Arguments, scenarios and probabilities as tools for reasoning and uncertainty

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Hybrid Intelligence

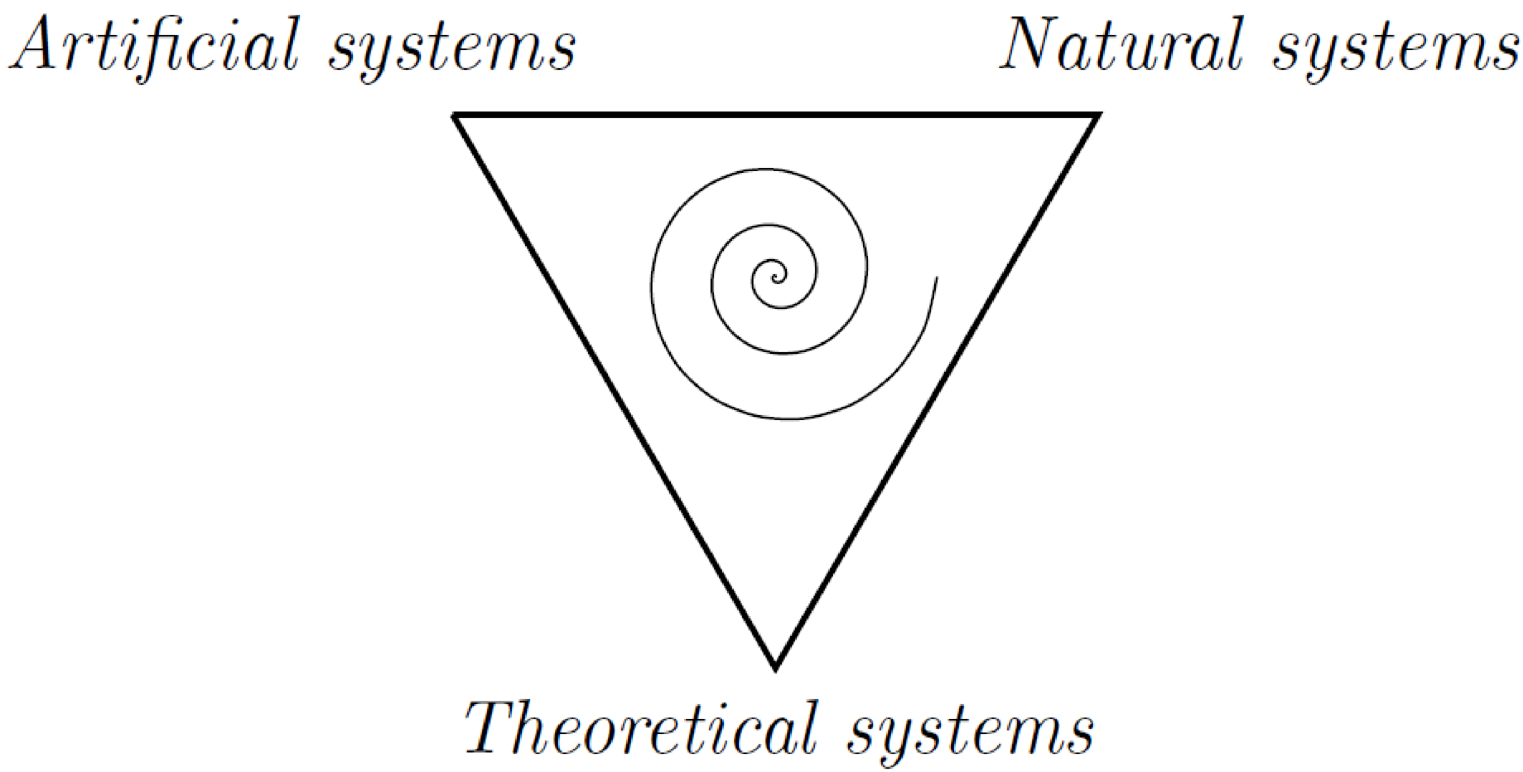
DSSC
Data Science & Systems Complexity

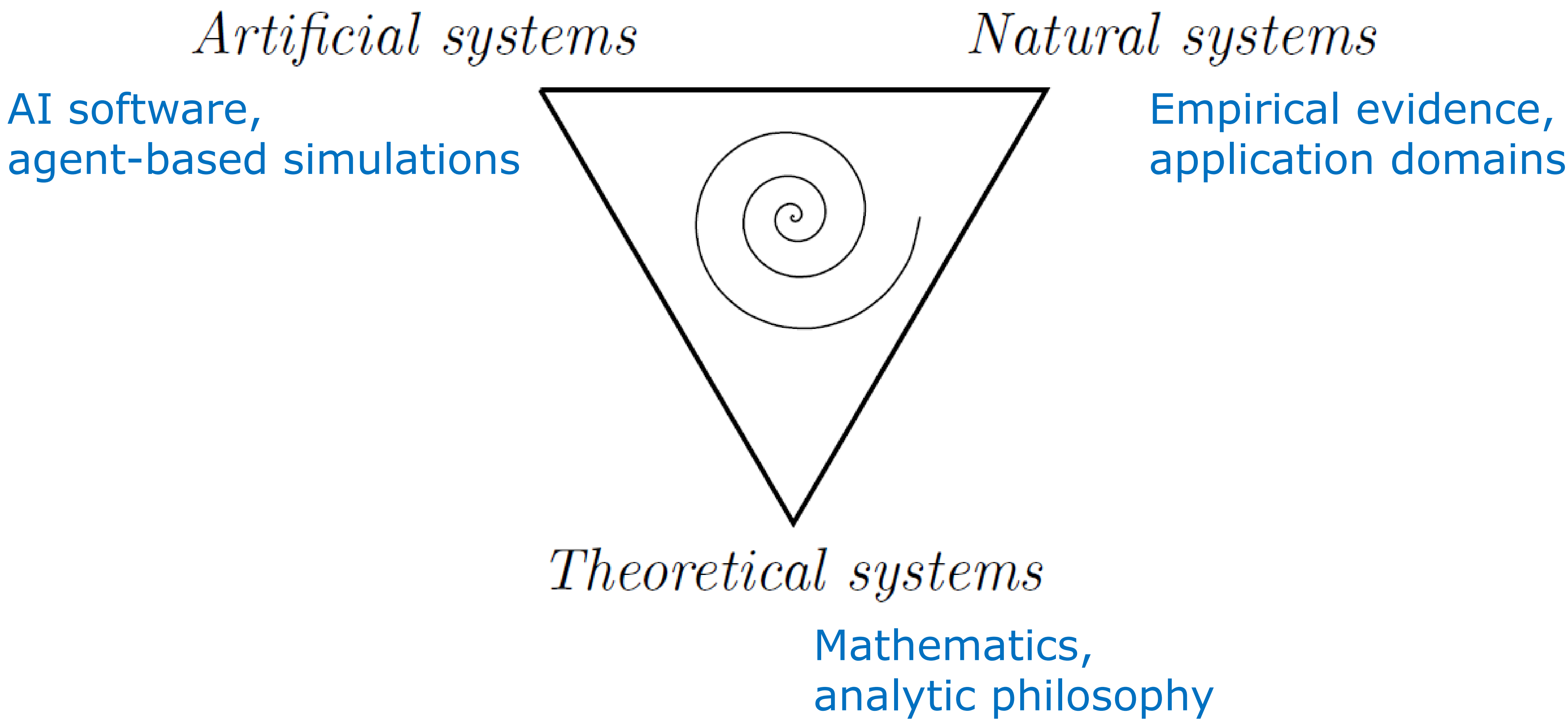
university of groningen

Reasoning and uncertainty: probabilistic, logical, and psychological perspectives

- `manage uncertainty and incomplete knowledge'
- `combining conceptual, formal, empirical'
- `normative and descriptive dimensions'
- `(coherence-based) probability logic'
- `how to argue and make decisions rationally'

Workshop web site

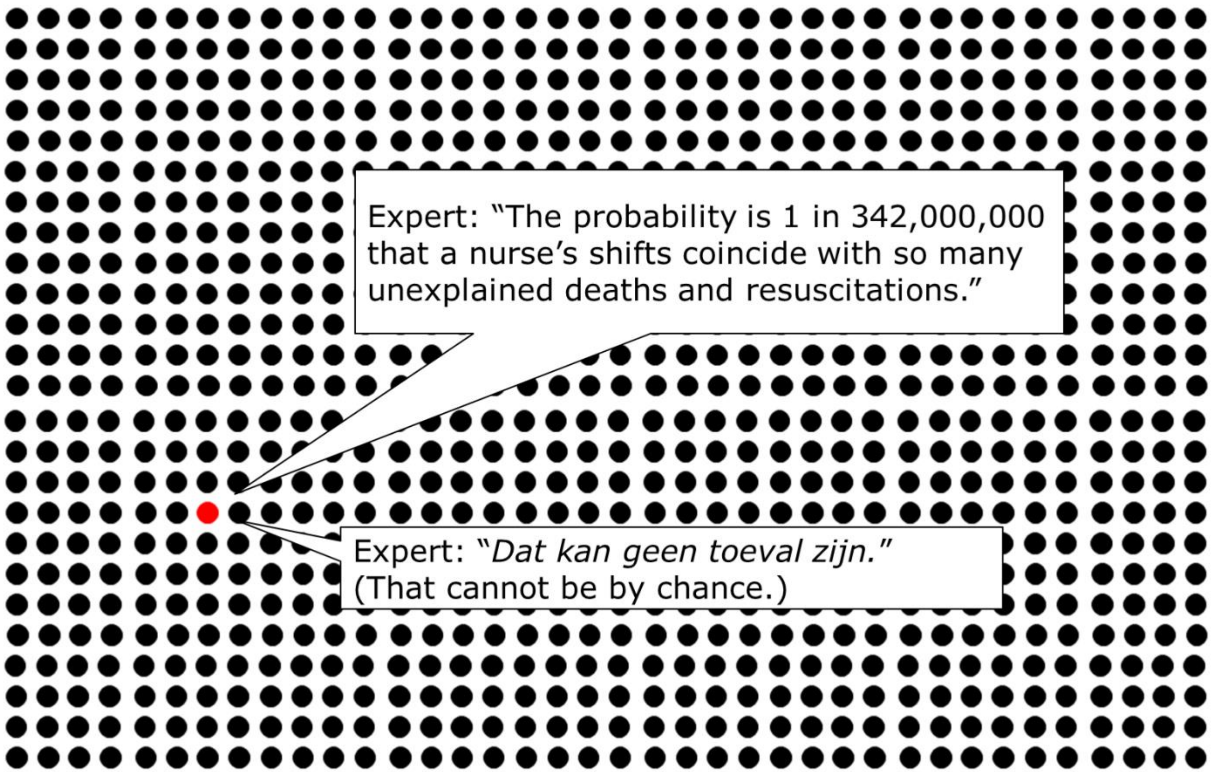

Artificial systems
Natural systems
Theoretical systems


Artificial systems
AI software,
agent-based simulations
Natural systems
Empirical evidence,
application domains
Theoretical systems
Mathematics,
analytic philosophy

Summary

- The understanding of rational reasoning with uncertainty can benefit from theoretical, empircal and computational insights.
- For reasoning with evidence, three normative tools are investigated: arguments, scenarios and probabilities
- Research has focused on the tools separately, and in various combinations.
- Contemporary AI requires similar combinations of reasoning, knowledge and data.

