Implementing Explanation-Based Argumentation using \textit{Answer Set Programming}

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Background
Argumentation

- Argumentation is traditionally seen in terms of *attack* and *support* relationships between *claims* brought by participants in a conversation.
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- Argumentation seems to operate at a *meta-level* in respect to the content of arguments.
Formal Argumentation

- Formal argumentation frameworks essentially target this *meta-level*
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- An *Argumentation framework* (AF) [Dung] consists of:
  - a set of arguments
  - attack relations between arguments

\[ \text{Arg1} \overset{\text{attacks}}{\rightarrow} \text{Arg2} \]
Formal Argumentation

- To interpret/evaluate an AF we need a semantics.

- For instance, *extension-based semantics* classify sub-sets of arguments collectively *acceptable* in *extensions*:
  
  \[ \rightarrow \text{the justification state of argument is defined in terms of memberships to extensions (skeptically/credulously justified)} \]
Application of AFs

- Considering the whole process of application of argumentation theories, we recognize three steps:
  - Observation
  - Modeling/Reduction to AF
  - Analysis of AF

traditional focus of formal argumentation

observer
modeler
analyst
Inside/Outside of *Argument Systems*

- In general, the extraction of attack relations may be problematic.
Inside/Outside of Argument Systems

- In general, the extraction of attack relations may be problematic.

\[ P \xrightarrow{\text{attacks}} \sim P \]

- Trivial case: a claim is explicitly directed against another claim (*syntaxic* definition of attack).
Inside/Outside of *Argument Systems*

- In general, the extraction of attack relations may be problematic.

\[
P \xrightarrow{\text{attacks}} ?
\]

- In a more general case, however, modelers have to use some background knowledge and underlying knowledge processing to identify the attacks.
Inside/Outside of *Argument Systems*

• Usual solution: to integrate in the modeling phase default/defeasible reasoning.

• e.g. *assumption-based argumentation (ABA)*
  - Argument: *conclusion ← assumptions*
  - Attack to an argument holds if the “contrary” of its assumptions can be proved, or of its conclusion (*rebuttal*).
Inside/Outside of Argument Systems

- In practice in ABA the stress is on the support relation, expressed via defeasible rules, and used to extract the correspondent AF.

- Observation
- Modeling/Reduction to AF
- Analysis of AF

(Part of) modeling is integrated, but still concerned by the meta-level!
The Puzzle
An interesting puzzle by Pollock

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A) Jones says that the gunman had a moustache.
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A) Jones says that the gunman had a moustache.

B) Paul says that Jones was looking the other way and did not see what happened.
An interesting puzzle by Pollock

A) Jones says that the gunman had a moustache.

B) Paul says that Jones was looking the other way and did not see what happened.

C) Jacob says that Jones was watching carefully and had a clear view of the gunman.
Argumentation scheme of the puzzle

Paul's claim
B

Jacob's claim
C

Jones' claim
A

Q

\sim Q

P
Argumentation scheme of the puzzle

A → B

Paul's claim

A → C

Jacob's claim

Jones' claim

Q

~Q

collective defeat

P
Argumentation scheme of the puzzle

- Jones' claim
- Paul's claim
- Jacob's claim

zombie argument

collective defeat

A

B

C

Q

\sim Q
1. we should not believe to Jones' claim (i.e. the zombie argument) carelessly
Targeting intuitive properties

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2. if we assume Paul more trustworthy than Jacob, Paul's claim should be justified but to a lesser degree
Targeting intuitive properties

1. We should not believe to Jones' claim (i.e. the zombie argument) carelessly.

2. If we assume Paul more trustworthy than Jacob, Paul's claim should be justified but to a lesser degree.

3. If Jacob had confirmed Paul's claim, its degree of justification should have increased.
Pollock's puzzle

- Underlying problems:
  - zombie arguments
  - (relative) judgments of trustworthiness/reliability
  - ...
  - how to approach justification?

- Pollock proposed a highly elaborate preliminary solution based on *probable probabilities*.

- We propose a different solution, based on *explanation-based argumentation*. 
Shift of perspective
Explanation-Based Argumentation

- Argumentation can be seen as a *dialectical process*, in which parties produce and receive messages.

- Argumentation does not concern only the matter of debate (e.g. a case, or *story*), but also the *meta-story* about the construction of such story.
EBA: observations

- The sequence of collected messages consists in the observation.
- Sometimes the observation is collected by a third-party adjudicator, entitled to interpret the case from a neutral position.

The Trial of Bill Burn under Martin's Act [1838]
EBA: explanations

- Given a disputed case, an *explanation* is a possible scenario which is compatible
  - with the content of the messages, *and*
  - with the generation process of the messages.

In general, the nature of such scenarios is of a *multi-representational* model, integrating physical, mental, institutional and abstract domains.
EBA: explanations

• Given a disputed case, an explanation is a possible scenario which is compatible
  - with the content of the messages, and
  - with the generation process of the messages.

• An explanation is valid if it reproduces the observation.

