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Signal-level fusion for indexing and retrieval of facial biometric data

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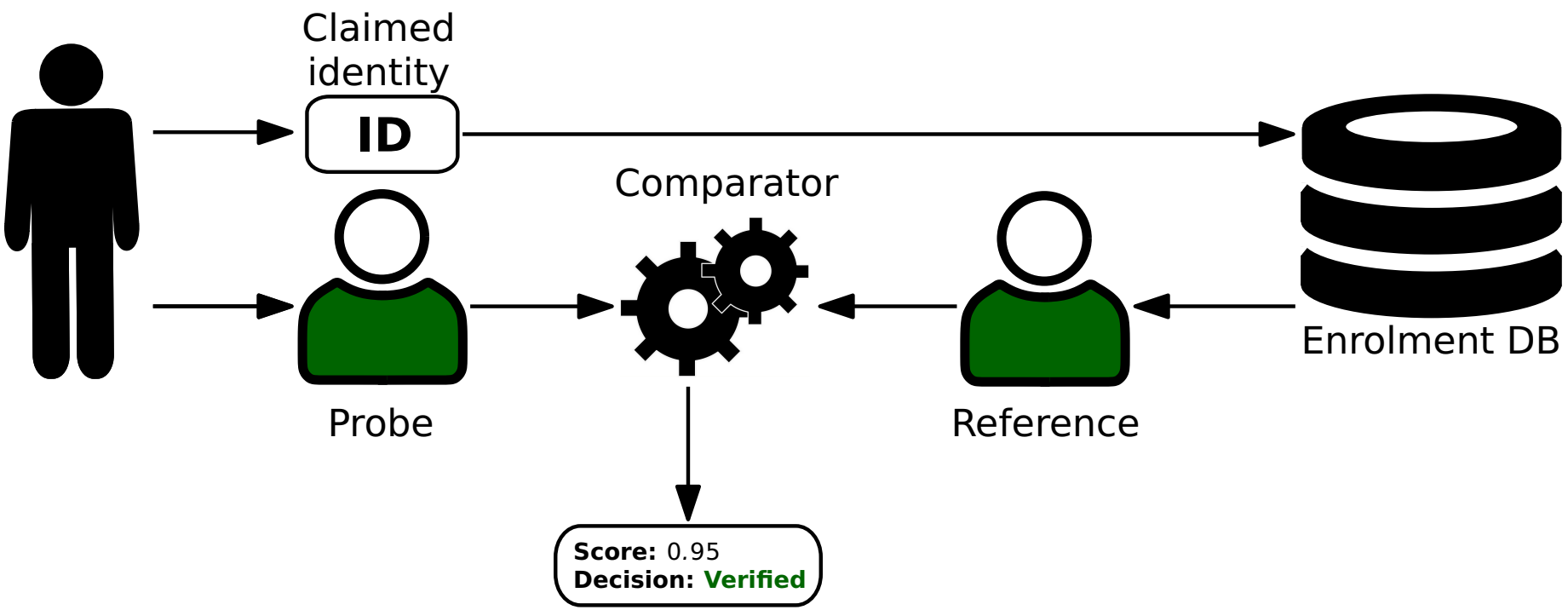
Contents

Biometric operation modes

Verification

- A biometric claim to an identity is made
- A 1:1 comparison is performed to reach a decision

