EINSTEIN Project - Assessing Facial Images for Quality and Morphing Attacks

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copy of slides available at:
https://christoph-busch.de/about-talks-slides.html

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Norwegian University of Science and Technology (NTNU), Norway

ATHENE

European Association for Biometrics eab Human Identity in Europe

EINSTEIN

NTNU

Norwegian Biometrics Laboratory (NBL)

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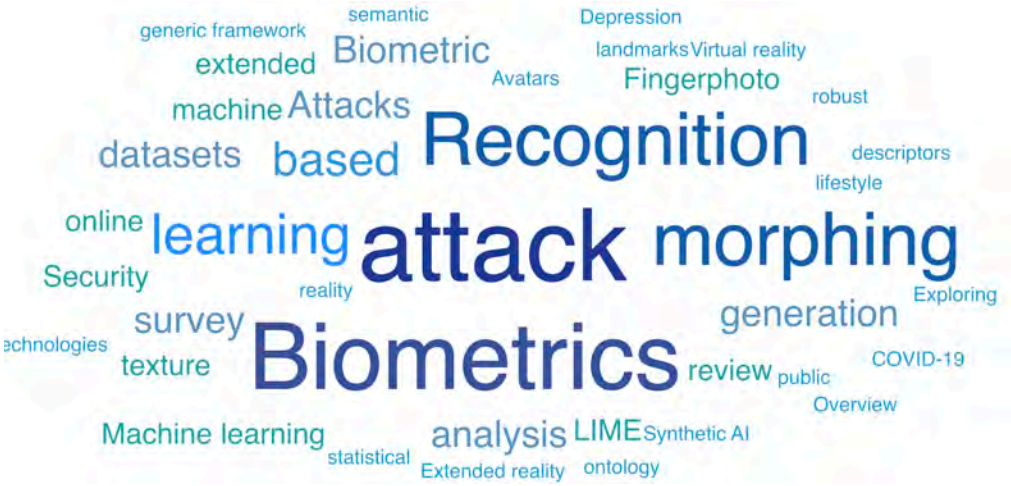


- Key-factors - since 2008:
  - 11 European funded projects,
    3 Norwegian funded projects
    2 US-government funded project,
    3 research projects funded by the German BSI,
    4 industrial projects
  - 988 publications with 494 institutions

https://www.ntnu.edu/nbl

Einstein Project

Project Facts

- Horizon Europe Framework Program (HORIZON)
- Call: HORIZON-CL3-2022-BM-01
- https://einstein-horizon.eu

EINSTEIN

GRANT AGREEMENT NO.
101121280

TYPE OF ACTION
INNOVATION ACTION (IA)

