Vulnerability Evaluation for Presentation + Morphing Attacks

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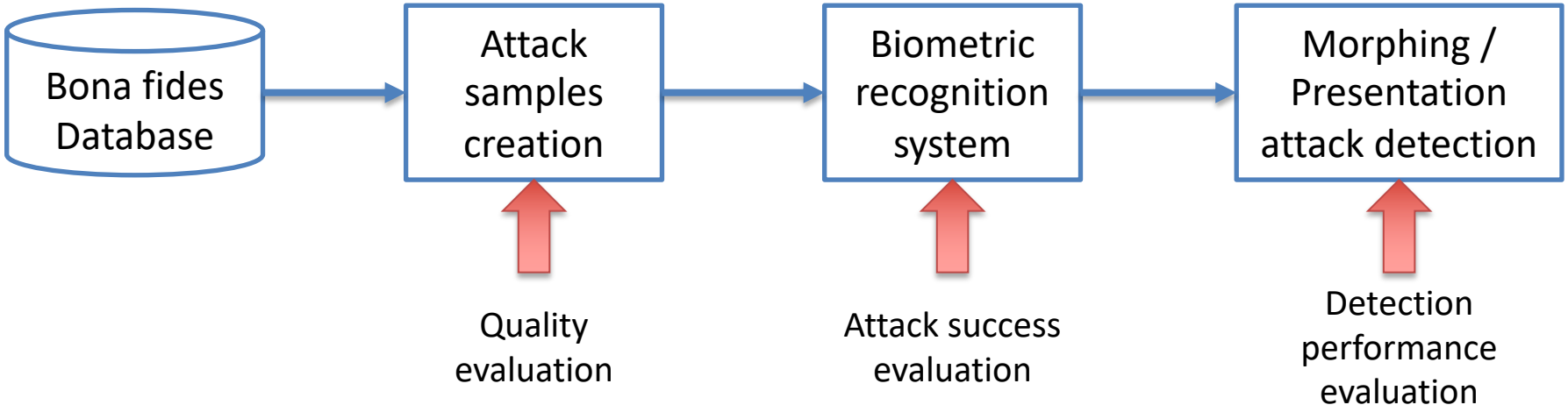
Outline

- Context
- Quality Evaluation
- Attack Success Evaluation
- Detection Performance Evaluation
- Conclusions

Context

Morphing / Presentation Attack Detection Steps

- To establish a fair and realistic benchmark, we first need to model a realistic scenario...
- Taking into account all the intermediate steps



U. Scherhag, A. Nautsch, C. Rathgeb, M. Gomez-Barrero, R. Veldhuis, L. Spreeuwers, M. Schils, D. Maltoni, P. Grother, S. Marcel, R. Breithaupt, R. Raghavendra, C. Busch: "Biometric Systems under Morphing Attacks: Assessment of Morphing Techniques and Vulnerability Reporting", in Proc. BIOSIG, 2017

Quality Evaluation

Quality Evaluation Goals

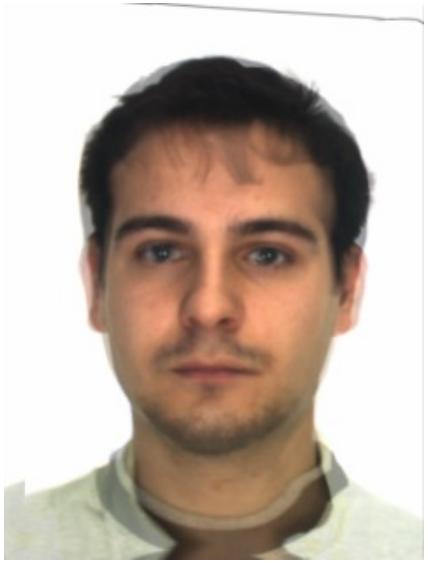
- Key question: is the attack **realistic**?

- Different aspects might influence presentation attack instruments (PAIs):
  - Unattended scenario: the PAI must “only” fool the system
  - Attended scenario: PAI appearance gains importance

- Major factors for achieving realistic morphed samples:
  - Morphing quality
  - Similarity of the constituent subjects (e.g., age, gender, etc.)
  - Consistent quality of the database (bona fides vs morphs)

Morphing Quality (I)

- Attackers can take a long time (even weeks) for each morphed sample creation ⇒ high quality morph
- For research, this task is automated ⇒ low quality morph
- Don‘t forget, that images must be accepted at the passport application office!