$\Rightarrow$ Computationally trivial

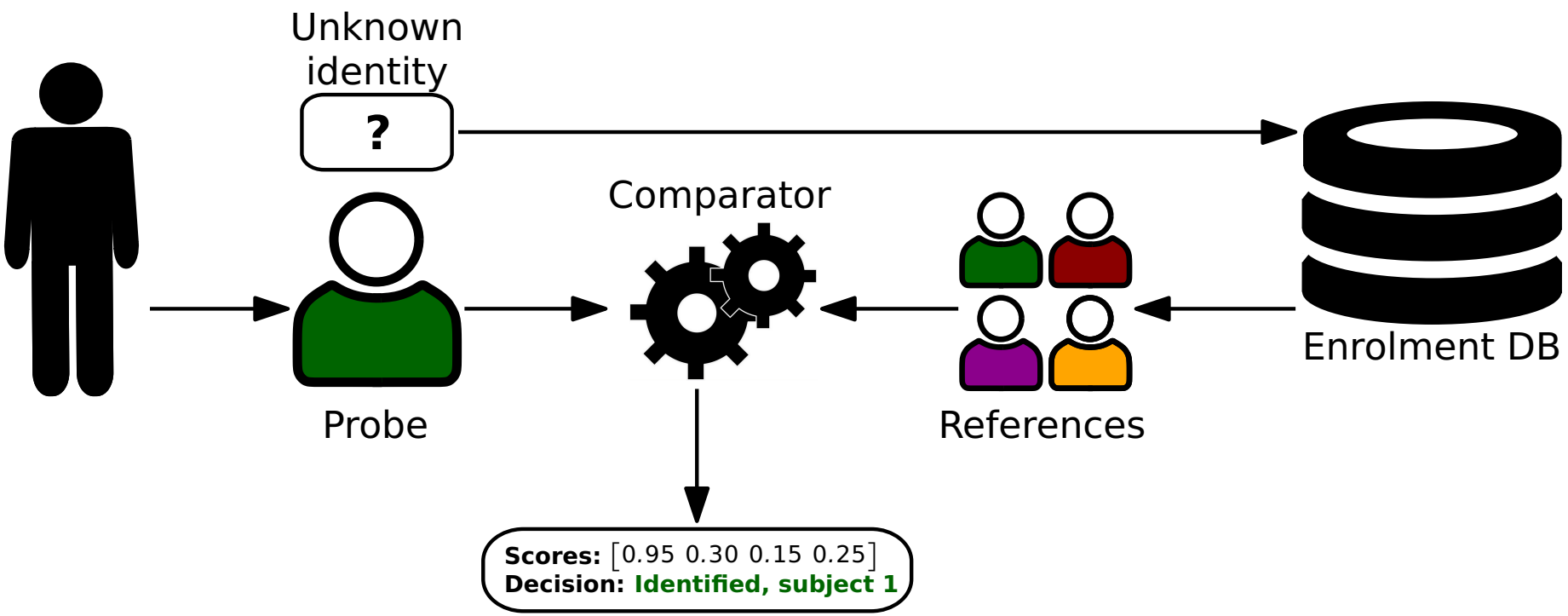


Biometric operation modes

Identification

- There is no biometric claim
- The decision has to be reached using the biometric data alone

$\Rightarrow$ Computationally expensive (in worst case, exhaustive search)



Biometric identification

Computational workload

- A system from one of market leaders: 35 million comparisons per second (face) on a high-end computer (i7 processor, 16GB RAM)

