Making Likelihood Ratios digestible for Cross-Application Performance Assessment

da/sec BIOMETRICS AND INTERNET-SECURITY RESEARCH GROUP

UNIVERSITY OF TWENTE.

Netherlands Forensic Institute
Ministry of Justice and Security

UNIVERSIDAD AUTONOMA DE MADRID

UNIVERSITAS GOTHOBURGENSIS 1891

ANDREAS NAUTSCH[1], DIDIER MEUWLY[2], DANIEL RAMOS[3], JONAS LINDH[4], CHRISTOPH BUSCH[1]

[1]da/sec – Biometrics and Internet Security Research Group, Hochschule Darmstadt, Germany
[2]Universiteit Twente, Netherlands and the Netherlands Forensic Institute, The Hague, Netherlands
[3]AuDIaS – Audio, Data Intelligence and Speech, EPS, Universidad Autónoma de Madrid, Spain
[4]Göteborgs Universitet, Sweden
andreas.nautsch@h-da.de,d.meuwly@utwente.nl,daniel.ramos@uam.es,
jonas.lindh@gu.se,christoph.busch@h-da.de

h_da HOCHSCHULE DARMSTADT UNIVERSITY OF APPLIED SCIENCES

LOEWE

CRISP Center for Research in Security and Privacy

Motivation

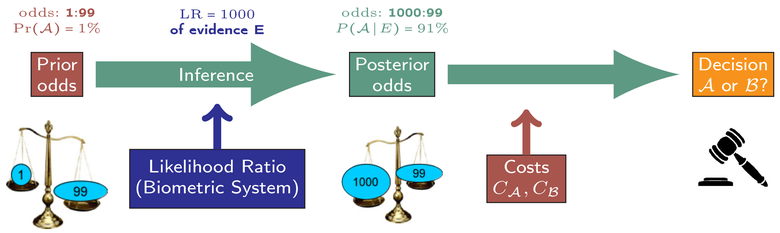
- Bridging Gaps between Communities: Biometrics ⇔ Forensics
- Bayesian Decision Theory (BDT)
  ⇒ formal way of denoting Thresholds
  ⇒ Scores are Likelihood Ratios (LRs)
- Meaningful Thresholds
- Research Questions
  - *LRs in Receiver Operating Characteristics (ROCs)?*
  - *Decision Evaluation in ROCs?*
  - *Visualization of C_{llr} criterion?*
  - How-To: set Operating Points?
    ⇒ Step-by-Step: Priors & Costs
    ⇒ Set Ranges of Thresholds

Bayesian Decision Framework

- Prior Belief: updated by LR (i.e., the evidence) ⟶ Posterior Belief in *Truth* of proposition $\mathcal{A}$ vs. $\mathcal{B}$
  Example: $\mathcal{A}$: *True Biometric Claim* ⇔ $\mathcal{B}$: *False Biometric Claim*
- Decisions by Incentives: costs $C_\mathcal{A}, C_\mathcal{B}$: Posterior Odds > Cost Odds?
- Log-LR Thresholds: $\eta = \text{logit}(1-c) + \text{logit}(1-\pi)$ *with:* $c = \frac{C_\mathcal{A}}{C_\mathcal{A}+C_\mathcal{B}}, \pi = \frac{\Pr(\mathcal{A})}{\Pr(\mathcal{A})+\Pr(\mathcal{B})}$
- Evaluation by Decision Cost Functions (DCFs)
- Evaluation by Goodness of Log-LRs

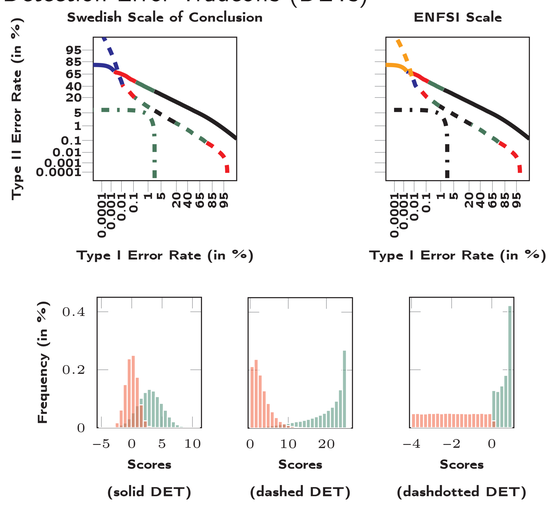
$$\text{DCF}(S\,|\,\eta) = \pi\, c\, p_{\mathit{II}}(S\,|\,\eta) + (1-\pi)\,(1-c)\, p_{\mathit{I}}(S\,|\,\eta)$$

