varphi_1, \ldots, \varphi_n \Rightarrow \varphi$ respectively (where φ_i, φ are meta-variables ranging over wff in $\mathcal{L}$), and such that $\mathcal{R}_s \cap \mathcal{R}_d = \emptyset$.
3. n is a naming convention for defeasible rules such that $n : \mathcal{R}_d \rightarrow \mathcal{L}$.

ASPIC$^+$ (cont.)

A *knowledge base* in $AS = (\mathcal{L}, \mathcal{R}, n)$ is a set $\mathcal{K} \subseteq \mathcal{L}$ where $\mathcal{K} = \mathcal{K}_n \cup \mathcal{K}_p$ where:

- $\mathcal{K}_n$ =*necessary* premises; and
- $\mathcal{K}_p$ =*ordinary* premises (assumptions).

An *argumentation theory* is a tuple $AT = (AS, \mathcal{K})$ where AS is an argumentation system and $\mathcal{K}$ is a knowledge base in AS.

ASPIC$^+$ (cont.)

An *argument* A on the basis of an argumentation theory with a knowledge base $\mathcal{K}$ and an argumentation system $(\mathcal{L}, \mathcal{R}, n)$ is:

- φ if $\varphi \in \mathcal{K}$, with: $\mathsf{Prem}(A) = \{\varphi\}$; $\mathsf{Conc}(A) = \{\varphi\}$; $\mathsf{Sub}(A) = \{A\}$; $\mathsf{Rules}(A) = \emptyset$; $\mathsf{DefRules}(A) = \emptyset$, $\mathsf{TopRule}(A) =$ undefined.
- $A_1, \ldots, A_n \rightarrow / \Rightarrow \psi$ if $A_1, \ldots, A_n$ are arguments such that there exists a strict/defeasible rule $\mathsf{Conc}(A_1), \ldots, \mathsf{Conc}(A_n) \rightarrow / \Rightarrow \psi$ in $\mathcal{R}_s/\mathcal{R}_d$, with:
  - $\mathsf{Prem}(A) = \mathsf{Prem}(A_1) \cup \ldots \cup \mathsf{Prem}(A_n)$,
  - $\mathsf{Conc}(A) = \psi$,
  - $\mathsf{Sub}(A) = \mathsf{Sub}(A_1) \cup \ldots \cup \mathsf{Sub}(A_n) \cup \{A\}$. Note that $A_1, \ldots, A_n$ are referred to as the proper sub-arguments of A,
  - $\mathsf{DefRules}(A) = \{r \mid r \in \mathsf{Rules}(A), r \in \mathcal{R}_d\}$
  - $\mathsf{StRules}(A) = \{r \mid r \in \mathsf{Rules}(A), r \in \mathcal{R}_s\}$
  - $\mathsf{TopRule}(A) = \mathsf{Conc}(A_1), \ldots, \mathsf{Conc}(A_n) \rightarrow / \Rightarrow \psi$

where Prem returns the set of formula from $\mathcal{K}$ (premises) that used to build A, Conc returns its conclusion, Sub returns all its sub-arguments, DefRules and StRules respectively return the set of defeasible and strict rules in A, and TopRule returns the last inference rule applied in A.

ASPIC$^+$: Types of Argument

An argument A is:

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

ASPIC$^+$: Attack and Defeat

- Argument A *undercuts* argument B (on B') iff $\text{Conc}(A) = \neg n(r)$ for some $B' \in \text{Sub}(B)$ such that B''s top rule r is defeasible.
- Argument A *rebuts* argument B (on B') iff $\text{Conc}(A) = {\sim}\varphi$ for some $B' \in \text{Sub}(B)$ of the form $B''_1, \ldots, B''_n \Rightarrow \varphi$.
- Argument A *undermines* B (on φ) iff $\text{Conc}(A) = {\sim}\varphi$ for an ordinary premise φ of B.

Argument A *attacks* B iff A undercuts, rebuts or undermines B.