Table: Transaction times for an example system

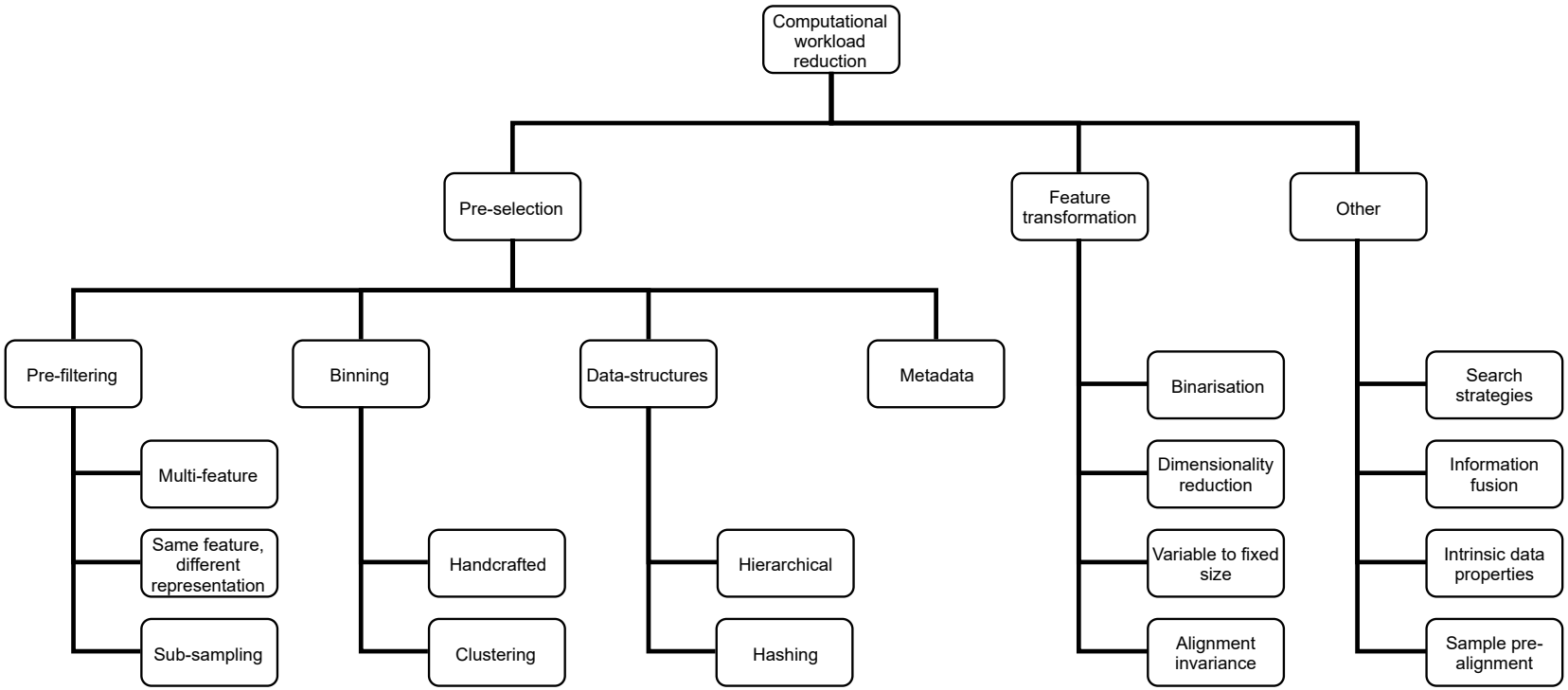
					
Location	Berlin	Germany	EU	India	World
Population (millions)	3.75	83	512	1339	7800
1:N time	107 ms	2.37 s	14.62 s	38.25 s	3.43 m
N:N time	3.5 days	6 years	237 years	1624 years	55121 years

- A system for specialised hardware (Multicore Xeon processors, 512 GB RAM): 1.2 billion comparisons per second (face) – ∼35 times faster
- Infrastructure: more computers/servers to distribute the computations

⇒ **High monetary costs** (hardware itself, maintenance, and software licenses)

Biometric identification

Computational workload **reduction**



$\Rightarrow$ Software- or Hardware-based acceleration speeds up the transactions, but does not yield computational workload reduction

[1] Drozdowski, P., Rathgeb, C., and Busch, C. Computational workload in biometric identification systems: An overview. *IET Biometrics 8*, 6 (November 2019), 351–368.

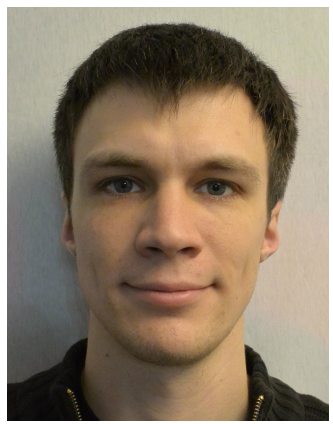
Signal-level fusion

Morphing

- By using image morphing methods, it is possible to create biometric samples which *contain biometric information from multiple distinct data subjects*. A typical morphing process includes:
  1. Facial landmark detection and triangulation in two or more images
  2. Landmark averaging to a single set of landmarks
  3. Image warping and alpha blending
- Two or more subjects can be morphed together

