Implementing Explanation-Based Argumentation using *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

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

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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

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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*:

  → 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

observer

modeler

analyst

traditional focus of formal argumentation

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Inside/Outside of *Argument Systems*

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

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- Trivial case: a claim is explicitly directed against another claim (*syntaxic* definition of attack).

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Inside/Outside of *Argument Systems*

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

- In a more general case, however, modelers have to use some background knowledge and underlying knowledge processing to identify the attacks.

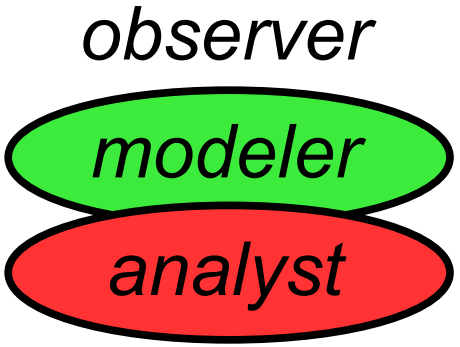
Inside/Outside of *Argument Systems*

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



*(Part of) modeling is integrated, but still concerned by the **meta-level**!*

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The Puzzle

An interesting puzzle by Pollock

- John Pollock presents in in “Reasoning and probability”, *Law, Probability, Risk* (2007) a lucid analysis about the difficulties in reproducing certain intuitive properties with current formal argumentation theories.

An interesting puzzle by Pollock

A) Jones says that the gunman had a moustache.

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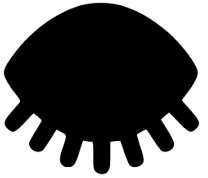
B) Paul says that Jones was looking the other way and did not see what happened.



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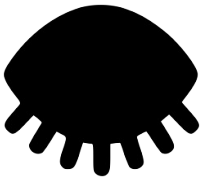

C) Jacob says that Jones was watching carefully and had a clear view of the gunman.

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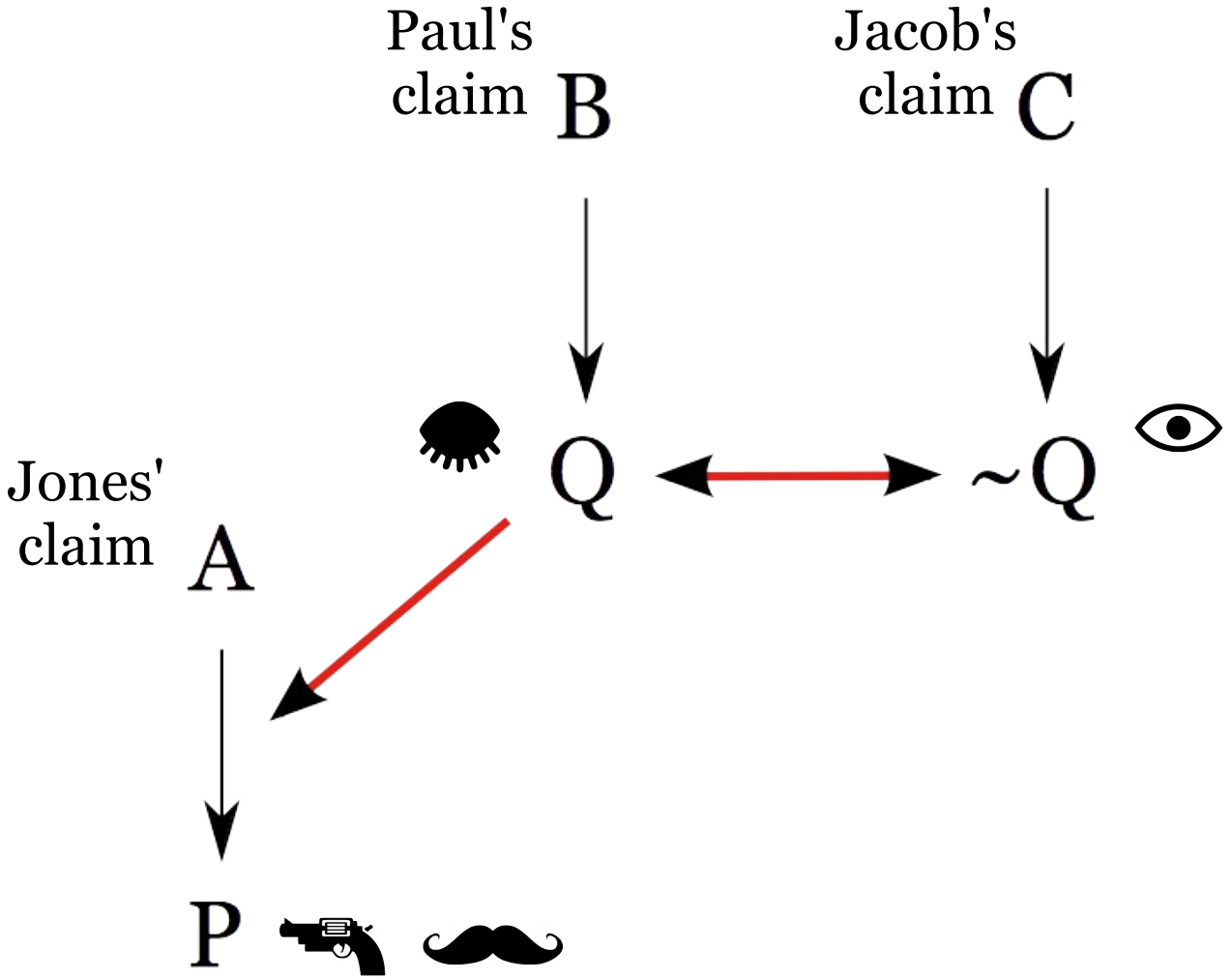
Argumentation scheme of the puzzle