Morphing Quality (II)

- Equal quality for bona fide and morphed samples is important
- Otherwise, the classifier is biased towards different quality levels

Impact of Compression

Bona fide sample

BRISQUE = 21.0

Uncompressed morphed sample

BRISQUE = 29.1

Compressed morphed sample

BRISQUE = 50.0

Blind / Referenceless Image QUality Evaluator (BRISQUE)

Attack Success Evaluation

Attack Success Evaluation Goals

- Key question: is the system **vulnerable** to the attacks?
  - We need to evaluate the percentage of successful attacks
  - This depends on the operating point of the system!
    ⇒ decision threshold $\boldsymbol{\delta}$

- Key question 2: is the system still **convenient**?
  - We can choose a high security operating point, and then reject all bona fide samples as well!

- Note: all comparisons should be uncorrelated (Mansfield, Wayman)

Presentation Attack Success: IAPMR

- ISO/IEC 30107-3 on Presentation Attack Detection evaluation defines:
  - **Impostor Attack Presentation Match Rate (IAPMR)**: in a full system evaluation of a verification system, the proportion of impostor attack presentations […] in which the target reference is matched

$$\mathrm{IAPMR} = \frac{1}{M} \cdot \sum_{m=1}^{M} \{[S_m] > \delta\}$$

- But a morph is only successful if **all** contributing subjects are matched.

Morphing Attack Success: MMPMR

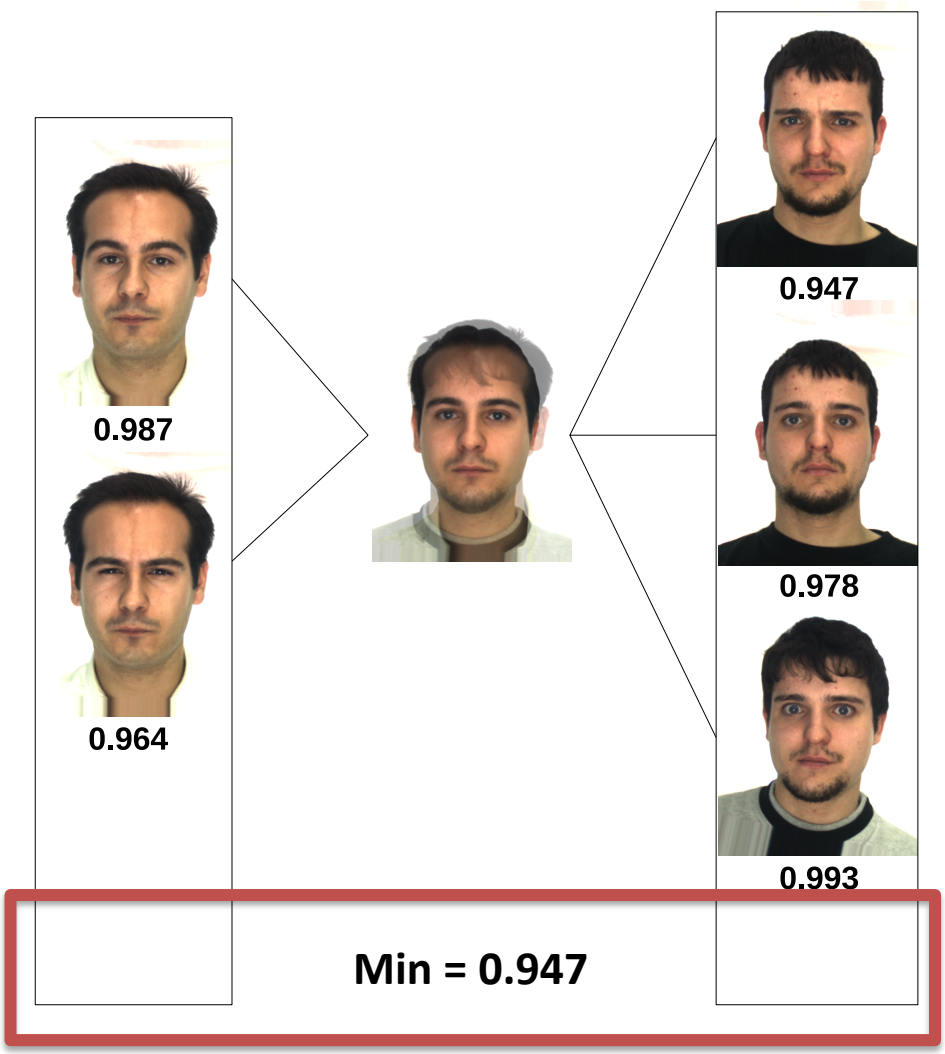
- ***Mated Morph Presentation Match Rate (MMPMR)***: proportion of mated morph presentations (i.e., the morph image is compared to a bona fide samples stemming from one of the constituent subjects) in which the target reference is matched

