Spring School on Argumentation in Artificial Intelligence and Law

Day 3 Thursday April 12

Evidence

8:30 Burdens of proof in the law (Giovanni Sartor)
10:00 Break
10:30 Three approaches to rational proof in criminal cases (Henry Prakken)
12:00 Break
14:30 Hybrid models of rational legal proof (Bart Verheij)
16:00 Break
16:30 Discussion
17:30
Hybrid models of rational legal proof

Bart Verheij

_Institute of Artificial Intelligence and Cognitive Engineering_

www.ai.rug.nl/~verheij
How can forensic evidence be handled effectively and safely?

Expert: “The probability is 1 in 342,000,000 that a nurse’s shifts coincide with so many unexplained deaths and resuscitations.”

Expert: “Dat kan geen toeval zijn.”
(That cannot be by chance.)
Analyses of what went wrong

1. The statistical calculations were erroneous.
   Wrongly combining p-values
Analyses of what went wrong

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

2. The statistics were erroneous.
   Biased data collection
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 context
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.
- ...
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 victim was a drug dealer involved in a gang war.
- …
Goal:
   promote rational handling of evidence in courts

Tool needed:
   a normative framework
       shared between experts and factfinders
DNA profiling

Successful

High information value

Scientific foundation

Precise statistical information
(Random Match Probability)
### DNA profiling

<table>
<thead>
<tr>
<th>DNA Profile</th>
<th>Allele frequency from database</th>
<th>Genotype frequency for locus</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Locus</strong></td>
<td><strong>Alleles</strong></td>
<td><strong>Times allele observed</strong></td>
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<tr>
<td>CSF1PO</td>
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<td>109</td>
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<td></td>
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<td>64</td>
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<tr>
<td>vWA</td>
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<td>91</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>

**Profile frequency** = 0.00014

Roughly 1 in 7000

Random Match Probability

Charles H. Brenner
“The DNA effect”

By the success and nature of DNA the following idea has gained momentum:

Evidence is only valuable when it comes with scientifically supported statistics.

(Cf. the CSI effect; http://en.wikipedia.org/wiki/CSI_effect)
Proof
With and Without Probabilities

Bart Verheij
Institute of Artificial Intelligence and Cognitive Engineering
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Goal:
  promote rational handling of evidence in courts

Tool needed:
  a normative framework
    shared between experts and factfinders
Three normative frameworks

Arguments

Probabilities

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

Posterior odds = Likelihood ratio $\cdot$ Prior odds

Scenarios
Three normative frameworks

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

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

Posterior odds = Likelihood ratio \cdot Prior odds

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

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.
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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
Introduction

Hybrid models

AI & Law
Anchored narratives

H.F.M. CROMBAG, P.J. VAN KOPPEN & W.A. WAGENAAR

DUBIEUZE ZAKEN

De psychologie van strafrechtelijk bewijs
Ten universal rules of evidence

1. The prosecution must present at least one well-shaped narrative.
2. The prosecution must present a limited set of well-shaped narratives.
3. Essential components of the narrative must be anchored.
4. Anchors for different components of the charge should be independent of each other.
5. The trier of fact should give reasons for the decision by specifying the narrative and the accompanying anchoring.
6. A fact-finder's decision as to the level of analysis of the evidence should be explained through an articulation of the general beliefs used as anchors.
7. There should be no competing story with equally good or better anchoring.
8. There should be no falsifications of the indictment's narrative and nested sub-narratives.
9. There should be no anchoring onto obviously false beliefs.
10. The indictment and the verdict should contain the same narrative.

Anchored narratives

ANT can be regarded as a mixed approach, with story-based and argument-based elements.