Argument A *defeats* B iff for some B'

- A undermines B on $B' = \phi$ and not $A \preceq \phi$; or
- A rebuts B on B' and not $A \preceq B'$; or
- A undercuts B on B'

ASPIC$^+$: Some Properties

Argument Structure

- Directed acyclic graphs where
  - Nodes are wff of a logical language $\mathcal{L}$
  - Links are applications of inference rules
    - $\mathcal{R}_s$ = Strict rules ($A_1, \ldots, A_n \rightarrow \psi$); or
    - $\mathcal{R}_s$ = Defeasible rules ($A_1, \ldots, A_n \Rightarrow \psi$)
  - Reasoning starts with a knowledge base $\mathcal{K} \subseteq \mathcal{L}$

Defeat

- Attack on conclusion, premise or inference, + preferences

Argument acceptability

- The justified ASPIC$^+$ arguments are evaluated w.r.t Dung's argumentation framework relating ASPIC$^+$ arguments by defeat relation.

Defeasible Logic (DL)

- Rule-base, without disjunction

$$r : A(r) \hookrightarrow C(r)$$

  where
  - r is the unique identifier of the rule
  - $A(r) = a_1, \cdots, a_n$ the *antecedent* of the rule (where a_i is a literal)
  - $\hookrightarrow = \{\rightarrow, \Rightarrow, \rightsquigarrow\}$ denotes the type of the rule ($\rightarrow$=*strict rule*, $\Rightarrow$=*defeasible rule*, and $\rightsquigarrow$=*defeater*)
  - $C(r)$ the *consequent* (or *head*) of the rule
- Classical negation is used in the heads and bodies of rules
  - Negation-as-failure is **NOT** used but can be emulated
- Rules may support conflicting conclusions
- Direct Skeptical: conflicting rules do not fire
  - consistency is preserved
- Priorities on rules (*superiority relation*) may be used to resolve some conflicts among rules

Defeasible Logic (cont.)

A conclusion of a DL theory D is a tagged literal and can have one of the following forms:

- $+\Delta l$ meaning that we have a definite derivation of l;
- $-\Delta l$ meaning that we do not have a definite derivation of l;
- $+\partial l$ meaning that we have a defeasible derivation of l;
- $-\partial l$ meaning that we do not have a defeasible derivation of l.

Defeasible Logic (cont.)

A proof is a finite sequence $P = (P(1), \ldots, P(n))$ of tagged literals. For example,

$+\Delta$) If $P(n+1) = +\Delta q$ then either
- (1) $q \in F$; or
- (2) $\exists r \in R_s[q]$ such that r is Δ-applicable.

$+\partial$) If $P(n+1) = +\partial q$ then either
- (1) $+\Delta q \in P(1..n)$; or
- (2) $-\Delta{\sim}q \in P(1..n)$, and
  - (1) $\exists r \in R_{sd}[q]$ such that r is ∂-applicable, and
  - (2) $\forall s \in R[{\sim}q]$ either
    - (1) s is ∂-discarded; or
    - (2) $\exists t \in R_{sd}[q]$ such that t is ∂-applicable and $t \succ s$.

- The inference condition for negative proof tags (-$\Delta$and -∂) is based on the Principle of Strong Negation [3].

Variants of DL

Example (Presumption of Innocence)

Consider a DL theory with the following rules.

$$\begin{aligned} r_1 &: \ \ \mathit{evidenceA} \Rightarrow \neg \mathit{responsible} \\ r_2 &: \ \ \mathit{evidenceB} \Rightarrow \mathit{responsible} \end{aligned} \qquad \begin{aligned} r_3 &: \ \ \mathit{responsible} \Rightarrow \mathit{guilty} \\ r_4 &: \ \ \Rightarrow \neg \mathit{guilty} \end{aligned}$$

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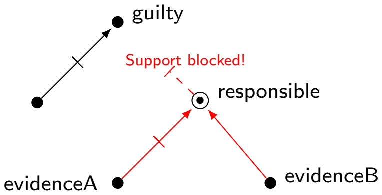
r_2: & evidenceB \Rightarrow responsible & \quad & r_3: & responsible & \Rightarrow guilty \\
 & & & r_4: & & \Rightarrow \neg guilty
\end{array}
$$

Given both *evidenceA* and *evidenceB*, r_3 is not applicable. So $+\partial\neg guilty$ is concluded (ambiguity blocking).



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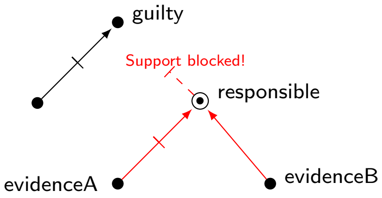

Notice that there are no justified arguments in the grounded extension, thus $\neg$*guilty* is not a skeptical conclusion in ASPIC$^+$.