How can forensic evidence be handled effectively and safely?



Analyses of what went wrong

1. The statistical calculations were erroneous.
   Wrongly combining p-values

2. The statistics were erroneous.
   Biased data collection

3. The statistics only show that what happened is rare.
   Lack of concrete contextual evidence

What makes a suspect’s guilt convincing?

When the context speaks for itself.

E.g.,

- The murder weapon is found.
- Fingerprints found on the gun match the suspect’s.
- The suspect has `shooting hands’.
- The suspect is a known hitman.
- The victim was a drug dealer involved in a gang war.
- …

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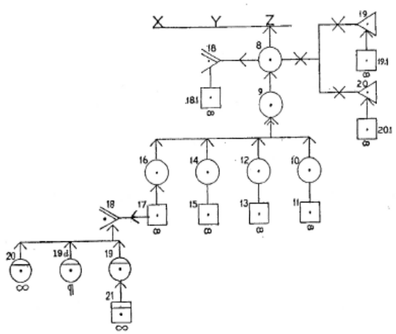
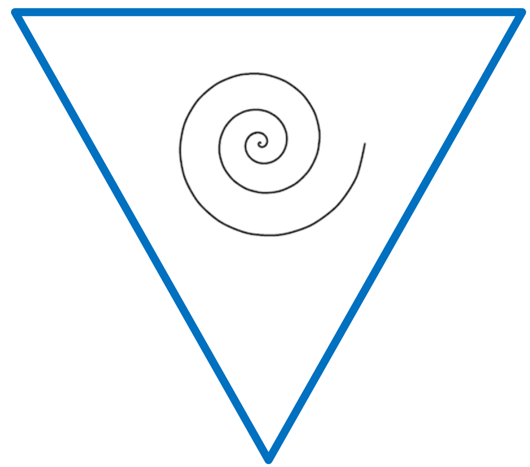
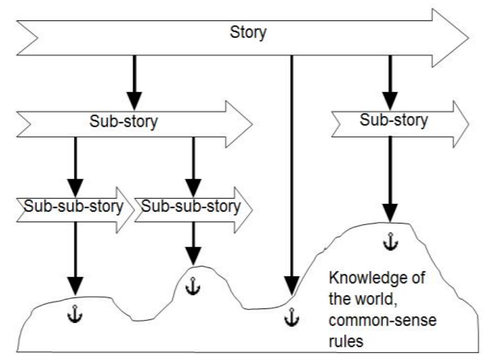
Three normative frameworks

Arguments





Scenarios



Probabilities

$$\frac{p(H|E)}{p(not\!-\!H|E)} = \frac{p(E|H)}{p(E|not\!-\!H)} \cdot \frac{p(H)}{p(not\!-\!H)}$$

Posterior odds = Likelihood ratio · Prior odds

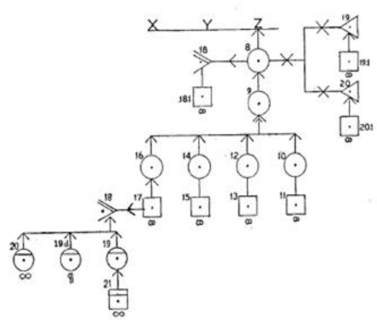
Three normative frameworks

$$\frac{p(H|E)}{p(not\text{-}H|E)} = \frac{p(E|H)}{p(E|not\text{-}H)} \cdot \frac{p(H)}{p(not\text{-}H)}$$

Posterior odds = Likelihood ratio · Prior odds

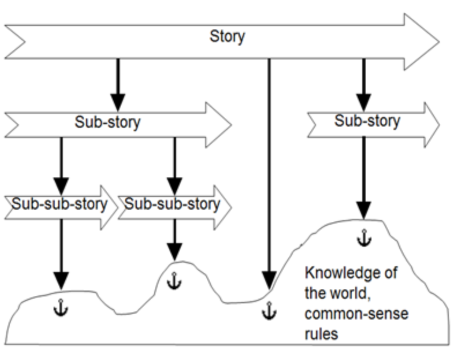
Probabilities

E.g., follow the calculus, don’t transpose conditional probabilities, don’t forget prior probabilities



Argumentation

E.g., take all arguments into account, both pro and con, assess strength and relative strength, avoid fallacies



Scenarios

E.g., consider alternative scenarios, assess plausibility and coherence, consider which evidence is explained or contradicted

Three normative frameworks

$$\frac{p(H|E)}{p(not\!-\!H|E)} = \frac{p(E|H)}{p(E|not\!-\!H)} \cdot \frac{p(H)}{p(not\!-\!H)}$$

Posterior odds = Likelihood ratio · Prior odds

Probabilities

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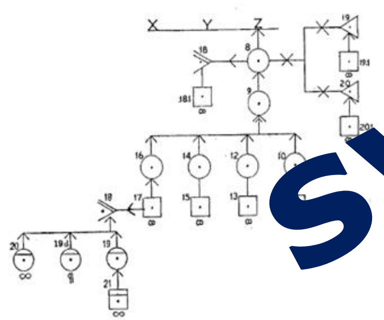
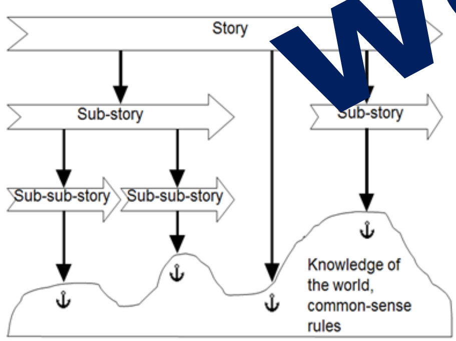


Argumentation

E.g., take all arguments into account, both pro and con, assess strength and relative strength, avoid fallacies



Scenarios

E.g., consider alternative scenarios, assess plausibility and coherence, consider which evidence is explained or contradicted

systematic, well-managed

EVIDENTIAL REASONING
Chapter for the Handbook of Legal Reasoning

Marcello Di Bello & Bart Verheij – April 19, 2017

Contents

Conflicting evidence

Arguments Three kinds of attack can be distinguished: rebutting, undercutting and undermining. Three kinds of support can be distinguished: multiple, subordinated and coordinated. Arguments can involve complex structures of supporting and attacking reasons.

Scenarios There may be conflicting scenarios about what has happened. Evidence can be explained by one scenario, but not by another. Scenarios can be contradicted by evidence.

Probabilities Support can be characterized as "probability increase" or "positive likelihood ratio". Attack can be characterized as "probability decrease" or "negative likelihood ratio". The conflict between two pieces of evidence can be described probabilistically.

Evidential value

Probabilities The incremental evidential value is measured by probabilistic change. The overall evidential value is measured by the overall conditional probability. The use of evidence with high incremental evidential value has complications.

Arguments The reasons used can be conclusive or defeasible. Arguments can be evaluated by asking critical questions. It can be subject to debate whether a reason supports or attacks a conclusion.

Scenarios Scenarios can be plausible and logically consistent. The more evidence a scenario can explain, the better. The more pieces of evidence a scenario is consistent with, the

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- Contemporary AI requires similar combinations of reasoning, knowledge and data.

Toulmin on logic (1958)

Logic as psychology

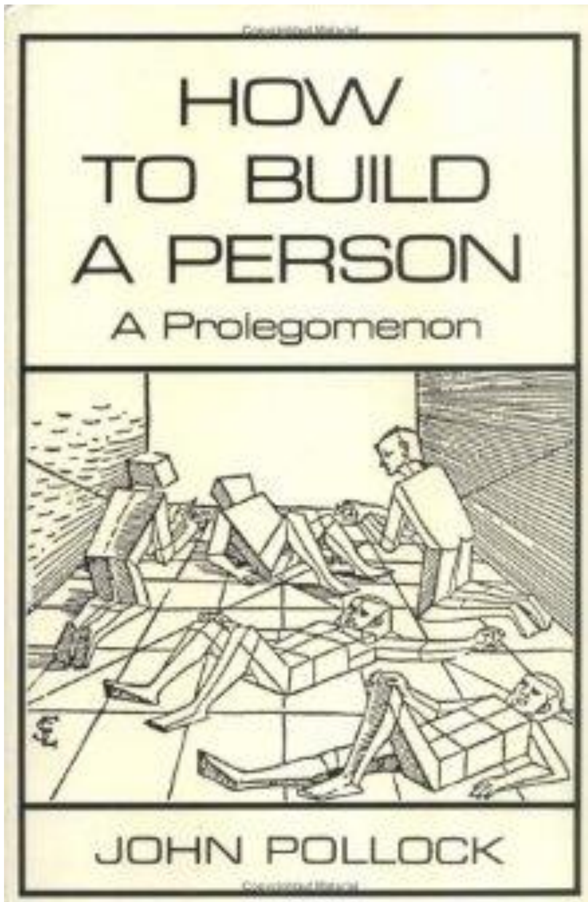
Logic as sociology

Logic as technology

Logic as mathematics

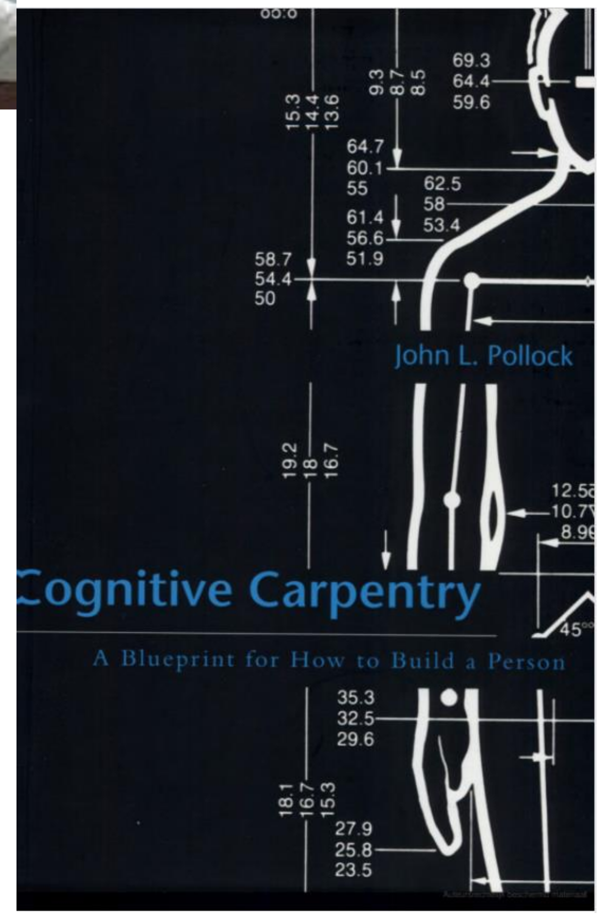
Logic as argumentation

For the AI connection see: Verheij, B. (2009). The Toulmin Argument Model in Artificial Intelligence. Or: How Semi-Formal, Defeasible Argumentation Schemes Creep into Logic. *Argumentation in Artificial Intelligence* (eds. Rahwan, I., & Simari, G.), 219-238. Dordrecht: Springer.