- We compare all N_m samples of each of the M constituent subjects to the morphed sample

- If **all samples** are matched (i.e., scores above δ) ⇒ **success**!

$$\mathrm{MMPMR} = \frac{1}{M} \cdot \sum_{m=1}^{M} \left\{ \left[\min_{n=1,\ldots,N_m} S_m^n \right] > \delta \right\}$$

Morphing Attack Success: MMPMR



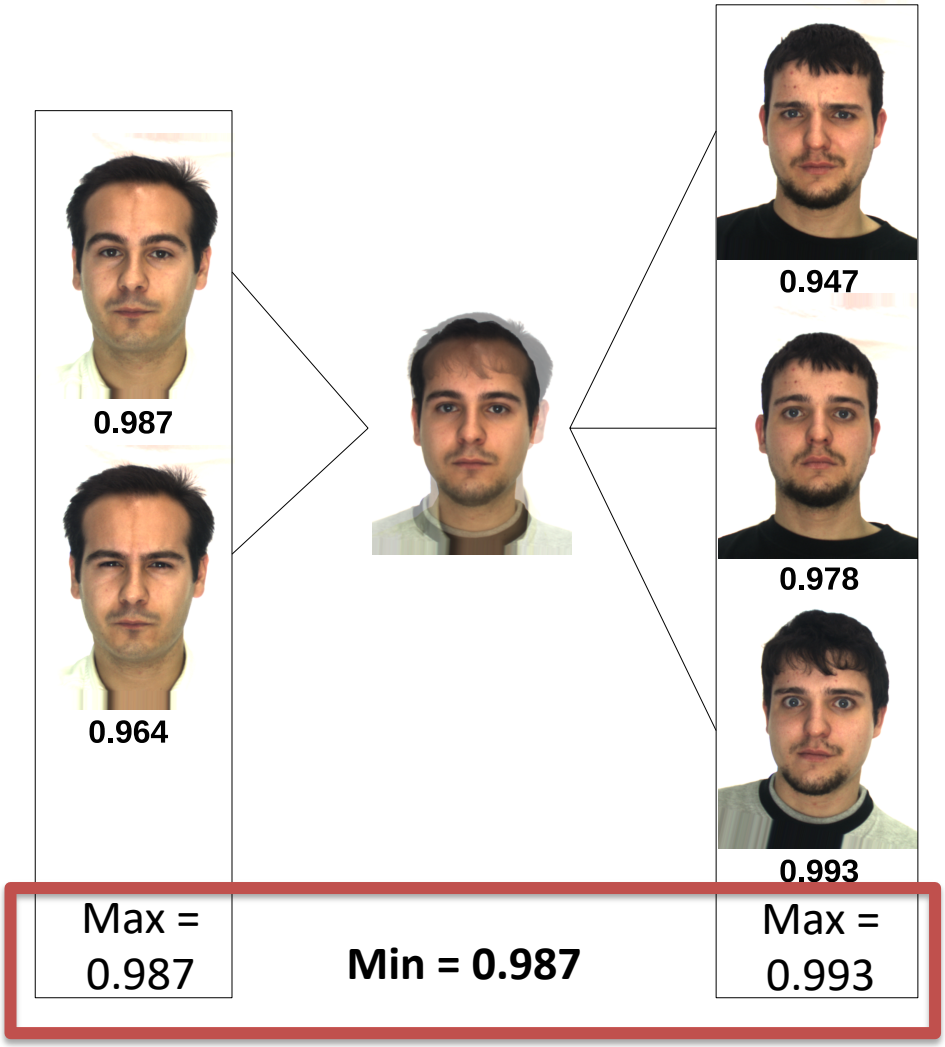
Morphing Attack Success: MinMax-MMPMR

- But in a border control scenario, the attacker is able to conduct **several authentication attempts** (and is successful if **one** is positive).