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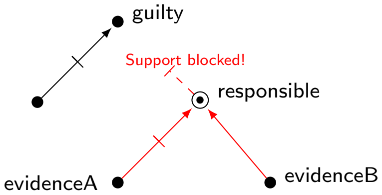

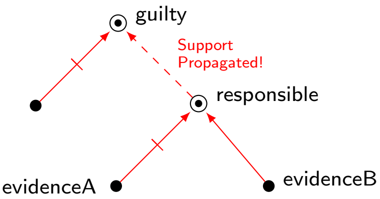

Consequently the literals *guilty* and $\neg$*guilty* are ambiguous; hence an undisputed conclusions cannot be drawn, and we refer to this behaviour as *ambiguity propagation*.

Variants of DL: Ambiguity propagation

$+\sigma$) If $P(n+1) = +\sigma q$ then either
  (1) $+\Delta q \in P(1..n)$ or
  (2) (1) $-\Delta{\sim}q \in P(1..n)$, and
    (2) $\exists r \in R_{sd}[q]$ such that
      (1) r is σ-applicable, and
      (2) $\forall s \in R[{\sim}q]$ either
        s is δ-discarded or $s \not> r$.

$+\delta$) If $P(n+1) = +\delta q$ then either
  (1) $+\Delta q \in P(1..n)$; or
  (2) $-\Delta{\sim}q \in P(1..n)$, and
    (1) $\exists r \in R_{sd}[q]$, r is δ-applicable, and
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Variants of DL: Team Defeat

Example

Consider the DL theory below.

$$
\begin{array}{ll}
r_1\colon \mathit{general} \Rightarrow \mathit{kill} & r_2\colon \mathit{bishop} \Rightarrow \mathit{kill} \\
r_1'\colon \mathit{captain} \Rightarrow \neg \mathit{kill} & r_2'\colon \mathit{priest} \Rightarrow \neg \mathit{kill}
\end{array}
$$

the facts are *general*, *bishop*, *captain* and *priest*; and the superiority relation is $r_1 \succ r_1'$ and $r_2 \succ r_2'$.

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the facts are *general*, *bishop*, *captain* and *priest*; and the superiority relation is $r_1 \succ r_1'$ and $r_2 \succ r_2'$.

- All rules are applicable, so we can argue pro *kill* using r_1, then we have to consider all possible attacks to it. r_1' is defeated by r_1 itself and r_2' is defeated by r_2. So *kill* is justified (i.e., $+\partial \mathit{kill}$) since for every reason against this conclusion there is a stronger reason defeating it (r_1 and r_2 respectively).

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- All rules are applicable, so we can argue pro *kill* using r_1, then we have to consider all possible attacks to it. r_1' is defeated by r_1 itself and r_2' is defeated by r_2. So *kill* is justified (i.e., $+\partial \mathit{kill}$) since for every reason against this conclusion there is a stronger reason defeating it (r_1 and r_2 respectively).
- Alternatively, we can say that there are two distinct hierarchies of rules both converging to the same conclusion. It is easy to verify that there are no justified arguments concluding *kill* in the grounded extension of the theory when the preference over the rules is the same as the superiority relation in DL, thus *kill* is not a skeptical conclusion in ASPIC$^+$ under the grounded semantics.

Variants of DL: Team Defeat

$+\partial^*$) If $P(n+1) = +\partial^* q$ then either

- (1) $+\Delta p \in P(1..n)$; or
- (2) $-\Delta{\sim}q \in P(1..n)$, and
  - (1) $\exists r \in R_{sd}[q]\ \forall a \in A(r), +\partial^* a \in P(1..n)$, and
  - (2) $\forall s \in R[{\sim}q]$ either
    - (1) s is ∂^*-discarded; or
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  - (2) $\forall s \in R[{\sim}q]$ either
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    - (2) $r \succ s$

DL: Argumentation Semantics

The two variants of argumentation semantics of DL, namely

1. Ambiguity blocking - corresponds to the semantics of DL, and
2. Ambiguity propagation - corresponds to the grounded semantics of Dung's argumentation framework .

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- Both formalism are *relative consistent* (or *indirect consistent* in ASPIC$^+$ term).
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- Preference among ordinary premises and rules can be defined in ASPIC$^+$; while preferences can only be defined among conflicting rules in DL.
- Negation as failure (NAF) is supported in ASPIC$^+$, but NOT in DL. However, it is possible to capture this behavior in DL.