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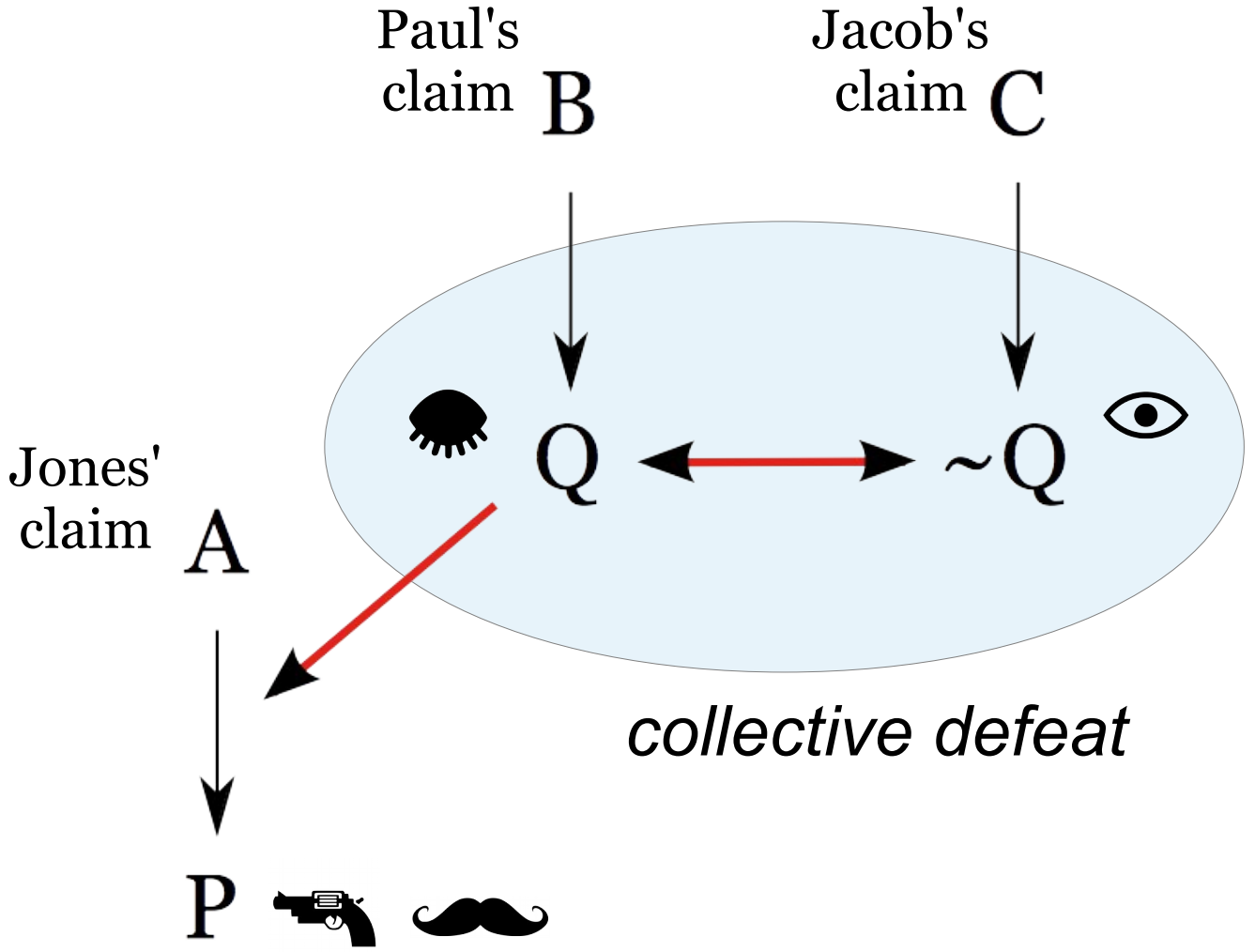