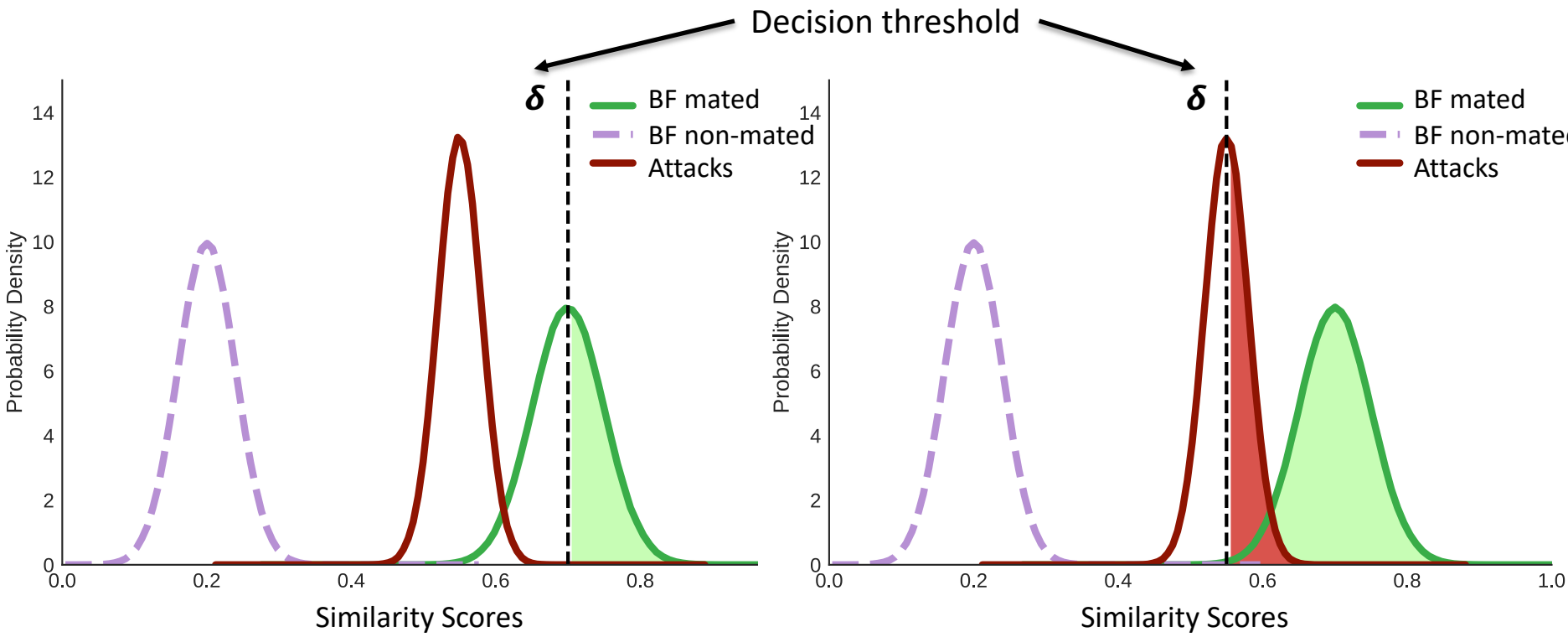
$$\text{MinMax-MMPMR} = \frac{1}{M} \cdot \sum_{m=1}^{M} \left\{ \left(\min_{n=1,\ldots,N_m} \left[\max_{i=1,\ldots,I_m^n} S_m^{n,i} \right] \right) > \delta \right\}$$

Attack Success Eval.