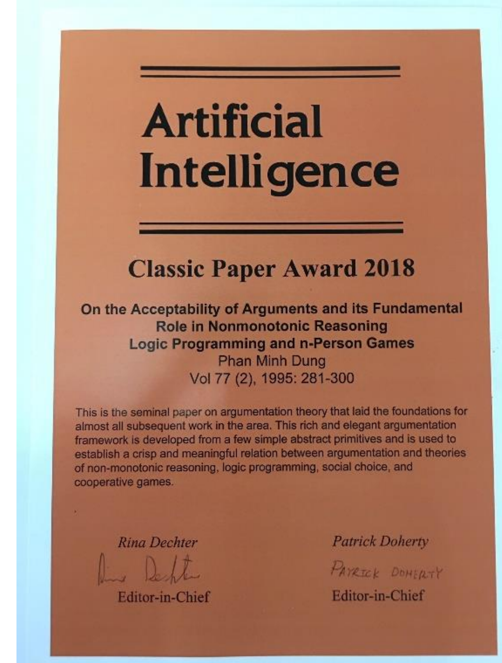
1989

John Pollock



1995

Abstract argumentation (Dung 1995)



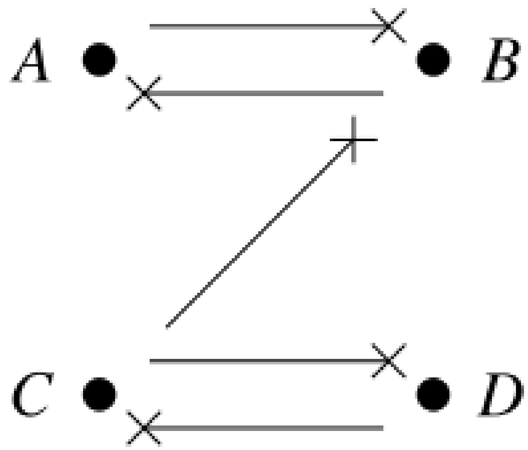
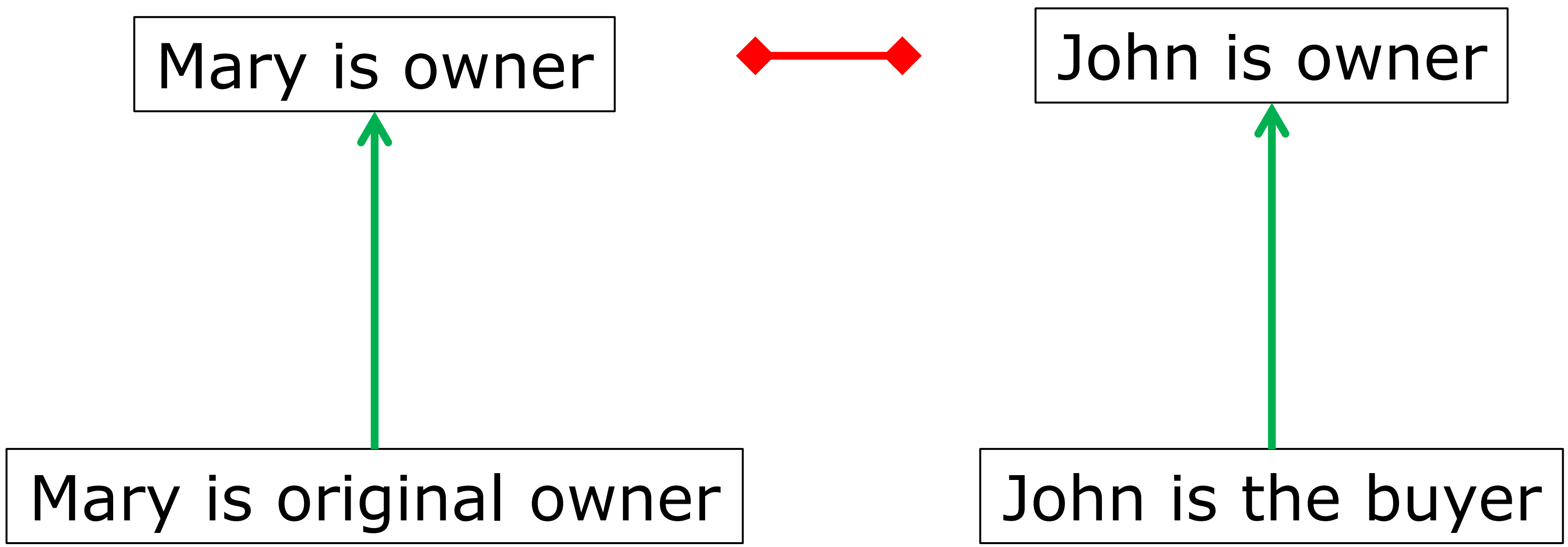


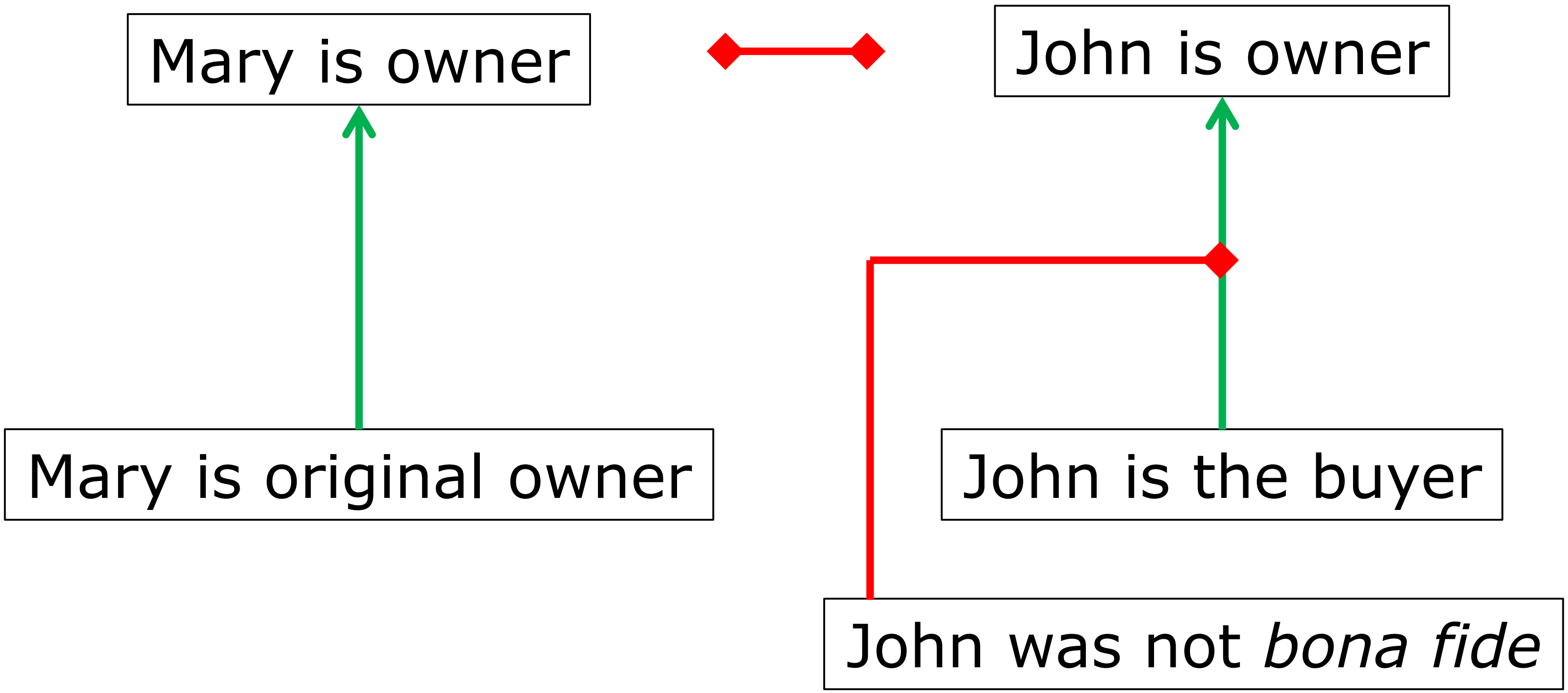
Fig. 1. Abstracting to the attacks between the four example arguments.

Dung, P.M. (1995). On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games, *Artificial Intelligence* 77, 321–357.

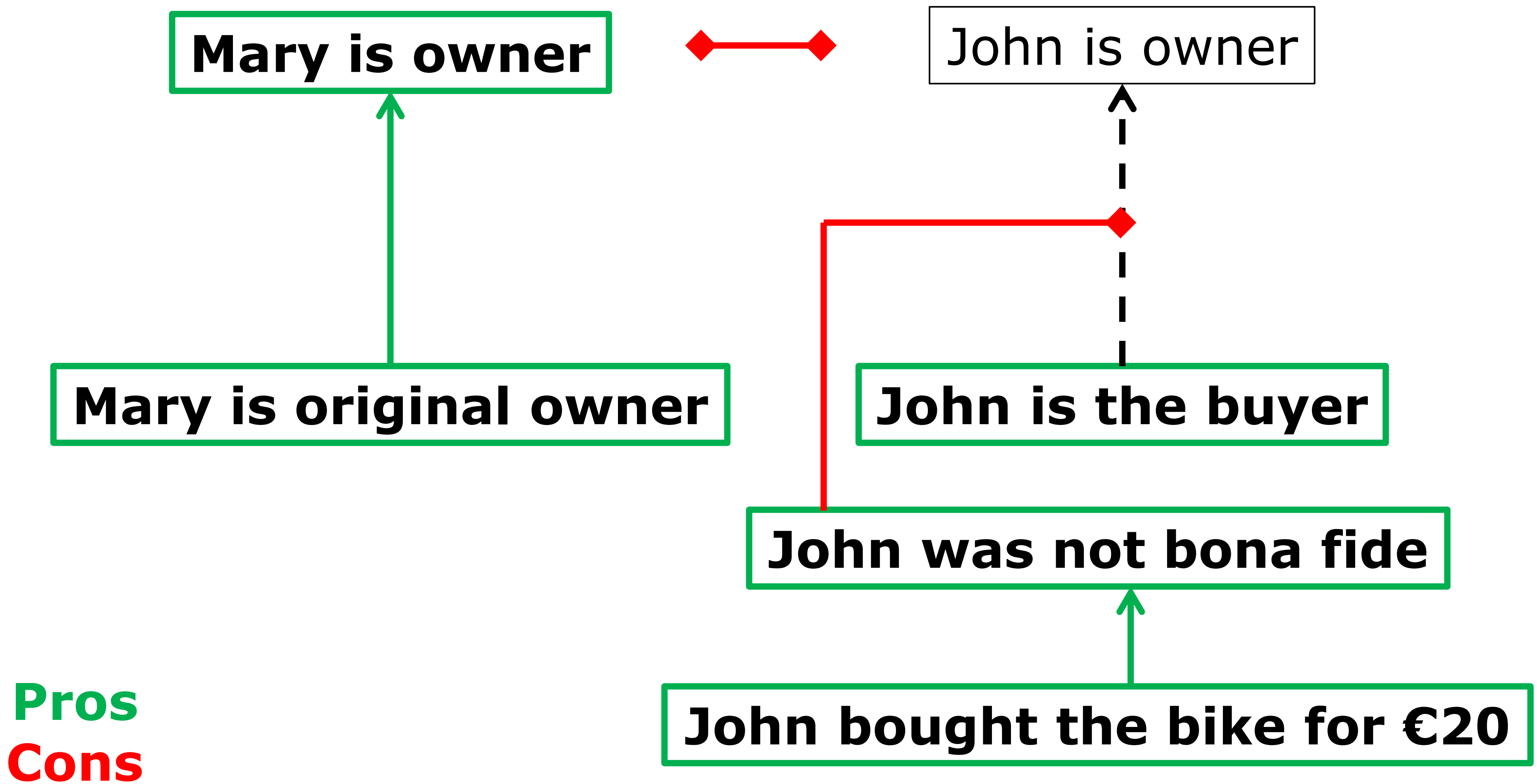
Baroni, P., Toni, F., & Verheij, B. (eds.) (2020). *Argument & Computation* 11 (1-2). On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games: 25 years later

