Objective evaluation - Linkability

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Linkability: Definition

First introduced for biometric template protection evaluation in [Gomez-Barrero et al. 2017].

Input: scores $S$ of the ASV

Two types of trials: $H$ mated and $\bar{H}$ non-mated

The goal is to measure:

$$\text{Linkability}(s) = p(H \mid s) - p(\bar{H} \mid s)$$
Linkability: Definition

\[ \text{Linkability}(s) = p(H \mid s) - p(\overline{H} \mid s) \]

**Local measure of linkability**

After some transformation with the likelihood ratio

\[ LR(s) = \frac{p(s \mid H)}{p(s \mid \overline{H})} \]

and the prior ratio \( \omega = \frac{p(H)}{p(\overline{H})} \)

\[ D_{\leftrightarrow}(s) = \begin{cases} 
2 \cdot \omega \cdot LR(s) & \text{if } \omega \cdot LR(s) > 1 \\
\frac{1}{1 + \omega \cdot LR(s)} & \text{otherwise}
\end{cases} \]

**Global measure of linkability**

\[ D^{\text{sys}}_{\leftrightarrow} = \int p(s \mid H)D_{\leftrightarrow}(s) \, ds \]
Advantages

• No notion of threshold or attacker used.

• Any local separation between mated and non-mated scores can be detected.

Disadvantages

• The usage of bins to estimate the probabilities is not exact.

• Focus only on the mated cases, the strength of non-mated evidence is ignored.
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Linkability: No threshold

[DA Van Leeuwen & N Brümmer Speaker classification 2007]
Linkability: Advantages and Disadvantages

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Linkability: example of complex relation

\[ D_{\leftrightarrow}^{\text{sys}} = 0.99 \text{ (low privacy)} \]
\[ C_{\text{lrr}}^{\text{min}} = 0.81 \text{ (high privacy)} \]
Linkability: estimation of LRs

For $C_{llr}$, $LLRs$ are the scores of the ASV.

For $C_{llr}^{min}$, $LLRs$ are the calibrated scores of the ASV (PAV algorithm [Brummer et al. CSL’06]).

For $D_{\leftrightarrow}^{sys}$: the local conditional probability are estimated using Histograms

$$LR(s) = \frac{p(s \mid H)}{p(s \mid \overline{H})}$$

Bins are used to estimate the local probabilities
Linkability: Advantages and Disadvantages

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Linkability: only mated evidence

\[ D_{\leftrightarrow}(s) = \begin{cases} \frac{2 \cdot \omega \cdot LR(s)}{1 + \omega \cdot LR(s)} - 1 & \text{if } \omega \cdot LR(s) > 1 \\ 0 & \text{otherwise} \end{cases} \]

\[ p(H \mid s) > p(\overline{H} \mid s) \]

\[ D^{sys}_{\leftrightarrow} = \int p(s \mid H) D_{\leftrightarrow}(s) \, ds \]
Objective evaluation
Linkability
Linkability and EER

EER vs Linkability (means over all VoicePrivacy datasets)
Linkability and $C_{llr}^{\text{min}}$

One datapoint per dataset, attacker and system
Linkability and $C_{llr}^{\text{min}}$

One datapoint per dataset, attacker and system.
Interesting case

Vctk-test-f (o-a)

$D^{JS}_{o,a} = 0.17$
Linkability vs EER

One datapoint per dataset, attacker and system.
Linkability: EER vs ROCCH-EER

One datapoint per dataset, attacker and system
Interesting cases

Vctk-test-f (o-a)

$D^{ys}_{o-a} = 0.17$

Vctk-test-m (o-a)

$D^{ys}_{o-a} = 0.19$
Linkability vs Zebra

One datapoint per dataset, attacker and system