DURATION
36 MONTHS
JAN 2024 - DEC 2026

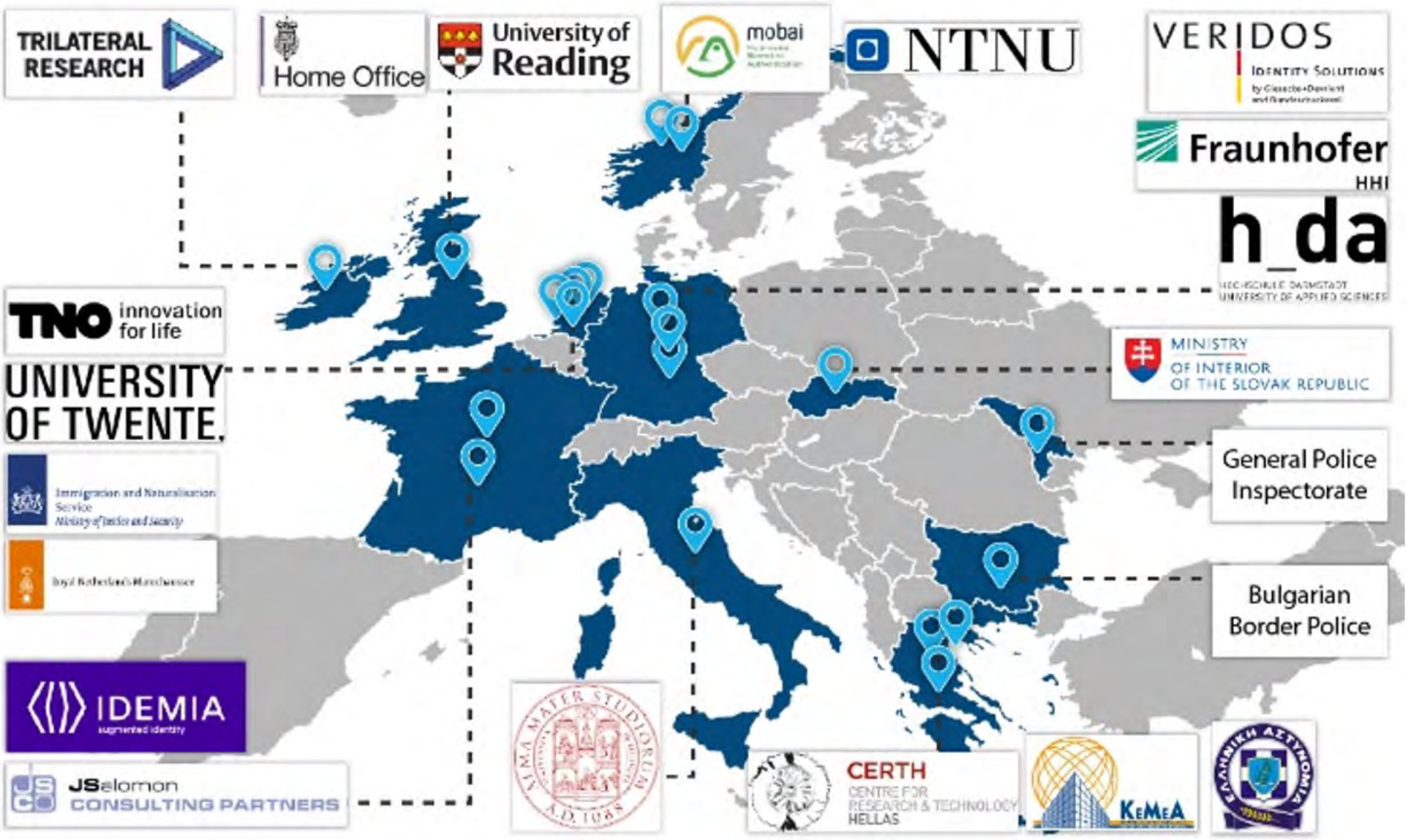
CONSORTIUM
21 PARTNERS
11 COUNTRIES

TOTAL BUDGET
€ 6M*

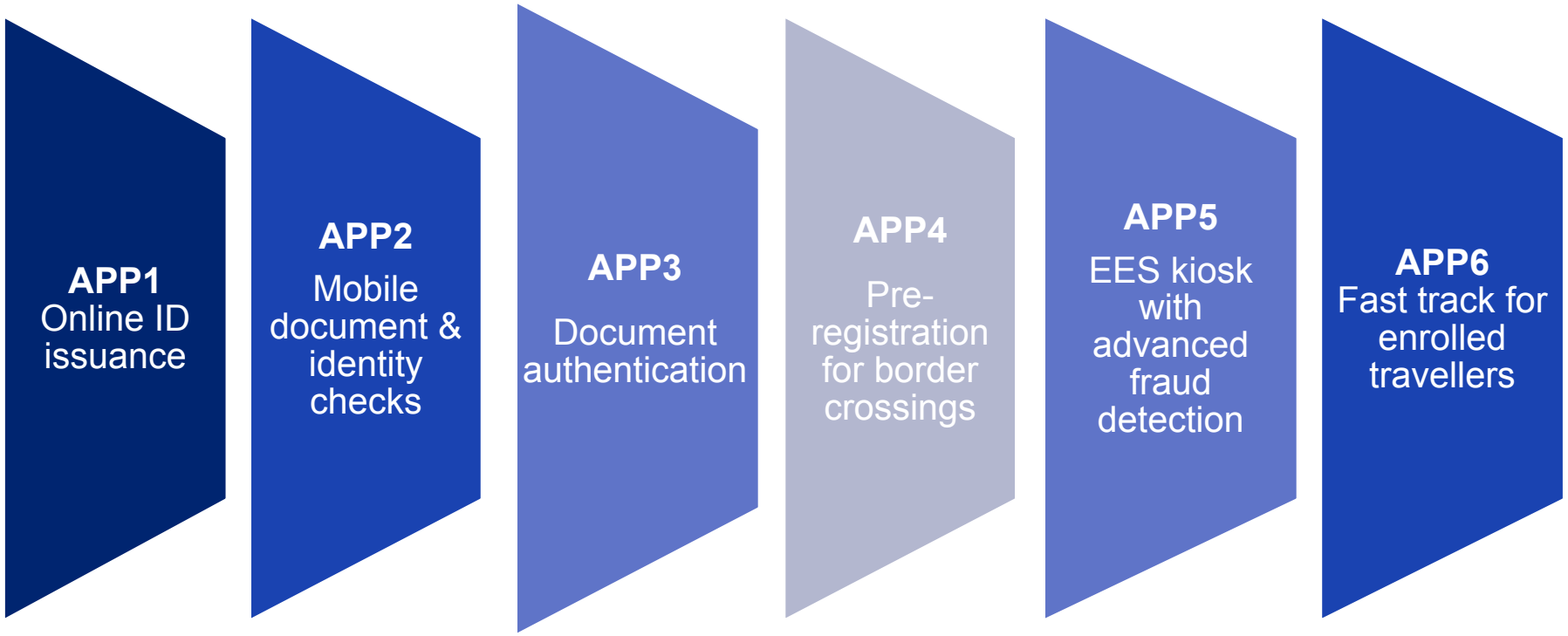
Co-funded by the European Union

The EINSTEIN project is funded by the European Union (EU) under G.A. no. 101121280 and UKRI Funding Service under IFS reference 10093453. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect the views of the EU/Executive Agency or UKRI. Neither the EU