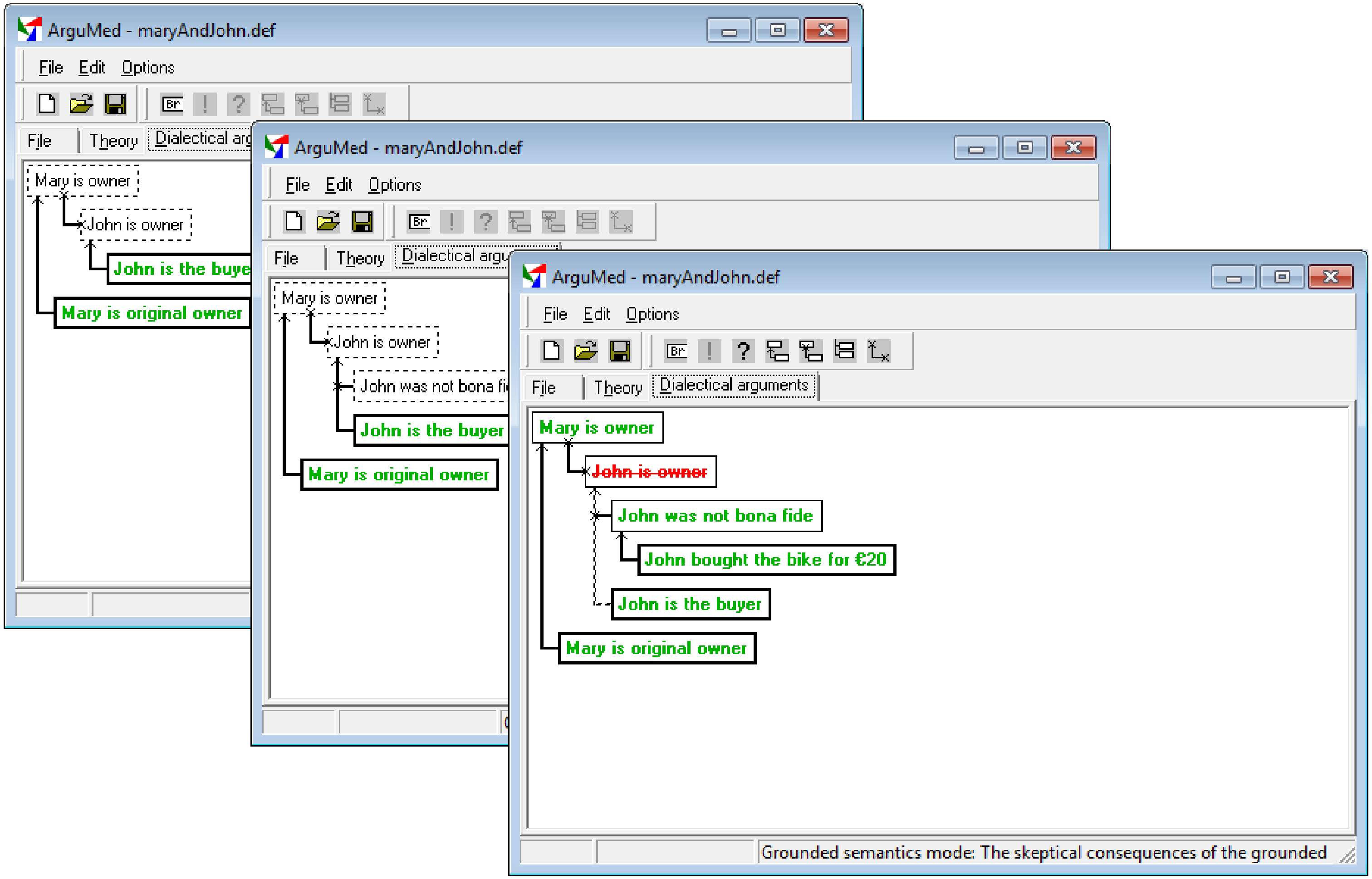

Mary is owner
John is owner
Mary is original owner
John is the buyer

Pros
Cons


Mary is owner
John is owner
Mary is original owner
John is the buyer
John was not *bona fide*

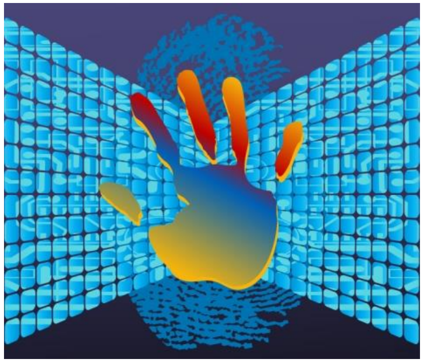
Pros
Cons


Mary is owner
John is owner
Mary is original owner
John is the buyer
John was not bona fide
John bought the bike for €20
Pros
Cons



Verheij, B. (2003). Artificial Argument Assistants for Defeasible Argumentation. *Artificial Intelligence* 150 (1-2), 291-324. dx.doi.org/10.1016/S0004-3702(03)00107-3

Verheij, B. (2005). *Virtual Arguments. On the Design of Argument Assistants for Lawyers and Other Arguers.* T.M.C. Asser Press, The Hague.



Designing and Understanding Forensic Bayesian Networks with Arguments and Scenarios (2012-2017)

Charlotte Vlek, Sjoerd Timmer

Henry Prakken, Silja Renooij, John-Jules Meyer, Rineke Verbrugge, Floris Bex

Netherlands Organisation for Scientific Research
Chemical & Physical Sciences Division

Netherlands Genomics Initiative

university of groningen

Universiteit Utrecht

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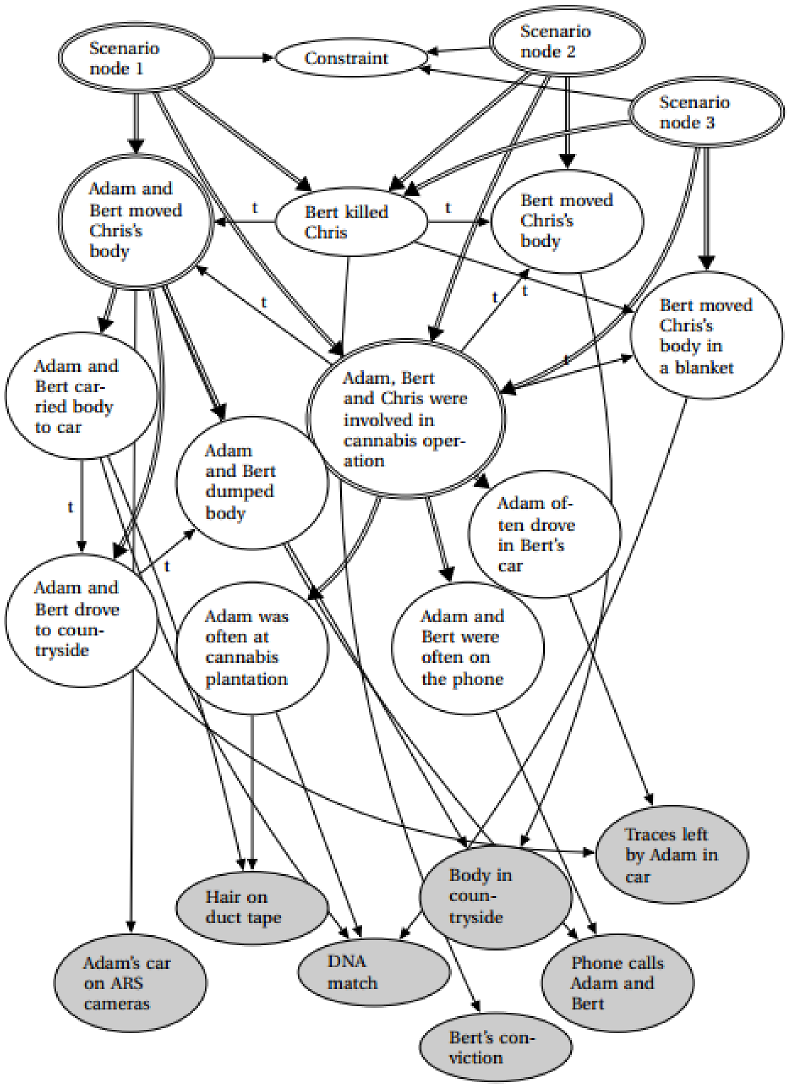


Figure 6.5: A network for the case study: The three scenarios with evidence. Evidential nodes are indicated as grey nodes.

- **Scenarios in the network**:
  - Scenario 1 (prior probability: 0.001, posterior probability: 0.5296):

    Scenario: Bert killed Chris, and Adam, Bert and Chris were involved in cannabis operation. Then Adam and Bert moved Chris's body.

    Adam, Bert and Chris were involved in cannabis operation: Adam was often at cannabis location and Adam and Bert were often on the phone and Adam often drove in Bert's car.

    Adam and Bert moved Chris's body: Adam and Bert carried body to car. Then Adam and Bert drove to countryside. Then Adam and Bert dumped body.
  - Scenario 2 (prior probability: 0.001, posterior probability: 0.1180):

    Scenario: Bert killed Chris, and Adam, Bert and Chris were involved in cannabis operation. Then Bert moved Chris's body.

    Adam, Bert and Chris were involved in cannabis operation: Adam was often at cannabis location and Adam and Bert were often on the phone and Adam often drove in Bert's car.
  - Scenario 3 (prior probability: 0.001, posterior probability: 0.2913):

    Scenario: Bert killed Chris, and Adam, Bert and Chris were involved in cannabis operation. Then Bert moved Chris's body in a blanket.

    Adam, Bert and Chris were involved in cannabis operation: Adam was often at cannabis location and Adam and Bert were often on the phone and Adam often drove in Bert's car.
- **Scenario quality**
  - Scenario 1 is complete and consistent. It contains the supported implausible element `Bert killed Chris`.
  - Scenario 2 is complete and consistent. It contains the supported implausible element `Bert killed Chris`.
  - Scenario 3 is complete and consistent. It contains the supported implausible element `Bert killed Chris`.
- **Evidence related to each scenario**
  - Evidence for and against scenario 1:
    * Adam's car not on ARS cameras: weak evidence to attack scenario 1.
    * DNA match: moderate evidence to support scenario 1.
    * Hair on duct tape: moderate evidence to support scenario 1.
    * Bert's conviction: moderate evidence to support scenario 1.
    * Body in countryside: strong evidence to support scenario 1.
    * Phone calls Adam and Bert: weak evidence to support scenario 1.
    * Traces of Adam in car: weak evidence to support scenario 1.
    * All evidence combined: strong evidence to support scenario 1.
  - Evidence for and against scenario 2:
    * Adam's car not on ARS cameras: weak evidence to attack scenario 2.
    * DNA match: moderate evidence to support scenario 2.