• Several explanations may be valid, i.e. fitting the same observation. Their competition is matter of justification.
Instead of being a static entity, the space of (hypothetical) explanations changes because of
- the incremental nature of the observation (introducing new factors and constraints),
- changes in strengths of epistemic commitment.
Explanation-based Argumentation

• Referring to these ingredients, we propose the following operationalization, based on three steps.
Explanation-based Argumentation

1. Generation
   - Relevant factors, related to the observation, are grounded into *scenarios*
Explanation-based Argumentation

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2. Deletion
   - Impossible scenarios are removed, leaving a set of hypothetical explanations
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*Operational assumption*: effective capacity of generating adequate scenarios
Explanation-based Argumentation

1. Generation
   - Relevant factors, related to the observation, are grounded into scenarios

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   - Impossible scenarios are removed, leaving a set of hypothetical explanations
   - Hypothetical explanations fitting the observation select the explanations
Explanation-based Argumentation

1. Generation
   - Relevant factors, related to the observation, are grounded into scenarios

2. Deletion
   - Impossible scenarios are removed, leaving a set of hypothetical explanations
   - Hypothetical explanations fitting the observation select the explanations

*Informational assumption*: an observation either fits an explanation or it doesn’t.
Explanation-based Argumentation

1. Generation
   - Relevant factors, related to the observation, are grounded into scenarios

2. Deletion
   - Impossible scenarios are removed, leaving a set of hypothetical explanations
   - Hypothetical explanations fitting the observation select the explanations

3. Justification
   - The relative position of explanations depends on the strengths of epistemic commitment
Explanation-based Argumentation

- Argumentation frameworks based on defeasible reasoning insist on the *inferential aspect* of the problem, rather than the *selection* of an adequate search space.

- The selection of (hypothetical) explanations hides already a certain commitment.

- Hypothetical explanations can be associated to a certain likelihood (*prior*).

- After some relevant message, the likelihood, i.e. the “strength” of explanations should change (*posterior*).
EBA: evaluation of explanations

- Bayesian probability
  - Subjective interpretation: probability counts as a measure of the strength of belief.
  - $L(E|O) = P(O|E)$
EBA: evaluation of explanations

- A relative ordinal judgment can be evaluated calculating the confirmation value for each explanation E (taken from Tentori, 2007):

\[
c(O|E) = \frac{P(O|E) - P(O|\neg E)}{P(O|E) + P(O|\neg E)}
\]
EBA: evaluation of explanations

• A relative ordinal judgment can be evaluated calculating the confirmation value for each explanation E (taken from Tentori, 2007):

\[ c(O|E) = \frac{P(O|E) - P(O|\neg E)}{P(O|E) + P(O|\neg E)} \]

Well-known explanatory space assumption:
\[ P(E_1) + P(E_2) + \ldots + P(E_n) \sim 1 \]
Implementation
Implementation of EBA in ASP

- *Answer set programming* is a declarative programming paradigm based on the *stable-model semantic*, oriented towards difficult (NP-hard) search problems.
  - In ASP, similarly to Prolog, the programmer models a problem in terms of rules and facts, instead of specifying an algorithm. The resulting code is given as input to a solver, which returns multiple *answer sets* or *stable models* satisfying the problem.

- We take advantage of the search capabilities of ASP solvers, in order to effectively perform the *generation* and *deletion* steps at once.
Implementation of EBA in ASP

- An ASP program related to an explanation-based argumentation consists of 3 parts:
  1. *allocation choices*, grounding all permutations of relevant factors,
  2. *world properties* and *ground facts*, modeling shared assumptions,
  3. *observation*, modeling the collected messages.
Implementation of EBA in ASP

An ASP program related to an explanation-based argumentation consists of 3 parts:

1. *allocation choices*, grounding all permutations of relevant factors,
2. *world properties* and *ground facts*, modeling shared assumptions,
3. *observation*, modeling the collected messages.

The ASP solver gives as output hypothetical explanations (with 1+2) and explanations (1+2+3).

- Assigning a prior probability to hyp. explanations, and analysing the final explanations we calculate the confirmation values.
A) Jones says that the gunman had a moustache.

B) Paul says that Jones was looking the other way and did not see what happened.

C) Jacob says that Jones was watching carefully and had a clear view of the gunman.
Relevant factors for assertion

- what an agent says may hold or not
- an agent may be *reliable* or not
- when he is reliable, what he says is what it holds.
Relevant factors for assertion

- what an agent says may hold or not
- an agent may be reliable or not
- when he is reliable, what he says is what it holds.
- e.g. Paul says Jones was not seeing the gunman. Writing “Paul is reliable” as paul and “Jones was seeing” as eye, we have:

  1{eye, -eye}1.
  1{paul, -paul}1.
  -eye :- paul.
Implementation of the puzzle in ASP

- An ASP program related to an explanation-based argumentation consists of 3 parts:
  1. *allocation choices*, grounding all permutations of relevant factors:

    1\{moustache, -moustache}\1.
    1\{eye, -eye\}1.
    1\{jones, -jones\}1.
    1\{paul, -paul\}1.
    1\{jacob, -jacob\}1.
Implementation of the puzzle in ASP

- An ASP program related to an explanation-based argumentation consists of 3 parts:
  1. allocation choices,
  2. world properties and ground facts, modeling shared assumptions:

    eye :- jones.
Implementation of the puzzle in ASP

- An ASP program related to an explanation-based argumentation consists of 3 parts:
  1. allocation choices,
  2. world properties and ground facts,
  3. observation, modeling the collected messages:

moustache :- jones.
-eye :- paul.
eye :- jacob.
Results

- We model the puzzle incrementally, so as to analyze the impact of each new message.