Subject 1

Morph

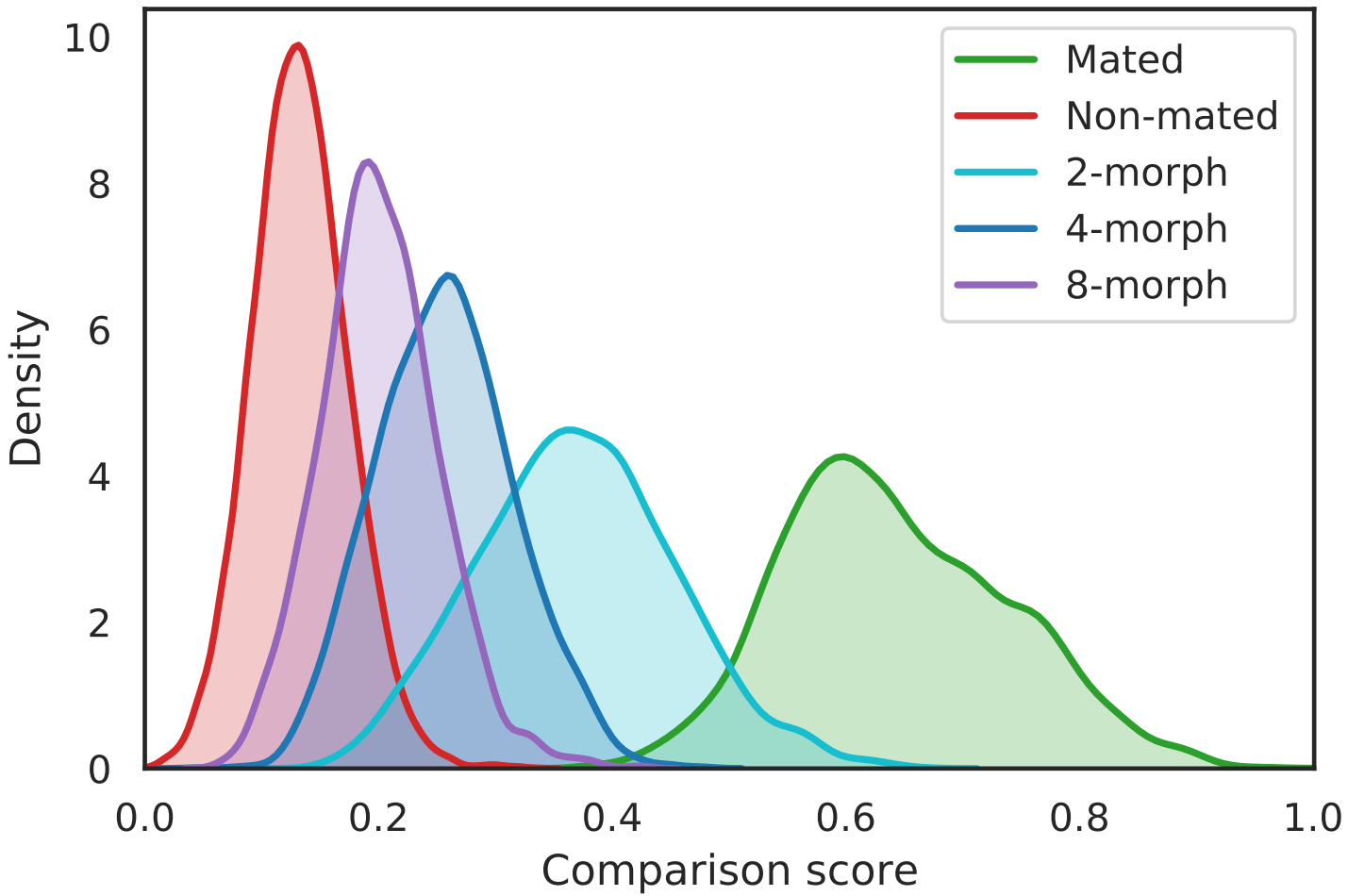


Subject 2

$\Rightarrow$ An **attack vector** against automated systems and human experts

Morphing

Why does it work?



The idea

Benefiting from properties of morphed images

- Using morphing to facilitate computational workload reduction
  $\Rightarrow$ A **vulnerability** is turned into an **asset**
- A two-stage biometric identification system
  1. Signal-level fusion at the first level
     $\Rightarrow$ Morphs of 2, 4, or 8 subjects
  2. Pre-selection of most promising candidates
     $\Rightarrow$ Normal comparisons at the second level
- Possible extension to a multi-stage system

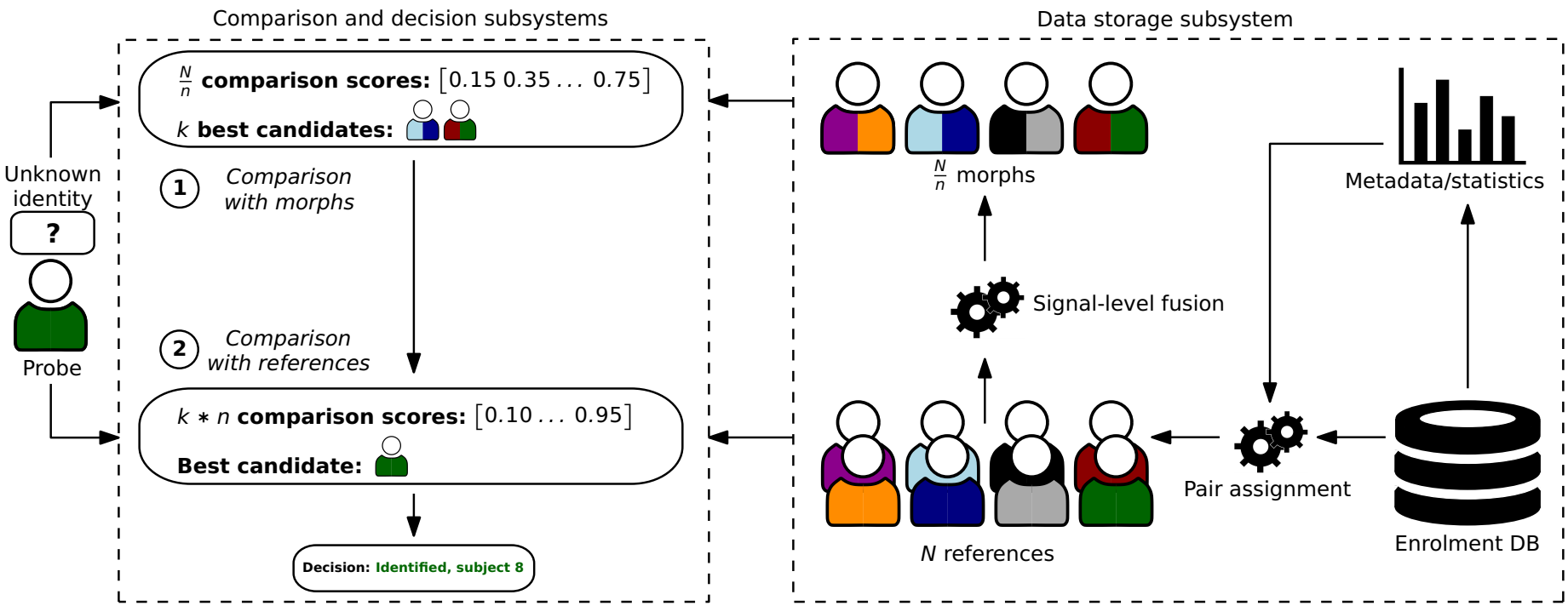
$\Rightarrow$ In theory, possibility to **reduce computational workload and maintain biometric performance**