Vlek 2016 dissertation

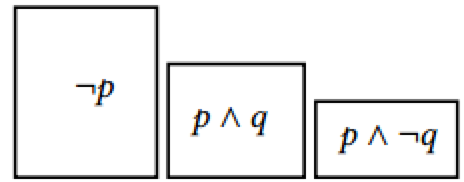
Case models

Definition 2.1. A *case model* is a pair $(C, \geq)$ with finite $C \subseteq L$, such that the following hold, for all φ, ψ and $\chi \in C$:

(1) $\not\models \neg\varphi$;
(2) If $\not\models \varphi \leftrightarrow \psi$, then $\models \neg(\varphi \wedge \psi)$;
(3) If $\models \varphi \leftrightarrow \psi$, then $\varphi = \psi$;
(4) $\varphi \geq \psi$ or $\psi \geq \varphi$;
(5) If $\varphi \geq \psi$ and $\psi \geq \chi$, then $\varphi \geq \chi$.

`With and without numbers'

A total preorder is qualitative (`without numbers'), but can be represented by a numerical function (`with numbers').



So given $(C, \geq)$, there exists a function $n: C \rightarrow \mathbf{R}$ with the following property:

$\neg p \geq p \wedge q \geq p \wedge \neg q$

$3 \geq 2 \geq 1$

$\varphi \geq \psi$ if and only if $n(\varphi) \geq n(\psi)$

$\pi \geq e \geq 1$

Since only the ordering matters, there are many such functions n.

googolplex $\geq$ googol $\geq$ 100

Argument validity (three kinds)

Coherent arguments

$(C, \geq) \models (\varphi, \psi)$ if and only if $\exists \omega \in C$: $\omega \models \varphi \wedge \psi$.

Conclusive arguments

$(C, \geq) \models \varphi \Rightarrow \psi$ if and only if $\exists \omega \in C$: $\omega \models \varphi \wedge \psi$ and $\forall \omega \in C$: if $\omega \models \varphi$, then $\omega \models \varphi \wedge \psi$.

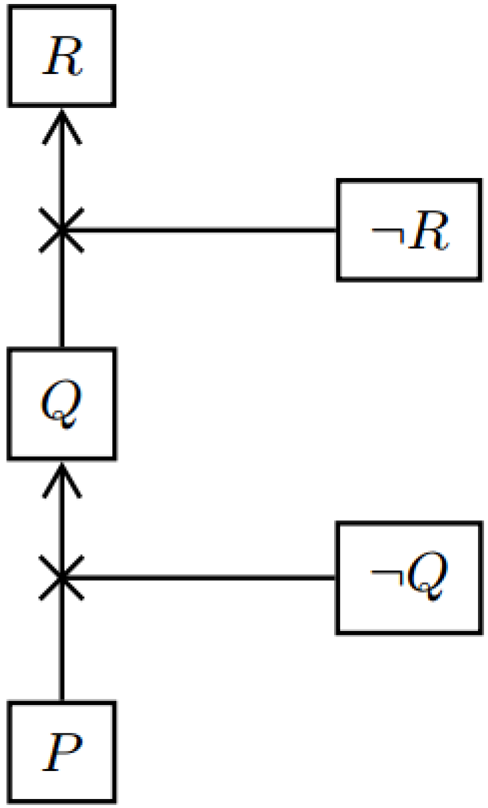
Presumptively valid arguments

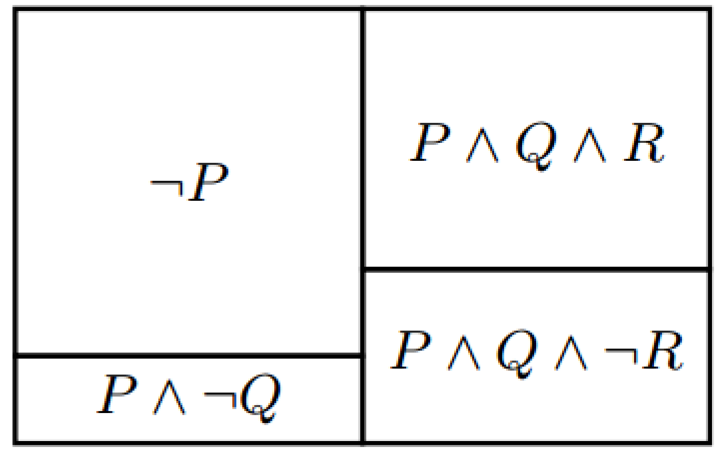
$(C, \geq) \models \varphi \rightsquigarrow \psi$ if and only if $\exists \omega \in C$:

1. $\omega \models \varphi \wedge \psi$; and
2. $\forall \omega' \in C$: if $\omega' \models \varphi$, then $\omega \geq \omega'$.

Argument attack and defeat

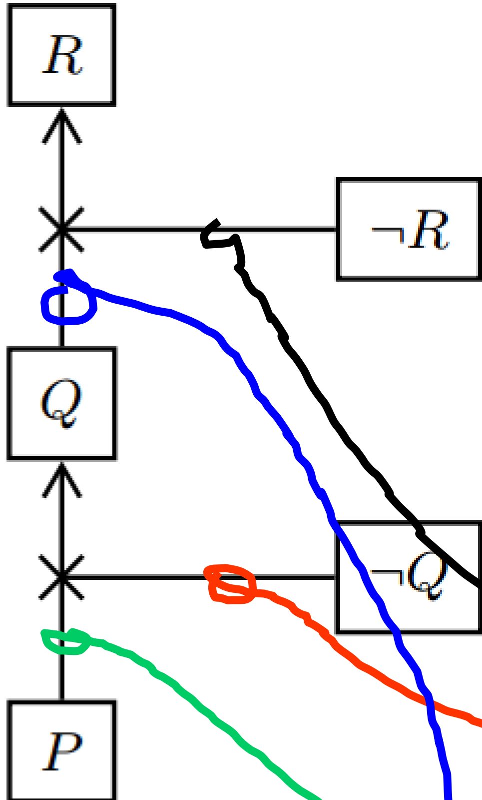
Definition 5.1. (Successful attack) Let $(C, \geq)$ be a case model, and (φ, ψ) a presumptively valid argument. Then circumstances χ are *defeating* or *successfully attacking* the argument when $(\varphi \wedge \chi, \psi)$ is not presumptively valid. We write $(C, \geq) \models \varphi \rightsquigarrow \psi \times \chi$. Defeating circumstances are *excluding* when $(\varphi \wedge \chi, \psi)$ is not coherent. A case $\omega \in C$ provides *grounding* for the attack if $\omega \models \varphi \wedge \chi$.

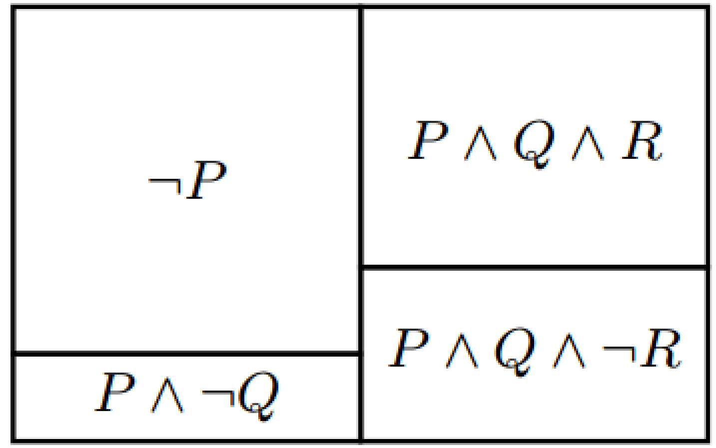




$$(C, \geq) \models P \rightsquigarrow Q \qquad (C, \geq) \not\models P \wedge \neg Q \rightsquigarrow Q$$
$$(C, \geq) \models Q \rightsquigarrow R \qquad (C, \geq) \not\models Q \wedge \neg R \rightsquigarrow R$$

$$(C, \geq) \models P \rightsquigarrow Q \wedge R \qquad (C, \geq) \models Q \Rightarrow P$$
$$(C, \geq) \models R \Rightarrow P \wedge Q \qquad (C, \geq) \models R \Rightarrow Q$$
$$(C, \geq) \models \top \rightsquigarrow \neg P$$





$$(C,\geq) \models P \rightsquigarrow Q$$
$$(C,\geq) \models Q \rightsquigarrow R$$

$$(C,\geq) \not\models P \wedge \neg Q \rightsquigarrow Q$$
$$(C,\geq) \not\models Q \wedge \neg R \rightsquigarrow R$$

$$(C,\geq) \models P \rightsquigarrow Q \wedge R$$
$$(C,\geq) \models R \Rightarrow P \wedge Q$$
$$(C,\geq) \models \top \rightsquigarrow \neg P$$

$$(C,\geq) \models Q \Rightarrow P$$
$$(C,\geq) \models R \Rightarrow Q$$

Theorem 20 *(Presumptive validity; in terms of strength) Let* $(C, \geq)$ *be a non-empty case model and* α *the maximal number of elements in an equivalence class of the preference relation. Let* L^*, v, w *and* s *be as above, with* v α*-separating (as in the lemma). Then the following are equivalent, for all* φ *and* $\psi \in L^*$*:*

1. *The argument from* φ *to* ψ *is presumptively valid;*
2. $s(\varphi, \psi) > 1/(\alpha + 1)$.

Presumptive validity can be represented by a probability function with a threshold

Properties of presumptive validity

Proposition 8 *Let $(C, \geq)$ be a case model. For all φ, ψ and $\chi \in L$:*

(LE) If $\varphi \mid\sim \psi$, $\models \varphi \leftrightarrow \varphi'$ and $\models \psi \leftrightarrow \psi'$, then $\varphi' \mid\sim \psi'$.
(Cons) $\varphi \not\mid\sim \bot$.
(Ant) If $\varphi \mid\sim \psi$, then $\varphi \mid\sim \varphi \wedge \psi$.
(RW) If $\varphi \mid\sim \psi \wedge \chi$, then $\varphi \mid\sim \psi$.
(CCM) If $\varphi \mid\sim \psi \wedge \chi$, then $\varphi \wedge \psi \mid\sim \chi$.
(CCT) If $\varphi \mid\sim \psi$ and $\varphi \wedge \psi \mid\sim \chi$, then $\varphi \mid\sim \psi \wedge \chi$.

Proposition 13 *Let $(C, \geq)$ be a case model, and $L^* \subseteq L$ the closure of C under negation, conjunction and logical equivalence. Writing $\mid\sim^*$ for the restriction of $\mid\sim$ to L^*, we have, for all φ, ψ and $\chi \in L^*$:*

(Coh) $\varphi \mid\sim \varphi$ if and only if $\exists \varphi^* \in L^*$ with $\varphi^* \not\models \bot$ and $\varphi^* \models \varphi$;
(Ch) If $\varphi \mid\sim^* \varphi$ and $\psi \mid\sim^* \psi$, then $\varphi \vee \psi \mid\sim^* \neg\varphi \wedge \psi$ or
$\varphi \vee \psi \mid\sim^* \varphi \wedge \psi$ or $\varphi \vee \psi \mid\sim^* \varphi \wedge \neg\psi$;
(OC) If $\varphi \vee \psi \mid\sim^* \varphi$ and $\psi \vee \chi \mid\sim^* \psi$, then $\varphi \vee \chi \mid\sim^* \varphi$.