Morphing Attack Success: MinMax-MMPMR



Reaching a Balance



IAPMR / MMPMR: 0% ☺
FNMR: 65% ☹

IAPMR / MMPMR: 41% ☹
FNMR: 1% ☺

Relative Morph Match Rate (RMMR)

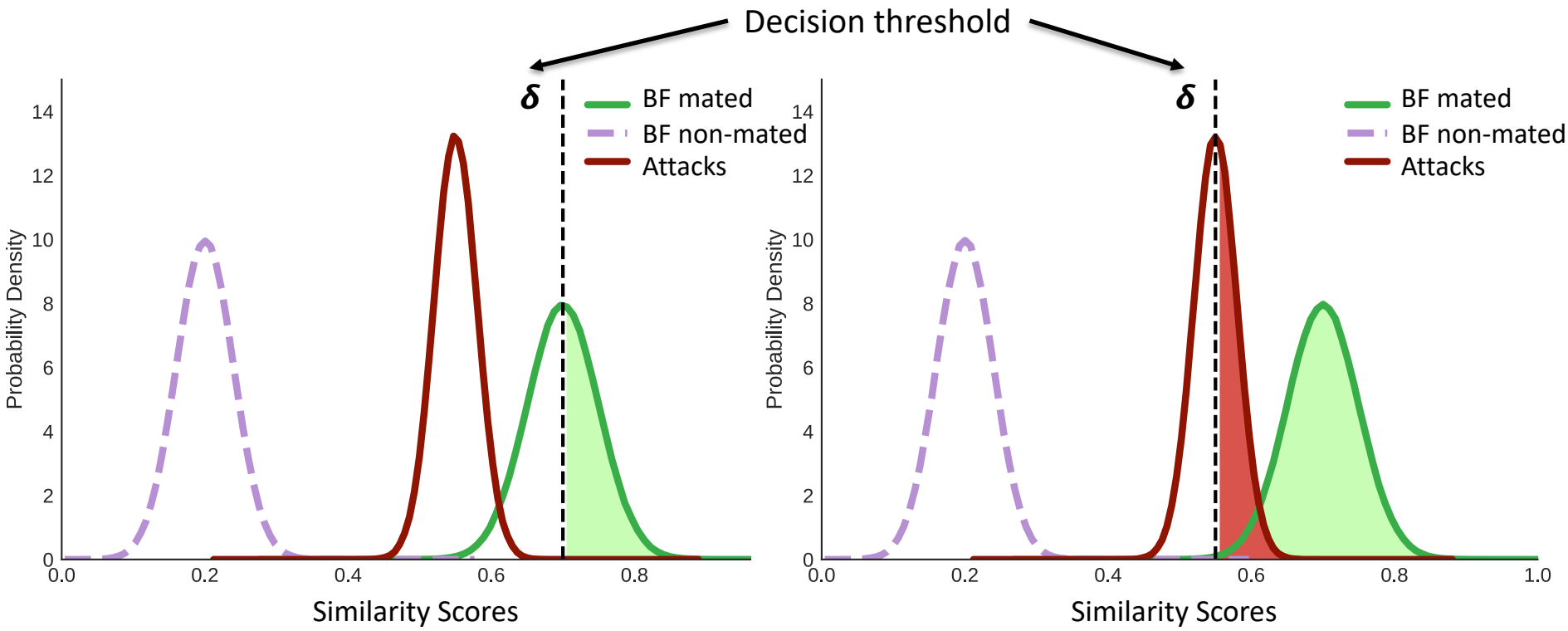
- The IAPMR and the MMPMR only measure the **vulnerabilities** of the system

- We need to take into account as well the system **convenience**
  - In terms of the FNMR or the TMR

- Both values depend on the decision threshold and can be combined in a single measure, the ***Relative Morph Match Rate (RMMR)***:

$$\begin{aligned} \mathrm{RMMR}(\delta) &= 1 + \mathrm{MMPMR}(\delta) - (1 - \mathrm{FNMR}(\delta)) \\ &= 1 + (\mathrm{MMPMR}(\delta) - \mathrm{TMR}(\delta)) \end{aligned}$$