$\Rightarrow$ Promising results in a proof-of-concept experimental evaluation

[2] Drozdowski, P., Rathgeb, C., and Busch, C. Turning a vulnerability into an asset: Accelerating Facial Identification with Morphing, *International Conference on Acoustics, Speech, and Signal Processing (ICASSP), (May 2019), 2582–2586.*

Indexing and retrieval

Overview



Indexing

Pair assignment

How to decide **who should get morphed with whom**?

⇒ A combinatorial optimisation problem

Choose a **global or local optimisation**?

⇒ Assignment problem-based definition

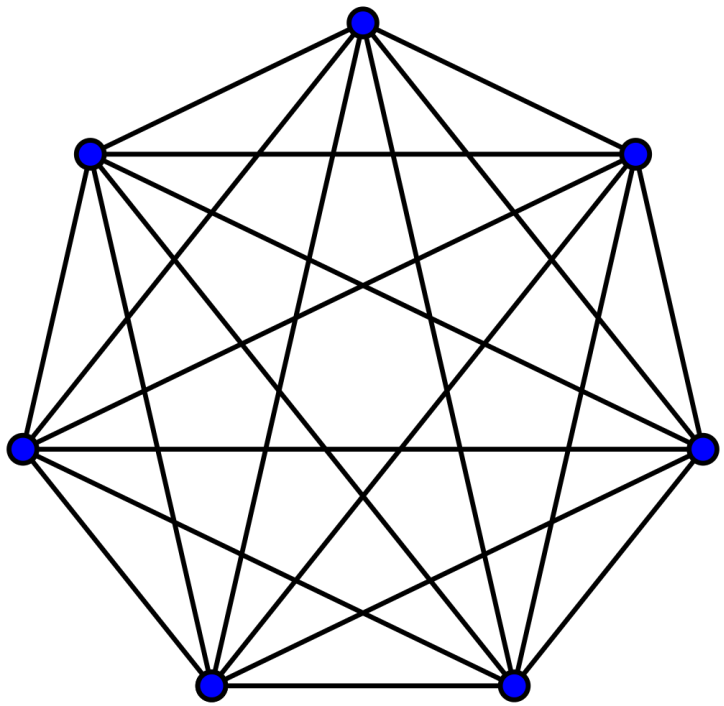
⇒ Hungarian algorithm

How to define the **cost function**?