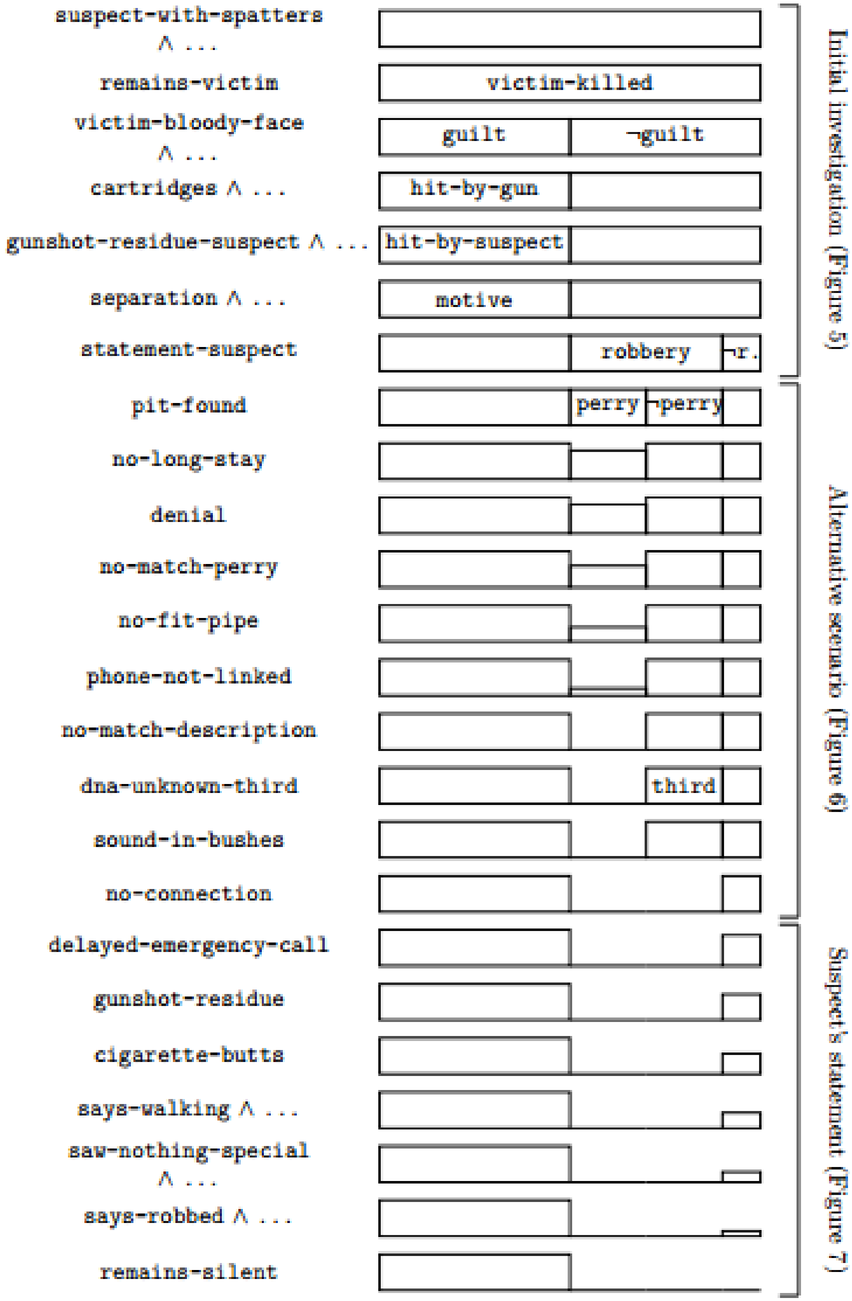
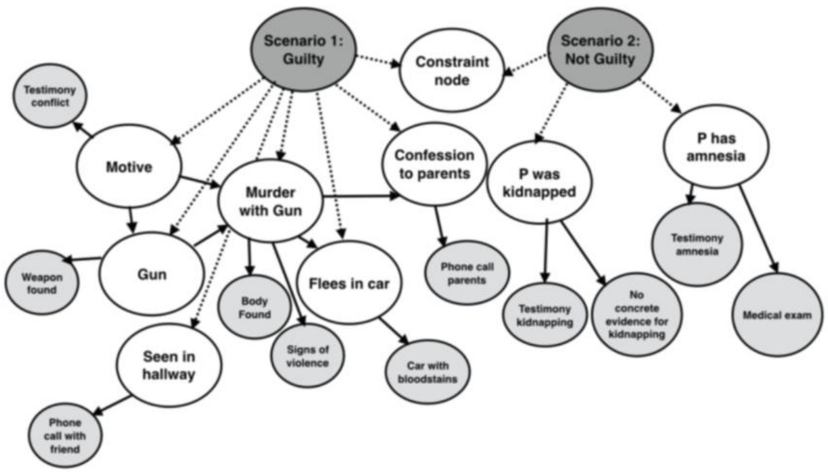
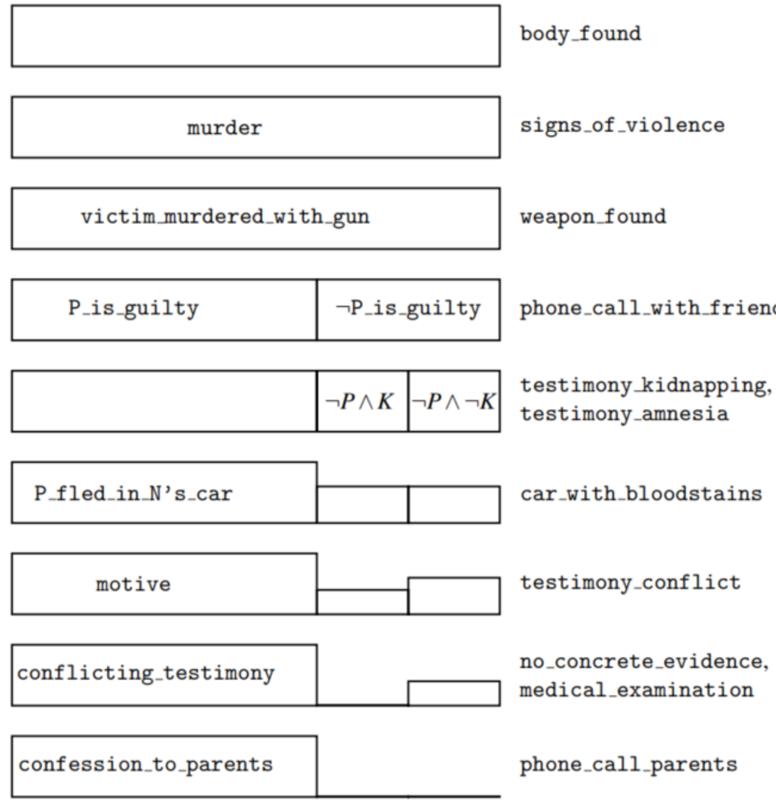


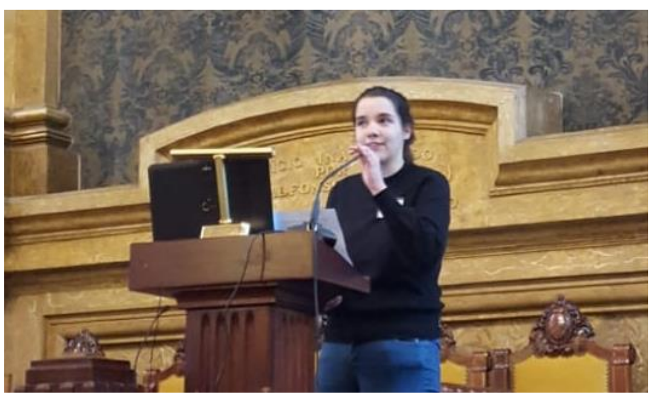
Figure 10: The Appellate Court's reasoning

Verheij, B. (2020). Analyzing the Simonshaven Case With and Without Probabilities. *TopiCS in Cognitive Science* 12 (4), 1175-1999. doi.org/10.1111/tops.12436