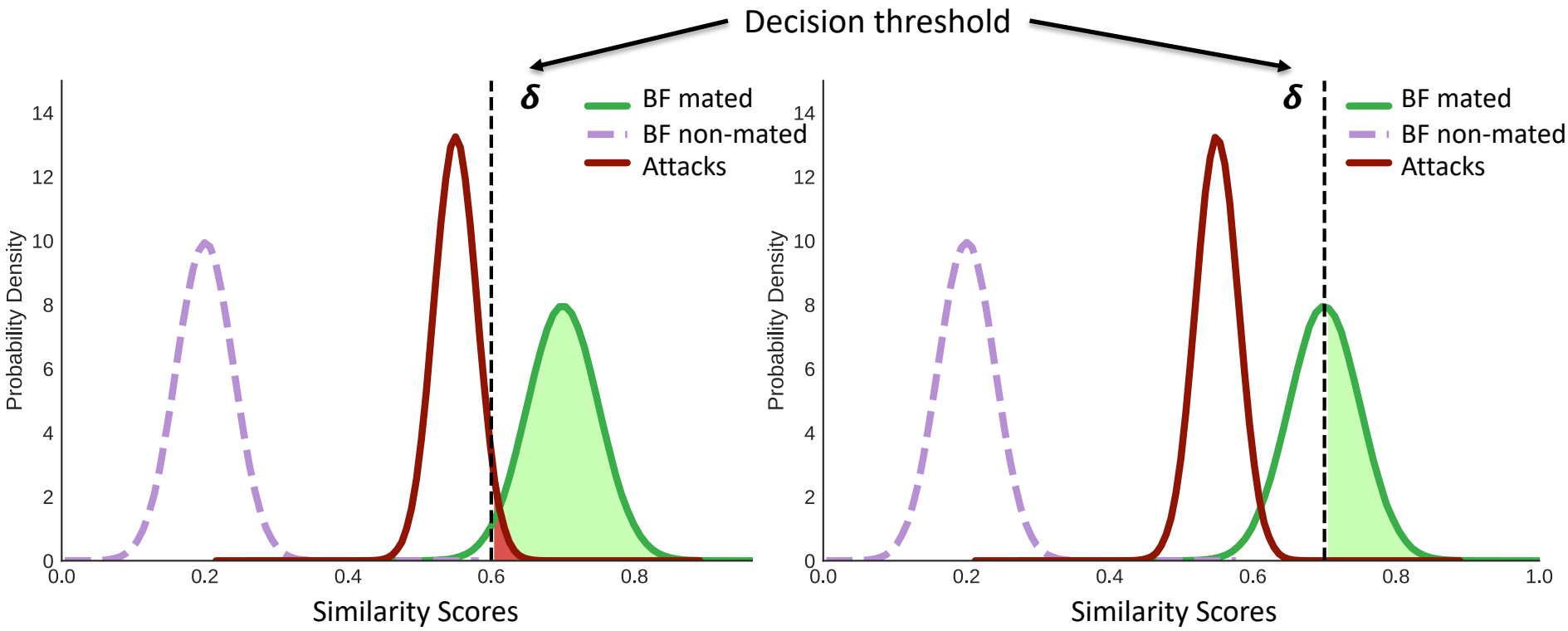
Reaching a Balance v2 (I)



IAPMR / MMPMR: 0% ☺
1 - FNMR: 45% ☹
RMMR: 55 ☹

IAPMR / MMPMR: 41% ☹
1- FNMR: 99% ☺
RMMR: 42 ☹

Reaching a Balance v2 (II)



IAPMR / MMPMR: 3% ☺
1 - FNMR: 96% ☺
RMMR: 7 ☺

IAPMR / MMPMR: 0% ☺
1 - FNMR: 55% ☹
RMMR: 45 ☹

Reaching a Balance in PAD: Relative IAPMR

- A similar approach can be followed for PAD

- ***Relative Impostor Attack Presentation Match Rate (RIAPMR)***: proportion of impostor attack presentations using the same PAI species in which the target reference is matched in relation to the proportion of completed biometric comparison trails that do not result in a false non-match:

$$\begin{aligned} \mathrm{RIAPMR}(\delta) &= 1 + \mathrm{IAPMR}(\delta) - (1 - \mathrm{FNMR}(\delta)) \\ &= 1 + \mathrm{IAPMR}(\delta) - \mathrm{TMR}(\delta) \end{aligned}$$