⇒ Random

⇒ Soft-biometrics

⇒ Similarity-score



Evaluation

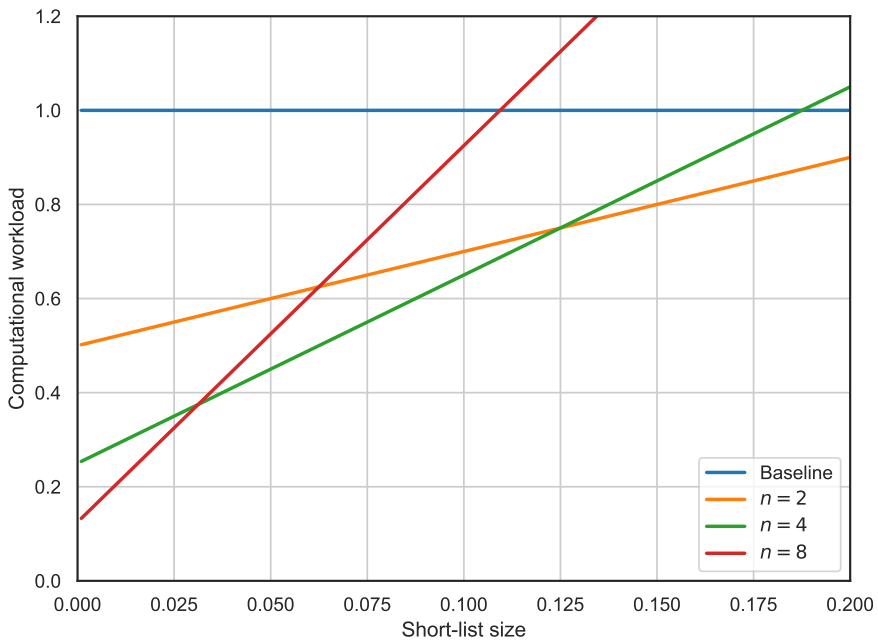
Experimental setup

- 1024 enrolled subjects (ICAO compliant, FERET + FRGC)
- 4 face recognition systems (OSS and COTS)
- 4 morphing algorithms (OSS and COTS)
- 3 strategies for selection of subjects to be morphed (random, soft-biometric, similarity-score)
- 3 numbers of samples contributing to a morph (2, 4, 8)
- A range of sizes of the pre-selected subset

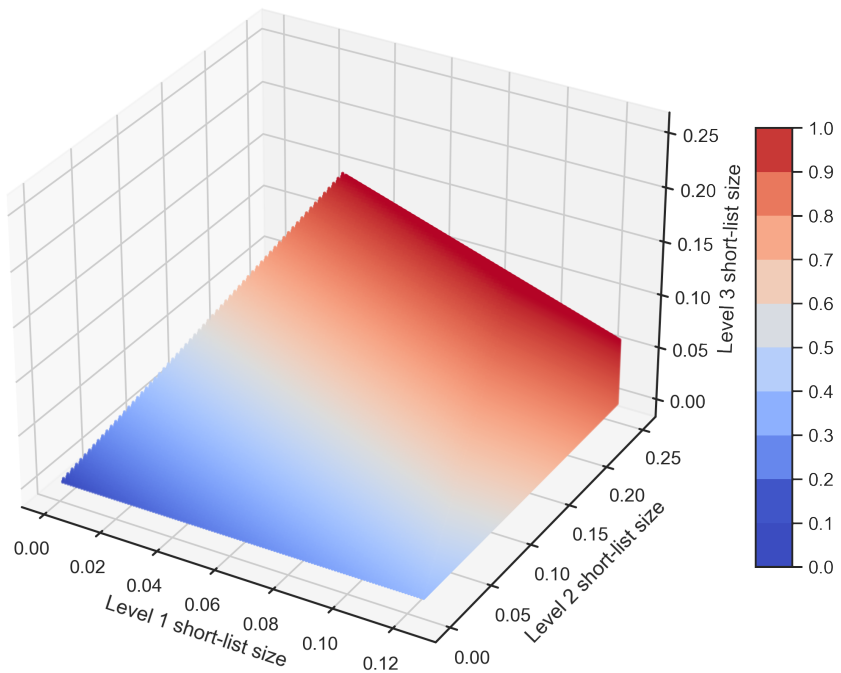
Evaluation

Why is the computational workload reduced?

- For some parameter configurations $W_{\text{proposed}} < W_{\text{baseline}}$
- $W_{\text{two-stage}} = \frac{N}{n} + k * n$ $\quad W_{\text{multi-stage}} = \frac{N}{n_1} + \sum_{l=1}^{\log_2 n_1} 2k_l$