$$C_{\text{llr}} = \int \text{DCF}(S\,|\,\eta)\,\mathrm{d}\eta \quad \textit{note:}\ C_{\text{llr}}^{\text{min}} = \int \min_{\eta} \text{DCF}(S\,|\,\eta)\,\mathrm{d}\eta$$



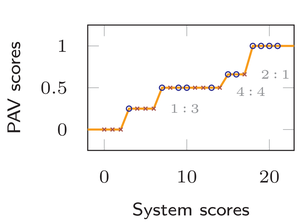
Verbal color-encoded DET

Detection Error Tradeoffs (DETs)

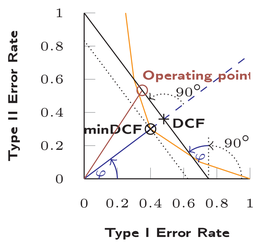


The ROC's Convex Hull (ROCCH) and angular Operating Points φ

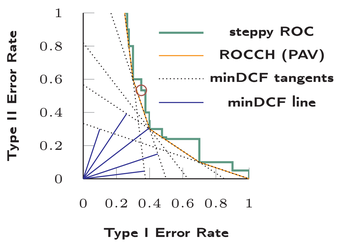
1) Simulate ideal Score Calibration



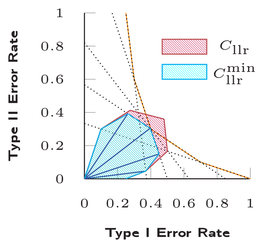
2) Geometric Analysis: DCFs and φ



3) ROC Convex Hull (ROOCH)



4) Interrelating C_{llr}



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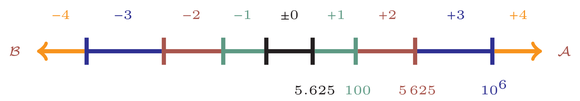
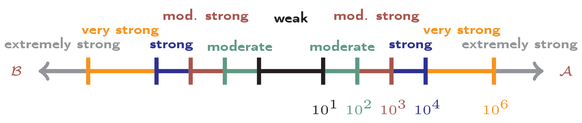
Verbal Scales: digestible LRs

- Introduced in Forensics since 1961 (Jeffreys)
  - LR Values: varying interpretation
  - Layman: verbal quantification
- Swedish Scale of Conclusion (2015)



- ENFSI Scale (2016)

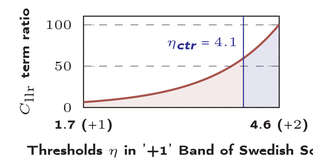


Setting Operating Points

- Decide on a Band in the Verbal Scale

⇒ Initialize with C_{llr} Center of Gravity η_{ctr}

C_{llr} **term ratio:** $\int_{\eta_1}^{\eta_{ctr}} \frac{\log(1+e^x)}{\log(1+e^{-x})}\,\mathrm{d}x = \int_{\eta_{ctr}}^{\eta_2} \frac{\log(1+e^x)}{\log(1+e^{-x})}\,\mathrm{d}x$



- Define Costs $C_\mathcal{A}, C_\mathcal{B}$ ⇒ derive π, c, η_{ctr}
- Fine-Tune c and π Parameters ⇒ η_{ctr}-offset δ

$$\begin{aligned}\delta &= \eta' - \eta \\ &= \text{logit}(1-c') + \text{logit}(1-\pi') - \text{logit}(1-c) - \text{logit}(1-\pi) \\ &= \log \frac{C'_\mathcal{B}}{C_\mathcal{B}} \frac{C_\mathcal{A}}{C'_\mathcal{A}} + \text{logit}\,\pi + \log\left(\frac{1}{\pi} - \frac{\pi'}{\pi}\right) - \log\frac{\pi'}{\pi}\end{aligned}$$

⇒ Lower & Upper Bound to Threshold Range