Complex arguments grounded in data

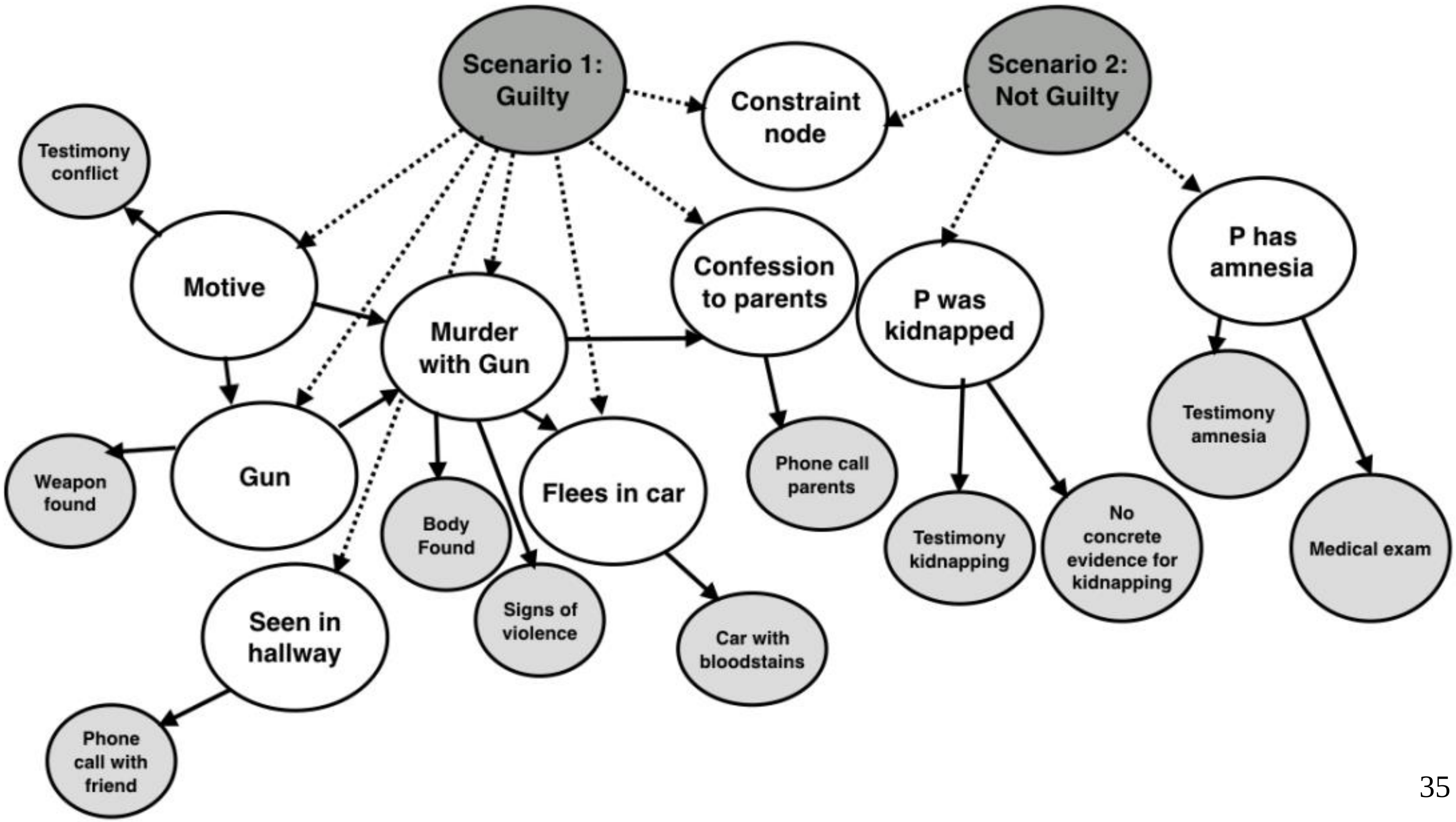






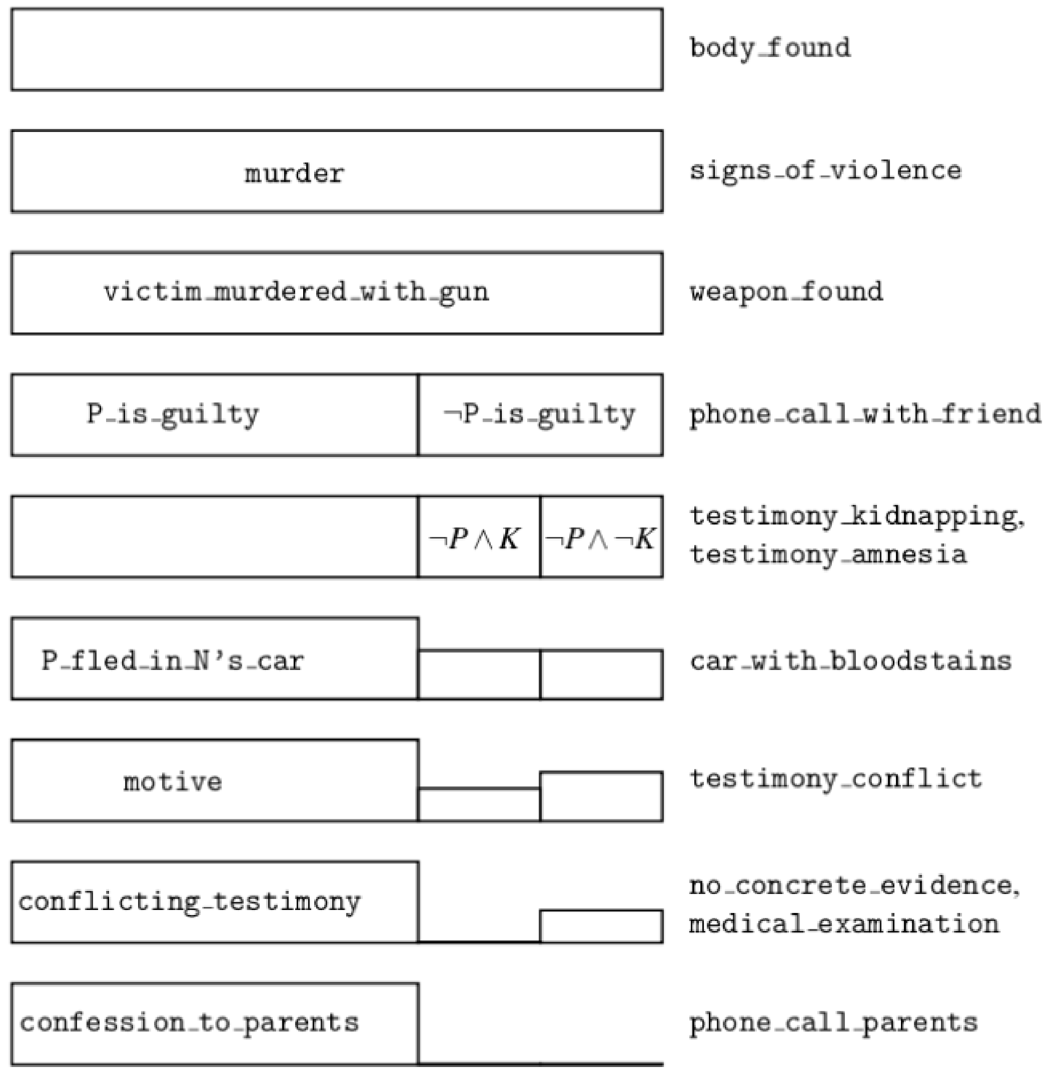
Ludi van Leeuwen JURIX 2019

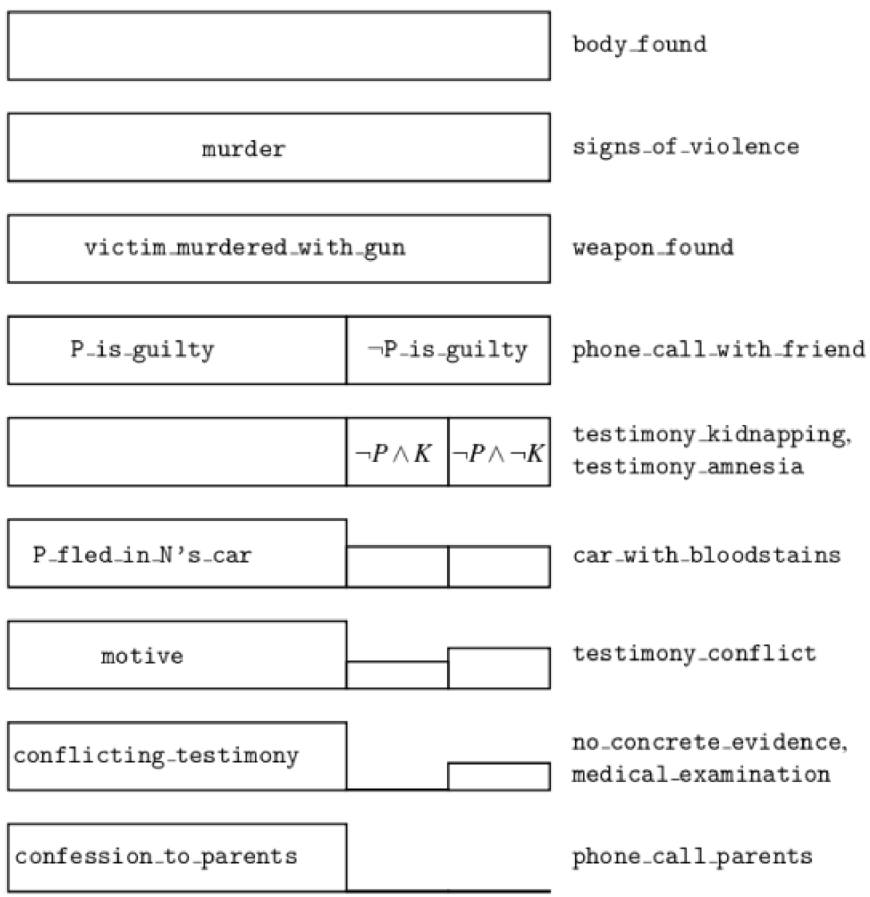
Bayesian network for the murder case



Setting the evidence to true (one by one)

Evidence	P(guilty) in %	P(not_guilty) in %
Start	50	50
Body found	43	56
Signs of violence	76	24
Weapon found	83	16
Phone call with friend	83	16
Testimony kidnapping	75	24
Testimony amnesia	64	35
Car with bloodstains	75	25
Testimony conflict	75	25
No kidnapping found	96	4
No amnesia found	99	1
Phone call parents	close to 100	close to 0


body_found
murder
signs_of_violence
victim_murdered_with_gun
weapon_found
P_is_guilty
¬P_is_guilty
phone_call_with_friend
$\neg P \wedge K$
$\neg P \wedge \neg K$
testimony_kidnapping,
testimony_amnesia
P_fled_in_N's_car
car_with_bloodstains
motive
testimony_conflict
conflicting_testimony
no_concrete_evidence,
medical_examination
confession_to_parents
phone_call_parents



P(Scenario 1) in %	P(Scenario 2) in %
50	50
43	56
76	24
83	16
83	16
75	24
64	35
75	25
75	25
96	4
99	1
close to 100	close to 0

Summary

- The understanding of rational reasoning with uncertainty can benefit from theoretical, empircal and computational insights.
- For reasoning with evidence, three normative tools are investigated: arguments, scenarios and probabilities
- Research has focused on the tools separately, and in various combinations.
- Contemporary AI requires similar combinations of reasoning, knowledge and data.

Robot knows what decision the court will make

Law Without knowing the meaning of words, a computer model can reasonably predict what decisions the European Court of Human Rights will make.

Merel Wiersma December 30, 2020 Reading time 2 minutes

Session room of the European Court of Human Rights in Strasbourg. With artificial intelligence, robot Juri tries to predict court decisions.
Photo Getty Images

Adapted from jurisays.com

JURI SAYS:

I'm predicting judgments of the European Court of Human Rights with an accuracy of 58% over the *past 150 cases.*

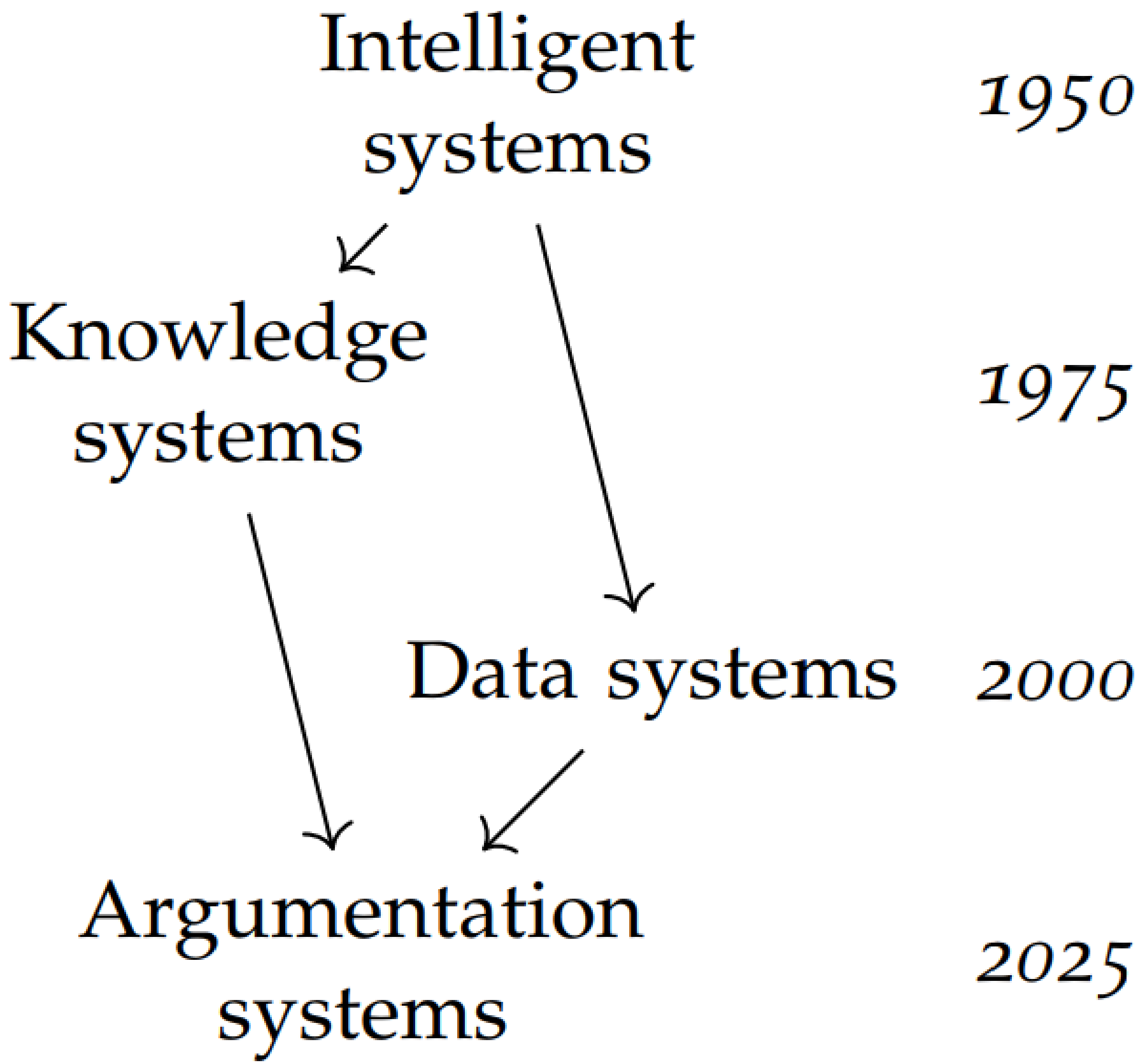
JURI reads published documents from previous years and decisions of the cases judged by the European Court of Human Righ
predicts decisions the Court will make. Every month it learns from its mistakes.