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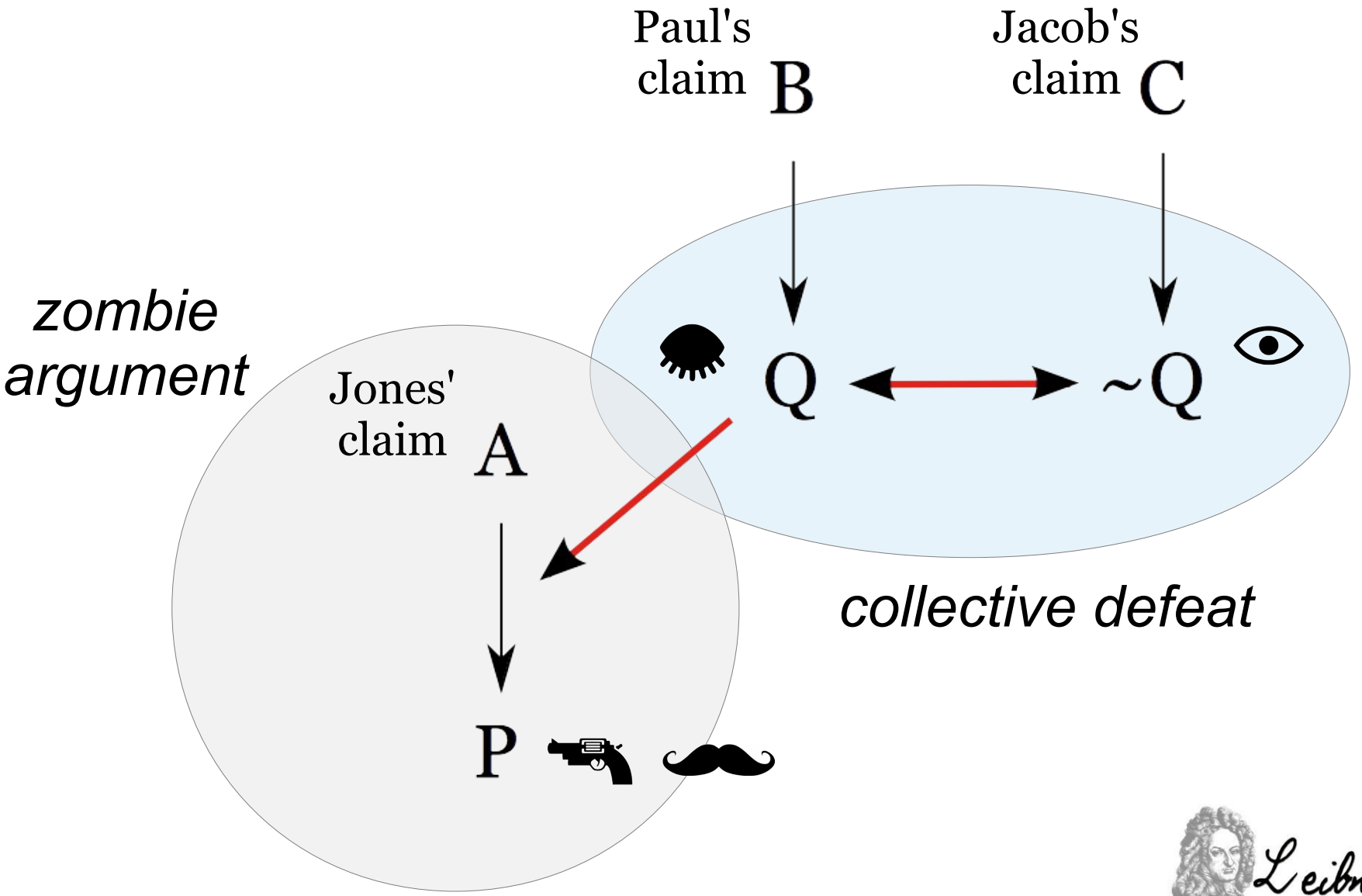
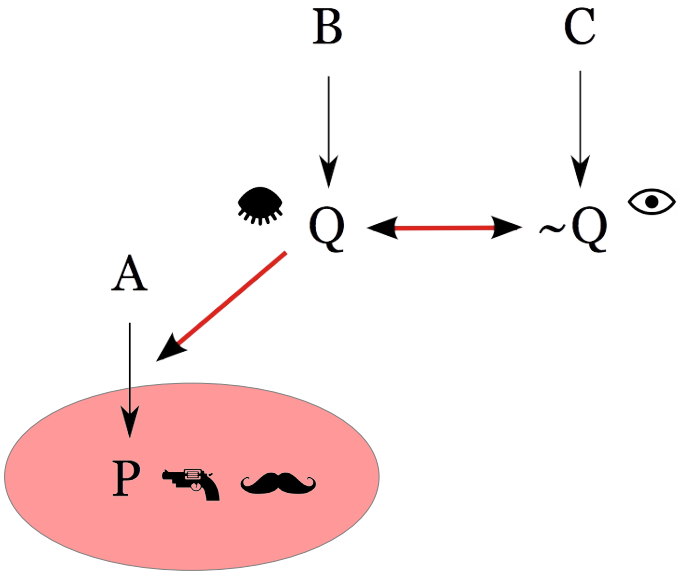