Ten universal rules of evidence

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Arguments and scenarios

A1
- evidence: John’s confession
  - John is the source of traces on Mary’s body

A2
- evidence: DNA match John
  - John killed Mary

S1
- John was cycling → John encountered Mary → John molested Mary → John killed Mary

S2
- AS was cycling → AS encountered Mary → AS molested Mary
  - AS killed Mary
  - AS is not the source of traces on Mary’s body
  - evidence: no DNA match AS

A3
- evidence: Mary was found dead
Connecting arguments and scenarios: a hybrid theory

Figure 4: The scenario $S_1$ as an instance of different scenario schemes

Bex 2009 dissertation
Bayesian networks

Figure 5: A Bayesian network structure with dependency relations

<table>
<thead>
<tr>
<th>John is the source</th>
<th>false</th>
<th>true</th>
</tr>
</thead>
<tbody>
<tr>
<td>John is the source = false</td>
<td>8000/8001</td>
<td></td>
</tr>
<tr>
<td>John is the source = true</td>
<td>1/8001</td>
<td></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Someone else is the source</th>
<th>false</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Someone else is the source = false</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Someone else is the source = true</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

DNA match

<table>
<thead>
<tr>
<th>John is the source</th>
<th>false</th>
<th>true</th>
</tr>
</thead>
<tbody>
<tr>
<td>Someone else</td>
<td>false</td>
<td>true</td>
</tr>
<tr>
<td>DNA match = false</td>
<td>0.5*</td>
<td>1 - 0.66 \cdot 10^{-21}</td>
</tr>
<tr>
<td>DNA match = true</td>
<td>0.5*</td>
<td>0.66 \cdot 10^{-21}</td>
</tr>
</tbody>
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</tr>
<tr>
<td>DNA match = true</td>
<td>0.5*</td>
<td>0.5*</td>
</tr>
</tbody>
</table>
Figure 4.11: Scenario 1 and scenario 2 with evidence. Evidential nodes are indicated as grey nodes.
Chapter 6. Case study: the Nijmegen case

- 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.
Figure 2: A small BN concerning psych reports are shown as tables inside the main graph.

Figure 7: Supporting variables are defined as random variables.

Figure 8: An argument graph resulting from our running example. Arrows show the immediate sub-argument relation. Besides the intuitively correct arguments $A_1, \ldots, A_4$ there are two additional arguments depicted that can also be made but that are successfully rebutted by $A_2$. The dashed arrows with crosshair tips show the defeat relation between arguments. Argument $A_5$ is defeated by $A_2$ because $(\text{Motive}, \text{true})$ is probabilistically stronger (using the likelihood ratio measure of strength in this case) than $(\text{Motive}, \text{false})$ based on this evidence. Any conclusion that builds on this second argument (such as $A_6$) is also defeated.
Figure 5.7: Modelling critical questions as a chain of exceptions.
NWO Forensic Science project

- A method to incorporate argument schemes in a Bayesian Network (Timmer, 2017; Timmer et al., 2015a);
- An algorithm to extract argumentative information from a Bayesian Network modeling hypotheses and evidence (Timmer, 2017; Timmer et al., 2016);
- A method to manually design a Bayesian Network incorporating hypothetical scenarios and the available evidence (Vlek, 2016; Vlek et al., 2014);
- A method to generate a structured explanatory text of a Bayesian Network modeled according to this method (Vlek, 2016; Vlek et al., 2016);
- A case study testing the design method (Vlek, 2016; Vlek et al., 2014);
- A case study testing the explanation method (Vlek, 2016).

http://www.ai.rug.nl/~verheij/nwofs/
Bayesian Network modeling with idioms

Strengths

Explicit complex model (allows for discussion)
Correct calculations (supported by software)
Systematic, reusable (idioms)

Issues

Design (numbers, dependencies, compositionality of idioms)
Interpretation (formal versus material meaning)
Goal:
   promote rational handling of evidence in courts

Tool needed:
   a normative framework
       *shared* between experts and factfinders
Integrating the three perspectives

- They are just three different ways of speaking about the same things, each emphasising some specific aspects

- There is no need to idolize any

- There is no need to demonize any
Hypothesis

There exists an integrated perspective on arguments, scenarios and probabilities as normative tools for evidential reasoning in which each has its natural and transparent place.
Arguments, scenarios and probabilities

**Definition 1.** (Case models) A case model is a pair \((C, \geq)\) with finite \(C \subseteq L\), such that the following hold, for all \(\varphi, \psi\) and \(\chi \in C\):

1. \(\not\models \neg \varphi\);
2. If \(\not\models \varphi \leftrightarrow \psi\), then \(\models \neg (\varphi \land \psi)\);
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 \(\varphi \geq \chi\).