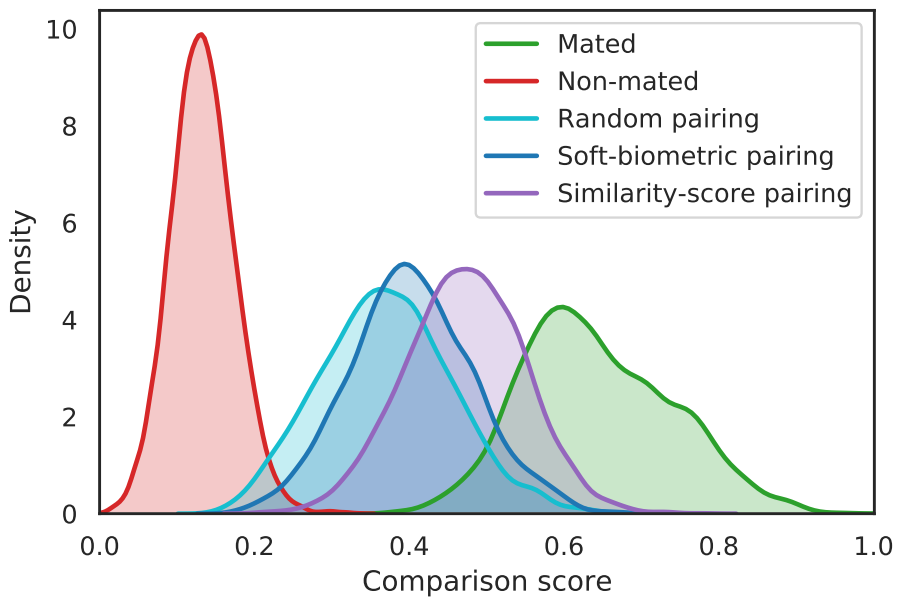
2-stage system



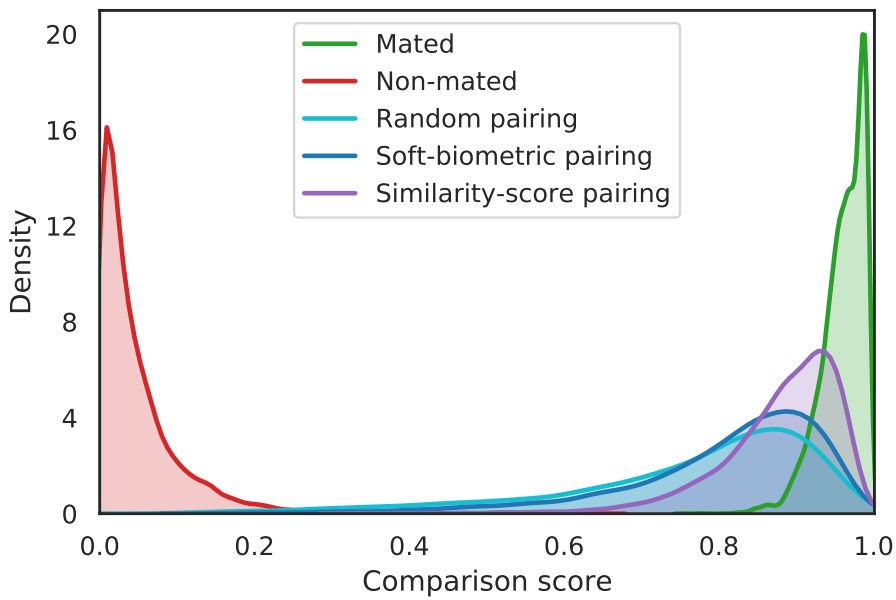
Multi-stage system

Evaluation

Effects of pair assignment strategies



OSS

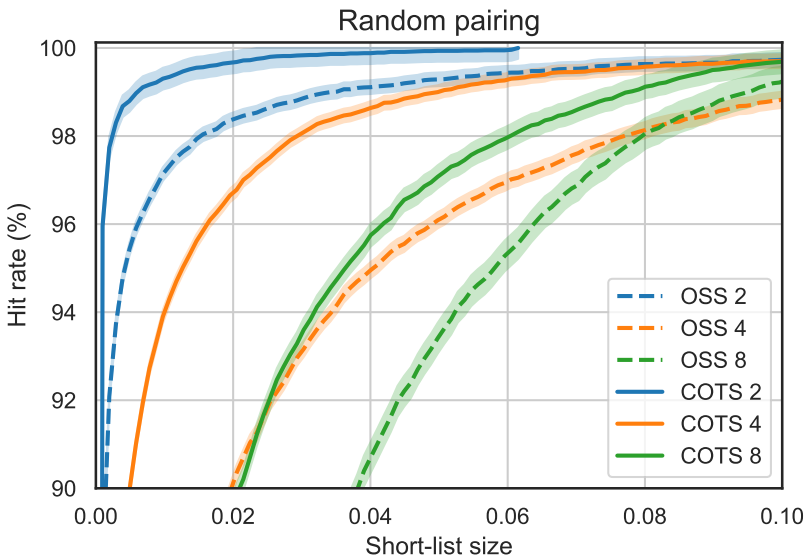


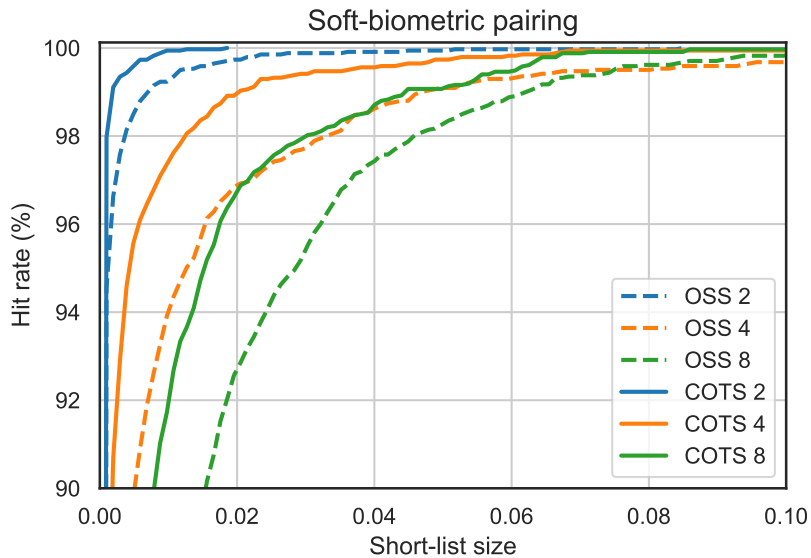
COTS

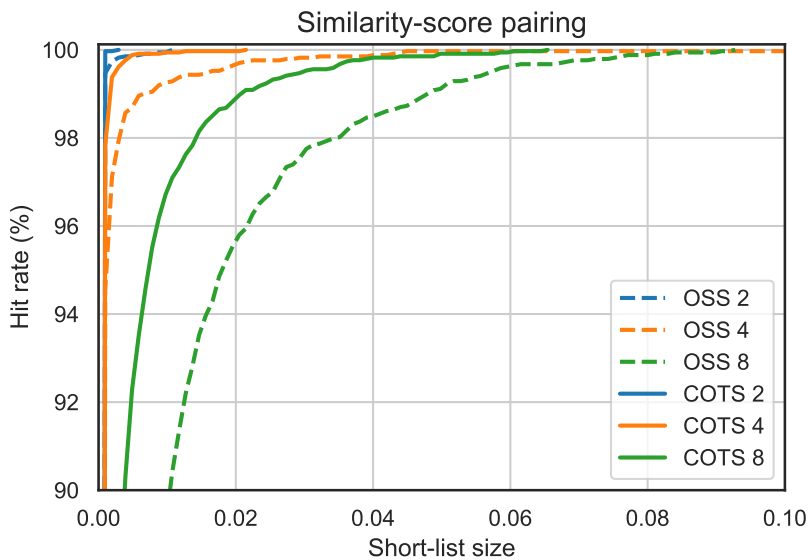
⇒ Mated-morph score distributions significantly shifted towards the mated score distribution as a result of the intelligent pairing

Evaluation

CMCs







Evaluation

Biometric performance and computational workload

Recognition system	Computational workload at			
	95% HR	99% HR	99.5% HR	100% HR
COTS	18.75%	25.78%	26.17%	33.59%
OSS	25.78%	26.17%	33.59%	52.15%

⇒ Intelligent pairing methods vastly outperforming random pair assignment. Best results with similarity-score-based pairing method

⇒ Better results with COTS-based recognition, especially at 100% HR

⇒ For some configurations, the computational workload is **reduced**, while biometric performance (false-negative errors) is **maintained**

⇒ Pre-selection causes the false positive errors to remain **unchanged (worst case)** or be **reduced (best case)**

Proposed system

Summary

- Signal-level fusion-based approach
- Computational workload reduced significantly
- Biometric performance not impaired
- Better results with COTS-based face recognition system
- High impact of the selection of subjects to be morphed on the results of the scheme

General take-away points

Biometric identification systems

- Biometric identification is much more challenging than biometric verification
  - Biometric performance
  - Computational workload
- Increasing computational requirements of the operational systems
  - Growing size, number, and scope of the deployments
  - Direct links to monetary costs and usability

$\Rightarrow$ **Computational workload reduction methods**

Research opportunities

In Germany and Norway (or remotely)

Interested in working with biometrics or information security?

- Visit websites:
  `https://dasec.h-da.de/` and `https://www.ntnu.edu/nbl/`
  - Ph.D. positions
  - Internships
  - B.Sc. and M.Sc. theses proposals with the possibility of a stipend
  - Student assistant positions
  - Collaborations with academia, industry, and governmental agencies
- Contact Prof. Dr. Christoph Busch at christoph.busch@h-da.de

Thank you for your attention!
Questions?