<table>
<thead>
<tr>
<th>#</th>
<th>$O_1$</th>
<th>$O_2$</th>
<th>$O_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>relevant factors</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<tr>
<td>scenarios</td>
<td>8</td>
<td>16</td>
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<tr>
<td>explanations</td>
<td>5</td>
<td>7</td>
<td>10</td>
</tr>
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</table>
Prior probabilities

• How to calculate the prior probabilities?

• As we know all relevant factors characterizing the explanations, assuming that they are independent in the allocation phase we have:

\[ P(E_i) = P(f_1) \times P(f_2) \times \ldots \times P(f_n) \]

• A neutral perspective is obtained assuming \( P(f_i) = 0.5 \)

• As the inclusion of world properties and ground facts decrease the number of explanations, a normalization phase is required.
### Evaluation vs targeted properties

<table>
<thead>
<tr>
<th></th>
<th>$E_U$ (Jacob attacks Paul)</th>
<th>$E_U$ (Jacob attacks Paul)</th>
<th>$E_U$ (Jacob attacks Paul)</th>
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<tr>
<td></td>
<td>$P$</td>
<td>$O_1$</td>
<td>$O_2$</td>
</tr>
<tr>
<td>moustache</td>
<td>.50</td>
<td>U</td>
<td>U</td>
</tr>
<tr>
<td>eye</td>
<td>.50</td>
<td>U</td>
<td>U</td>
</tr>
<tr>
<td>jones</td>
<td>.50</td>
<td>U</td>
<td>U</td>
</tr>
<tr>
<td>paul</td>
<td>.50</td>
<td>U</td>
<td>U</td>
</tr>
<tr>
<td>jacob</td>
<td>.50</td>
<td>U</td>
<td>-</td>
</tr>
<tr>
<td>$c(O</td>
<td>E_U)$</td>
<td>.27</td>
<td>.43</td>
</tr>
</tbody>
</table>

- we should not believe to Jones' claim carelessly
  
  → explanations in which the gunman has the moustache or not are confirmed to the same degree
Evaluation vs targeted properties

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<th></th>
<th>$P$</th>
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<th>$O_2$</th>
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</thead>
<tbody>
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<td>U</td>
<td>U</td>
<td>U</td>
<td>.50</td>
<td>U</td>
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<td>T</td>
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<tr>
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<tr>
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<td>U</td>
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<td>F</td>
<td>.55</td>
<td>-</td>
<td>-</td>
<td>T</td>
</tr>
</tbody>
</table>

$c(O|E_U)$

- .27 .43 .55
- .27 .45 .58
- .31 .48 .61

- if we assume Paul more trustworthy than Jacob, Paul's claim should be justified but to a lesser degree

→ the explanation in which Paul tells the truth is more confirmed than the others.
Evaluation vs targeted properties

<table>
<thead>
<tr>
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<th>$E_U$ (Jacob supports Paul)</th>
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- if Jacob had confirmed Paul's claim, its degree of justification should have increased.
  
  $\rightarrow$ explanations where they both say the truth are confirmed as much as explanations in which they both lie.
For each observation, we can refer to two dimensions of change:

- post $O_i - pre \ O_i$
- post $O_i - post \ O_{i-1}$

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>P</td>
<td>$c_{max}(f)/c_{max}(-f)$</td>
<td>$c_{max}(f)/c_{max}(-f)$</td>
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<td>$c_{max}(f)/c_{max}(-f)$</td>
</tr>
<tr>
<td>moustache</td>
<td>.50/.19</td>
<td>.31/.30</td>
<td>.18/.48</td>
<td>.84/.17</td>
<td>.61/.60</td>
<td>=/+=/+=</td>
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<tr>
<td>eye</td>
<td>.50/.19</td>
<td>.31/.30</td>
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Conclusion

• With EBA we stress the sharing of a deep-model of the domain, a model for the observation and the explicitation of strength of commitments for the justification.

  - (Modeling) the observation
  - (Modeling) the deep model
  - Extracting (justified) explanations / AF

observer
modeler
analyst
Conclusion

• We have validated a slightly "deeper model" of reasoning, using Pollock's puzzle with EBA.

• Advantages:
  – defines justification operationally
  – handles neutral prior probability

• Disadvantages:
  – increased overload for the deep-modeling
  – explosion of explanations
Further research

• Investigate other definitions of confirmation values
• Propose an analytical definition for attack/support relations
• Integrate agent-role models into ASP
• Integrate EBA in agent architectures for diagnoser agents
• Integrate Bayesian networks for prior probabilities