Case models are `with and without numbers' in a precise sense:

- the ordering can be derived from a numeric representation;
- it is without numbers since an ordering is a qualitative relation.
Proof With and Without Probabilities
Correct Evidential Reasoning with Presumptive Arguments,
Coherent Hypotheses and Degrees of Uncertainty

Bart Verheij

Received: date / Accepted: date

Abstract Evidential reasoning is hard, and errors can lead to miscarriages of justice with serious consequences. Analytic methods for the correct handling of evidence come in different styles, typically focusing on one of three tools: arguments, scenarios or probabilities. Recent research used Bayesian Networks for connecting arguments, scenarios, and probabilities. Well-known issues with Bayesian Networks were encountered: More numbers are needed than are available, and there is a risk of misinterpretation of the graph underlying the Bayesian Network, for instance as a causal model. The formalism presented here models presumptive arguments about coherent hypotheses that are compared in terms of their strength. No choice is needed between qualitative or quantitative analytic styles, since the formalism can be interpreted with and without numbers. The formalism is applied to key concepts in argumentative, scenario and probabilistic analyses of evidential reasoning, and is illustrated with a fictional crime investigation example based on Alfred Hitchcock’s film ‘To Catch A Thief’.

Evidence

One interpretation of the evidence

Another interpretation of the evidence

\[ p(H_1 | E) \]

\[ p(H_2 | E) \]
Proof With and Without Probabilities

An argumentation theory that connects
- presumptive arguments,
- coherent hypotheses, and
- degrees of uncertainty
using classical logic and standard probability theory.

Fig. 1 General idea: an argument with a counterargument (left); arguments for conflicting cases and their comparison (middle); cases and their comparative value (right)
- Patients have reported a sexual assault by their doctor (patients).
- The DNA of a trace of semen found on one patient is compared with the DNA in a blood sample taken from the doctor. There is no match (¬dna-match).
- The doctor had implanted a drain into his arm, filled with someone else’s blood (implant).

See https://en.wikipedia.org/wiki/DNA_profiling#Fake_DNA_evidence
By patients, we presume dna-match and guilt
patients ~> dna-match \land guilt

We find \neg dna-match, so now we presume \neg guilt
patients \land \neg dna-match ~> \neg guilt

We find implant, so we presume, in fact conclude, guilt
patients \land \neg dna-match \land implant ~> guilt
patients \land \neg dna-match \land implant => guilt
Case 1.1: guilt ∧ patients ∧ dna-match
Case 1.2: guilt ∧ patients ∧ ¬dna-match ∧ implant
Case 2: ¬guilt ∧ patients ∧ ¬dna-match

Case 1.1 > Case 2 > Case 1.2

Figure 2: Case model for the example
Case 1.1 > Case 2 > Case 1.2

3 > 2 > 1

Pr(Case1.1) = \frac{3}{3+2+1} = 50%
Pr(Case2) = \frac{2}{3+2+1} \sim 33%
Pr(Case1.2) = \frac{1}{3+2+1} \sim 17%
\( \pi > e > 1 \)

Pr(Case1.1) = \( \pi/(\pi+e+1) \) \( \sim \) 46%
Pr(Case2) = \( e/(\pi+e+1) \) \( \sim \) 40%
Pr(Case1.2) = \( 1/(\pi+e+1) \) \( \sim \) 14%

Case 1.1 > Case 2 > Case 1.2
Case 1.1 > Case 2 > Case 1.2

very high > low > extremely small

\[\text{Pr(Case1.1)} \sim 99\%\]
\[\text{Pr(Case2)} \sim 1\%\]
\[\text{Pr(Case1.2)} \sim 0.0\ldots01\%\]
Case 1.1 > Case 2 > Case 1.2

very high > low > extremely small

Pr(Case1.1) ~ 99%
Pr(Case2) ~ 1%
Pr(Case1.2) ~ 0.0..01%

(It seems that we don’t need the numbers)
Kinds of argument validity

Coherent arguments

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

Conclusive arguments

\((C, \geq) \models \varphi \Rightarrow \psi\) if and only if \(\exists \omega \in C: \omega \models \varphi \land \psi\) and \(\forall \omega \in C: \text{if } \omega \models \varphi, \text{ then } \omega \models \varphi \land \psi\).