Acceptability of Arguments: ASPIC$^+$ vs DL (cont.)

- In ASPIC$^+$, there is NO notion of rejected conclusion even though one could say that a conclusion is credulously/skeptically rejected if one of its contraries is credulously/skeptically accepted.

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Consider the theory containing only the rules below.

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- ASPIC$^+$ does not support infinite arguments.
- DL cannot infer any conclusions as p is undecidable unless we reason theory using *well-founded semantics* [6].

Mapping ASPIC$^+$ to DL: Motivation

Example (extracted from [7])

Consider an argument A with a strict top rule x and an argument B with a defeasible top rule for $\neg x$, as shown below.

$$\begin{aligned} A: &\quad \Rightarrow p, p \Rightarrow q, q \Rightarrow r, r \rightarrow x \\ B: &\quad \rightarrow d, d \rightarrow e, e \rightarrow f, f \Rightarrow \neg x \end{aligned}$$

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- However, in DL, we have the following conclusions:

$$\begin{array}{ll} D \vdash_{DL} -\Delta x & D \vdash_{DL} -\Delta \neg x \\ D \vdash_{DL} +\sigma^* x & D \vdash_{DL} +\sigma^* \neg x \end{array}$$

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Both x and $\neg x$ are supported by the DL theory and attack each other with the same strength. So, both will be rejected (i.e., $-\delta^* x$ and $-\delta^* \neg x$)!

Mapping ASPIC$^+$ to DL

- Despite the similarities, it is not possible to use directly an ASPIC$^+$ knowledge base as a DL theory, or the other way around.
- This is due to the treatment of (defeasible) arguments in DL which involve strict rules.

Mapping ASPIC$^+$ to DL: the Mapping

Assume:

- the same propositional language $\mathcal{L}$ has been used in both ASPIC$^+$ and DL;
- and in ASPIC$^+$:
  - the contrariness relation is an involutive negation;
  - last-link ordering is used; and
  - the preference ordering over ordinary premises is empty, i.e., $\preceq' = \emptyset$.

Mapping ASPIC$^+$ to DL: the Mapping

Based on the ambiguity propagation no team defeat variant of DL, we have the following definition.

Definition

Let $AT = ((\mathcal{L}, \mathcal{R}, n), \mathcal{K})$ be an ASPIC$^+$ theory and $D = (F, R, \succ)$ be a DL theory. An argument mapping is a function $D = T(TA)$ that map an argument in AT to rules in DL, such that:

$$
\begin{aligned}
F = \quad & \mathcal{K}_n \\
R = \quad & \{r : \ \Rightarrow q \mid q \in \mathcal{K}_p\} \cup \mathcal{R} \\
\succ = \quad & \{r \succ s \mid (s \leq r) \in \leq\} \cup \\
& \quad \{r \succ s \mid r \in \mathcal{R}_s[q],\, s \in \mathcal{R}_d[\sim q]\} \cup \\
& \quad \{r \succ s \mid r \in \mathcal{R}[\sim q],\, s \in R[q] \text{ such that } q \in \mathcal{K}_p\}
\end{aligned}
$$

Mapping ASPIC$^+$ to DL: the Mapping

- Given that we have to consider the relationship between conflicting rules and arguments to derive the superiority relations, the complexity of the transformation can be *quadratic* relative to the size of the rules.

Mapping ASPIC$^+$ to DL: the Mapping

- Given that we have to consider the relationship between conflicting rules and arguments to derive the superiority relations, the complexity of the transformation can be *quadratic* relative to the size of the rules.
- Given the complexity of computing the extensions of DL is linear we have the following result.

Corollary

Acceptability of a proposition in ASPIC$^+$ under grounded semantics can be computed in polynomial time.

Conclusions

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Conclusions

- Addressed the question of how to instantiate ASPIC$^+$ in DL.
- For other direction, it is possible to capture the ambiguity propagation no team defeat variant of DL in ASPIC$^+$, given that such a variant of DL is characterised by the grounded semantics and the two formalisms share the same language.
- While it is possible to adopt different argumentation semantics to be applied on top of ASPIC$^+$, this step alone might not be enough to model defeasible logic as an instance of ASPIC$^+$.
  - DL with ambiguity blocking would require to introduce a second attack relation on argument with ripple down effect on ASPIC$^+$;
  - DL with team defeat would require changes in the definition of what arguments are: an argument would be a set of proof trees instead of a single proof tree.

Thanks!

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