Detection Performance Evaluation

Detection Performance Evaluation Goals & How To

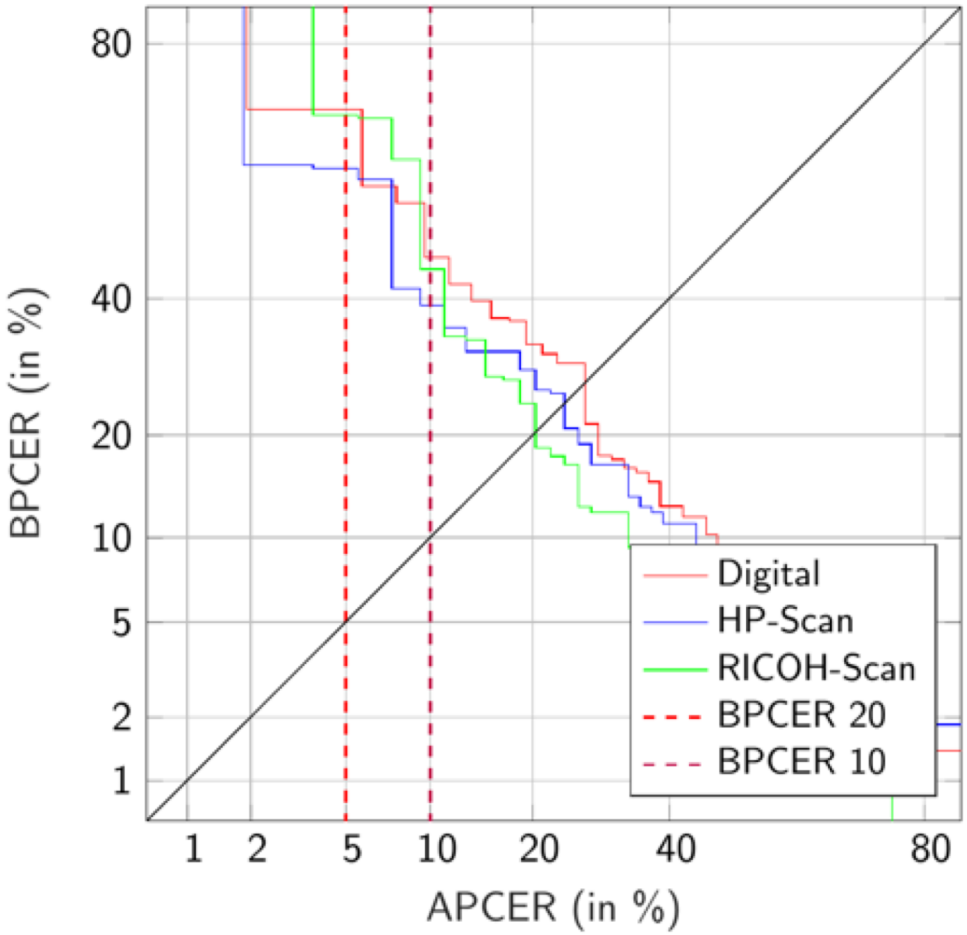
- Key question: can we **detect** the attacks?
- Key question 2: is the system still **covenient**?

- Follow **ISO/IEC 19795-1** on biometric performance testing and reporting:
  - Disjoint subdivision of training and test-set
  - Remember: one morphed sample is related to at least two subjects

- Follow **ISO/IEC 30107-3** on biometric presentation attack detection:
  - Attack Presentation Classification Error Rate (APCER) ⇒ **Security**
  - Bona Fide Presentation Classification Error Rate (BPCER) ⇒ **Convenience**

Detection Perf. Eval.

Example



Conclusions

Conclusions

- A complete evaluation should include:
  - Quality evaluation
  - Attack success evaluation: IAPMR / MMPMR[1] and RIAPMR / RMMR[1]
  - Detection performance evaluation: BPCER vs APCER (DET plot)

- And should follow the ISO/IEC 19795-1 and 30107-3 standards

- We should model a realistic scenario with
  - High quality attacks
  - Equal quality over the database (especially between morph and bona fide samples)

- We need to analyse both the security (APCER, MMPMR) and the convenience (BPCER, FNMR) ⇒ we need the RMMR and RIAPMR!

[1] Python implementations available at https://github.com/dasec/mvr

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