Cropped version of the original photo by Adrian Grycuk (license: CC BY-SA 3.0 PL).

Juri says:
87 out of 150 correct (58%)

Constant baseline:
135 out of 150 correct (90%)

(May 13, 2022)



Verheij 2017

Argumentation systems

Argumentation systems are systems that can conduct a critical discussion in which hypotheses can be constructed, tested and evaluated on the basis of reasonable arguments.

Akata, Z., Balliet, D., de Rijke, M., Dignum , F., Dignum, V., Eiben, G., Fokkens, A., Grossi, D., Hindriks, K., Hoos, H., Hung, H., Jonker, C., Monz, Christof, Neerincx, M.A., Oliehoek, F., Prakken, H., Schlobach, S., van der Gaag, L., van Harmelen, F., van Hoof, H., van Riemsdijk, B., van Wynsberghe, A., Verbrugge, R., Verheij, B., Vossen, P., & Welling, M. (2020).

Computer 53 (8), 18-28.

doi.org/10.1109/MC.2020.2996587

Hybrid Intelligence

Collaborative
Adaptive
Responsible
Explainable

6 universities
10 years
20 M€

Argumentation-based learning

Robot scenario

Failure recovery

Online learning

Low dimensional

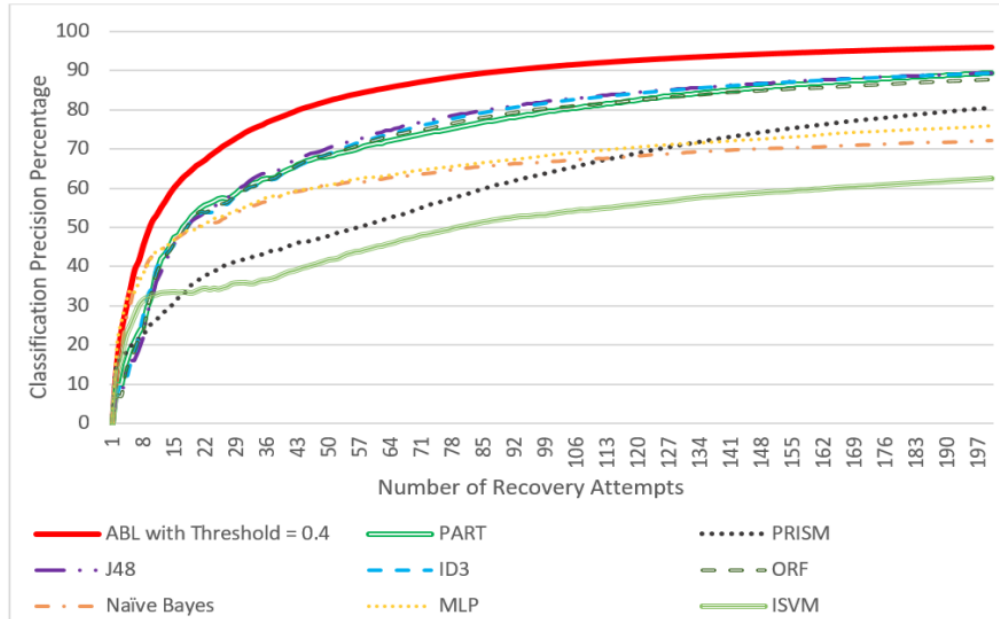
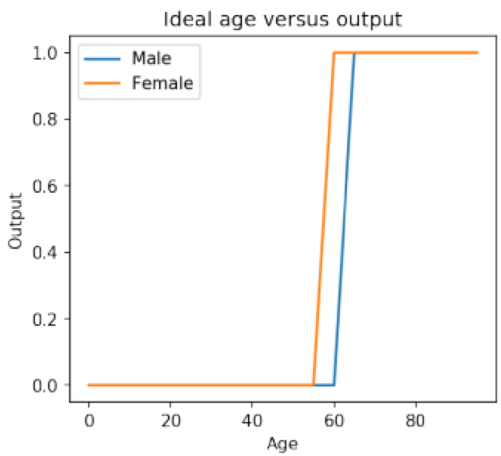


Fig. 7: The comparison of the Argumentation-Based Learning (ABL) with key methods for incremental online learning [17] using the test scenario.

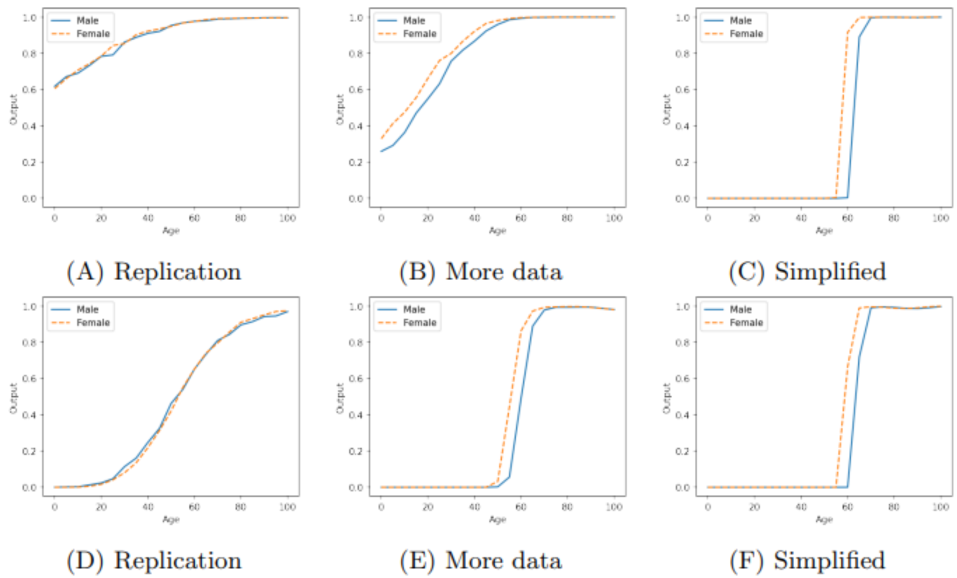
Hamed Ayoobi TASE 2021

Aligning learning and reasoning

Ideal



Closer to ideal



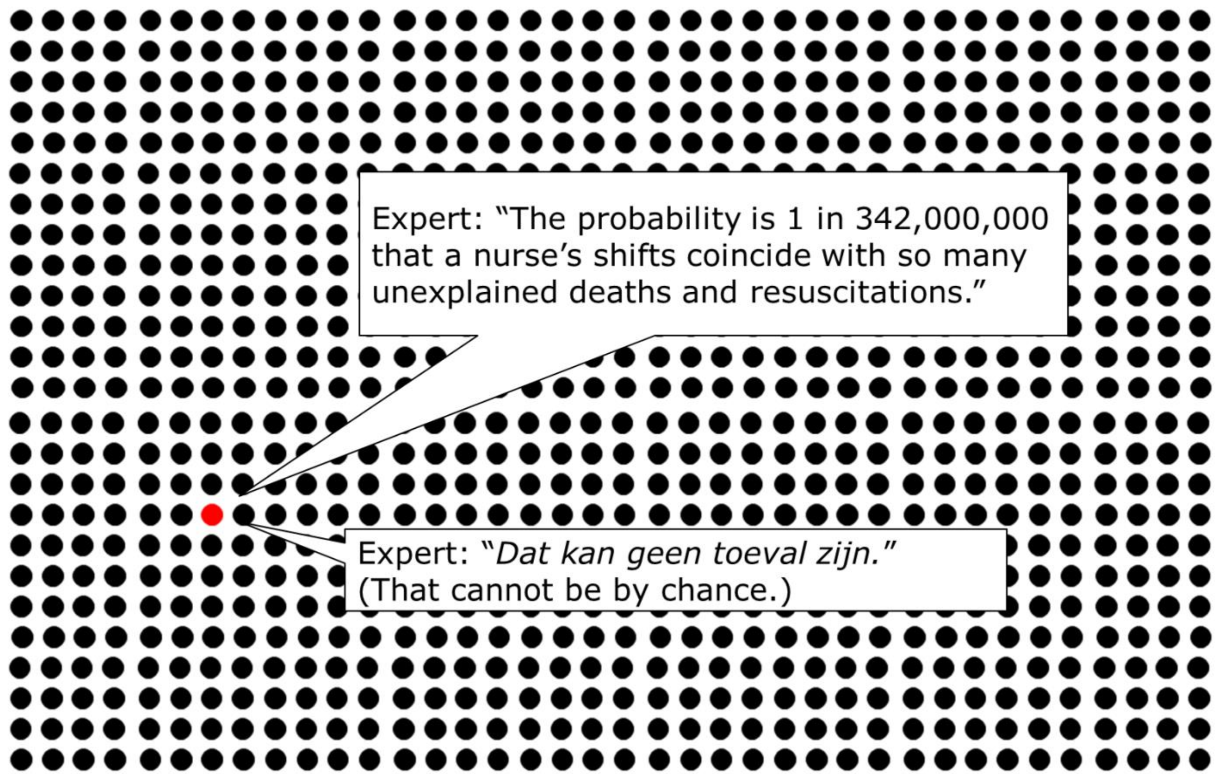
Closer to ideal

Learning a welfare benefit rule using a synthetic data set
(Bench-Capon ICAIL 1993)

The jump should be at 60 for women, 65 for men (difference 5)

More data, a simpler domain, more background knowledge

How can forensic evidence be handled effectively and safely?



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Arguments, scenarios and probabilities as tools for reasoning and uncertainty

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Reading

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