Presumptively valid arguments

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

1. \(\omega \models \varphi \land \psi\); and
2. \(\forall \omega' \in C: \text{if } \omega' \models \varphi, \text{ then } \omega \geq \omega'\).
<table>
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<tr>
<th>Arguments</th>
<th>Scenarios</th>
<th>Probabilities</th>
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<tr>
<td>Coherence</td>
<td>Coherence</td>
<td>p &gt; 0</td>
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<tr>
<td>Presumptive validity</td>
<td>Plausible</td>
<td>p maximal, p &gt; t</td>
</tr>
<tr>
<td>Conclusive</td>
<td>Beyond a reasonable doubt</td>
<td>p = 1</td>
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Three kinds of validity

Coherent arguments

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

Presumptive arguments

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

1. \(\omega \models \varphi \land \psi\); and
2. \(\forall \omega' \in C: \text{if } \omega' \models \varphi, \text{then } \omega \geq \omega'\).

Conclusive arguments

\((C, \geq) \models \varphi \Rightarrow \psi\) if and only if \(\exists \omega \in C: \omega \models \varphi \land \psi\) and \(\forall \omega \in C: \text{if } \omega \models \varphi, \text{then } \omega \geq \omega\).
Evidence

Hypotheses

<table>
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<tr>
<th>resemblance</th>
<th>robie</th>
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<td>j.</td>
<td>¬j.</td>
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<tr>
<td>finding</td>
<td></td>
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</table>

Hypothesis 1  Hypothesis 2  Hyp. 3  Hyp. 4
Block 1: Robie indeed was the thief
Block 3: Resistance friend Foussard’s daughter was the thief
coherent, presumptive, not conclusive

coherent, not presumptive, not conclusive
robie

\( \text{resemblance} \land \text{escape} \land \text{fight} \)

defeating, rebutting

defeating, rebutting

not coherent, not presumptive, not conclusive

cohesive, presumptive, conclusive
\neg \text{robie} \land \neg \text{fousard} \land \text{daughter} \land \text{jewelry} \\
\text{resemblance} \land \text{escape} \land \text{fight} \land \text{prosthesis} \land \text{arrest} \land \text{confession} \land \text{finding} \\
\text{coherent, presumptive, conclusive}
jewelry

finding

cohort, presumptive, not conclusive

cohort, presumptive, not conclusive

confession
Hypothesis

There exists an integrated perspective on arguments, scenarios and probabilities as normative tools for evidential reasoning in which each has its natural and transparent place.
Introduction
Hybrid models
AI & Law
Artificial intelligence and Law

Legal artificial intelligence
Artificial Intelligence and Law

Data

Knowledge
The two faces of Artificial Intelligence

Expert systems | Adaptive systems
Business rules | Machine learning
Open data | Big data
IBM’s Deep Blue | Watson
Complex structure | Adaptive structure

Knowledge Foundation:
- Logic
- Explainability

Data tech Foundation:
- Probability theory
- Scalability
Day 1 Tuesday April 10

Abstract and structured formal frameworks for argumentation

8:30  Introduction and abstract argumentation frameworks (Bart Verheij)
10:00 Break
10:30 Structured argumentation frameworks, in particular ASPIC+ (Henry Prakken)
12:00 Break
14:30 Legal defeasibility as modelled in abstract and structured argumentation frameworks (Giovanni Sartor)
16:00 Break
16:30 Discussion
17:30
Day 2 Wednesday April 11

Legal argumentation

8:30  Cases & Rules: HYPO, CATO and beyond (Henry Prakken)
10:00 Break
10:30 Case models (Bart Verheij)
12:00 Break
14:30 Balancing & interpretation (Giovanni Sartor)
16:00 Break
16:30 Discussion
17:30
Day 3 Thursday April 12

Evidence

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Spring School on Argumentation in Artificial Intelligence and Law

Invited graduate course
at the Institute of Logic and Cognition, Sun Yat-Sen University, Guangzhou

Henry Prakken, Giovanni Sartor, Bart Verheij, April 2018

http://www.ai.rug.nl/~verheij/sysu2018/
Three frameworks
  Di Bello & Verheij 2018
Hybrid models
  Verheij et al 2016
  Vlek et al 2017
  Timmer 2017
  Verheij 2017a
Bayesian Networks project
  http://www.ai.rug.nl/~verheij/nwofs/