Targeting intuitive properties

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



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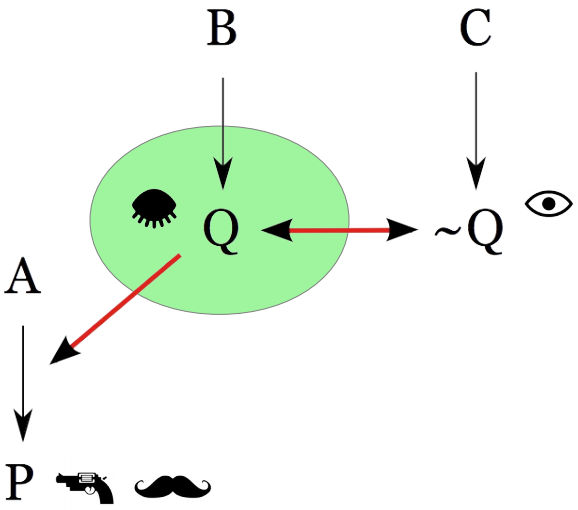
Targeting intuitive properties

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*



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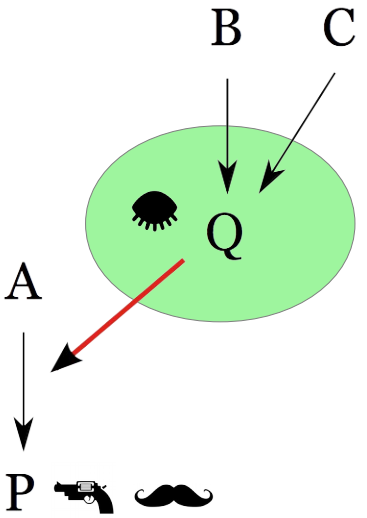
Targeting intuitive properties

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



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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 about the construction of such story.

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EBA: observations

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

- 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.

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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.

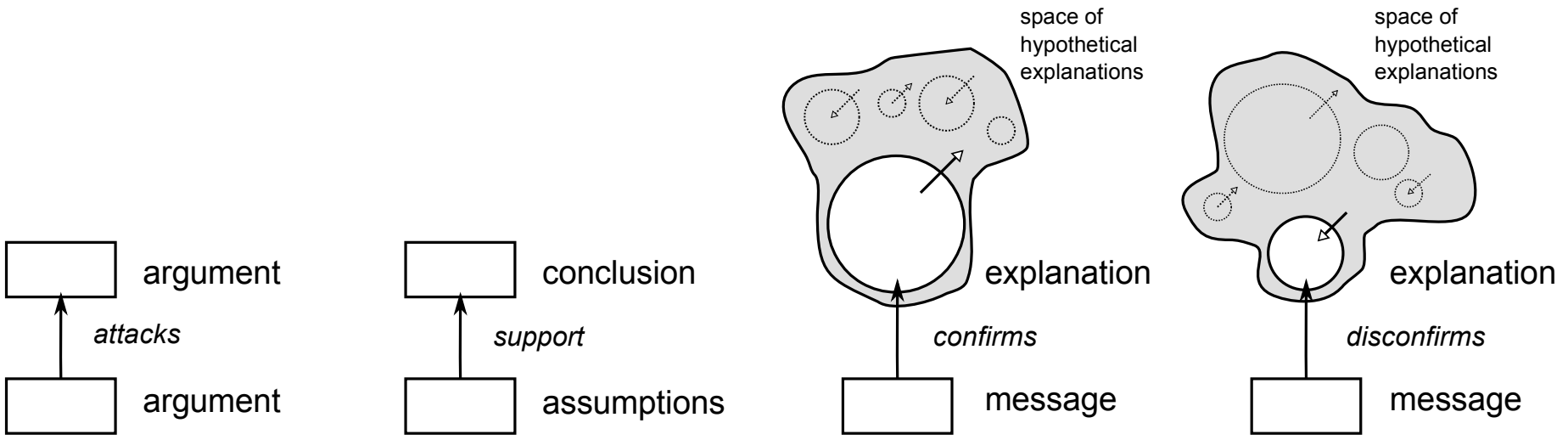
In general, the nature of such scenarios is of a *multi-representational* model, integrating physical, mental, institutional and abstract domains.

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 *justificatio*n.

EBA: space of explanations



- 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.

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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*

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Operational assumption: effective capacity of generating adequate scenarios

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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

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Well-known explanatory space assumption:
$P(E_1) + P(E_2) + .. + P(E_n) \sim 1$

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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.

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- 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.

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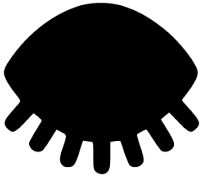
Relevant factors?

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.

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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.

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- what an agent says may hold or not
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- 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.
```

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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.
```

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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.
```

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Results

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

#	O_1	O_2	O_3
relevant factors	3	4	5
scenarios	8	16	32
hypothetical explanations	6	12	24
explanations	5	7	10

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:

  $P(E_i) = P(f_1) * P(f_2) * \ldots * P(f_n)$

- A neutral perspective is obtained assuming $P(f_i) = 0.5$
- As the inclusion of world properties and ground facts descrease the number of explanations, a normalization phase is required.

Evaluation vs targeted properties

	E_U (Jacob attacks Paul)											
	P	O_1	O_2	O_3	P	O_1	O_2	O_3	P	O_1	O_2	O_3
moustache	.50	U	U	U	.50	U	U	U	.50	T	U	T
eye	.50	U	U	U	.50	U	F	F	.50	T	U	T
jones	.50	U	U	U	.50	U	F	F	**.55**	T	U	T
paul	.50	-	U	U	**.55**	-	T	T	**.55**	-	U	F
jacob	50	-	-	U	.50	-	-	F	**.55**	-	-	T
$c(O\|E_U)$		.27	.43	.55		.27	.45	.58		.31	.48	.61

- we should not believe to Jones' claim carelessly

  → explanations in which the gunman has the moustache or not are confirmed to the same degree

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Evaluation vs targeted properties

	E_U (Jacob attacks Paul)											
	P	O_1	O_2	O_3	P	O_1	O_2	O_3	P	O_1	O_2	O_3
moustache	.50	U	U	U	.50	U	U	U	.50	T	U	T
eye	.50	U	U	U	.50	U	F	F	.50	T	U	T
jones	.50	U	U	U	.50	U	F	F	**.55**	T	U	T
paul	.50	-	U	U	**.55**	-	T	T	**.55**	-	U	F
jacob	.50	-	-	U	50	-	-	F	**.55**	-	-	T
$c(O\|E_U)$		.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

  $\longrightarrow$ the explanation in which Paul tells the truth is more confirmed than the others.

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Evaluation vs targeted properties

	E_U (Jacob supports Paul)							
	P	O_1	O_2	O_3	P	O_1	O_2	O_3
moustache	.50	U	U	U	.50	T	U	U
eye	.50	U	U	U	.50	T	U	F
jones	.50	U	U	U	**.55**	T	U	F
paul	.50	-	U	U	**.55**	-	U	T
jacob	.50	-	-	U	**.55**	-	-	T
$c(O\|E_U)$		.27	.43	.51		.31	.48	.57

- if Jacob had confirmed Paul's claim, its degree of justification should have increased.

  → explanations where they both say the truth are confirmed as much as explanations in which they both lie.

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Extraction of attack/support

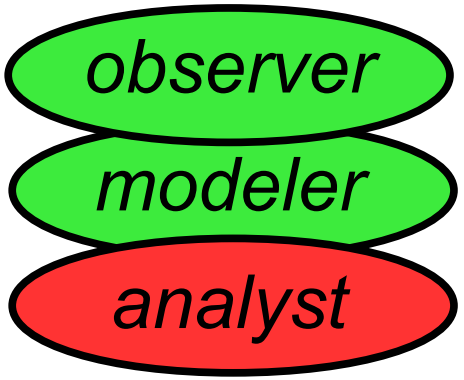
		$c_{max}(f)/c_{max}(-f)$					
		O_1		O_2		O_3	
	P	pre	post	pre	post	pre	post
moustache	.50	.19/.19	.31/.30	.18/.18	.48/.48	.17/.17	.61/.60
eye	.50	.19/.18	.31/.30	.18/.17	.48/.48	.17/.16	.61/.60
jones	.55	.19/.18	.31/.30	.18/.17	.48/.48	.17/.16	.61/.60
paul	.55			.18/.17	.48/.48	.17/.16	.60/.61
jacob	.55					.17/.16	.61/.60

	O_1	O_2	O_3
moustache	$+/+$	$=/-$	$+/+$
eye	$=/+$	$-/-$	$=/+$
jones	$=/+$	$-/-$	$=/+$
paul		$-/=$	$-/-$
jacob			$=/+$

- For each observation, we can refer to two dimensions of change:
  - post O_i − pre O_i
  - post O_i − post O_{i-1}

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



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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