nor the granting authority nor UKRI can be held responsible for them.

Einstein Project



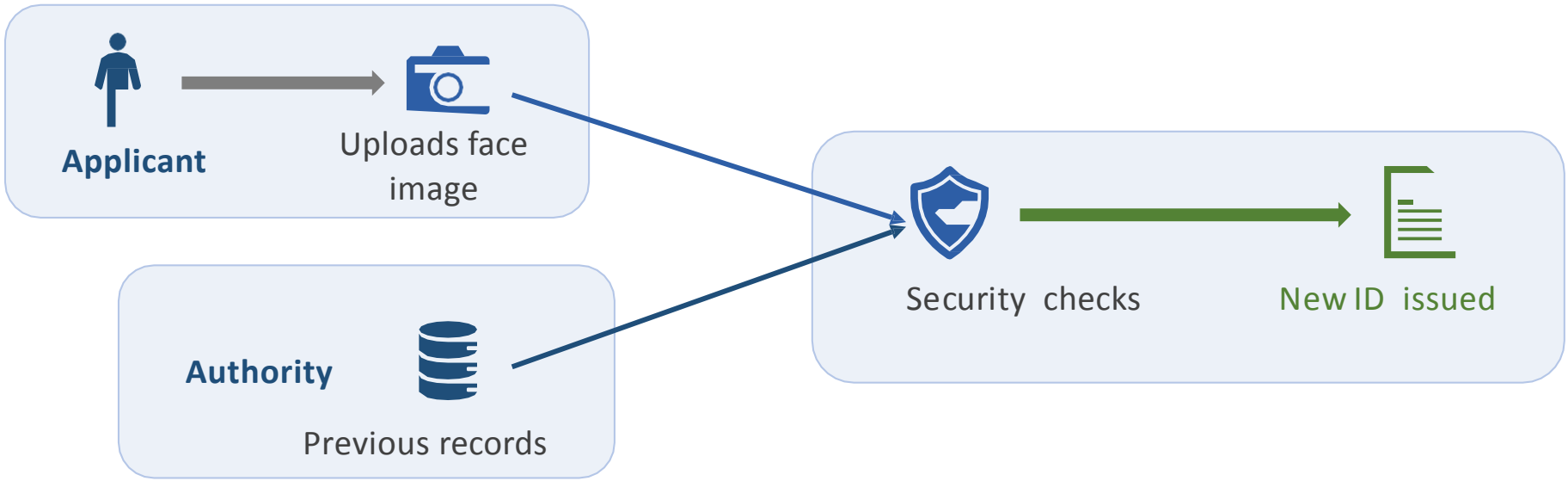
Applications addressed in EINSTEIN



Application1 in EINSTEIN

Application defined by UK Home Office

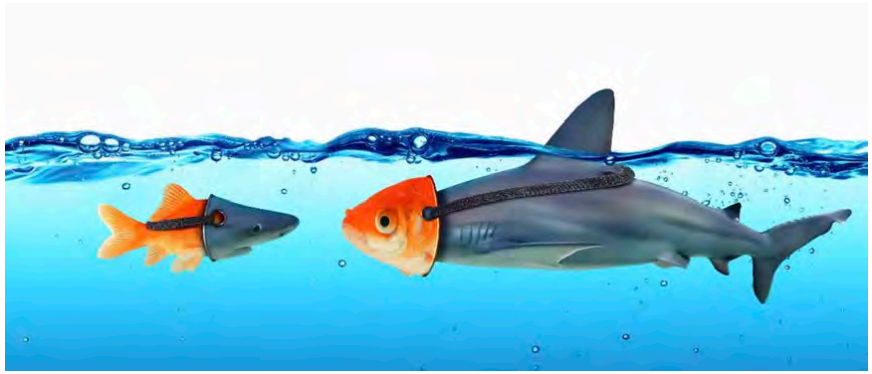
- ID document issuance and re-issuance is evolving rapidly
- Convenience vs. Security of biometrics
  "*automated recognition of individuals…*"
  https://www.iso.org/obp/ui/en/#iso:std:iso-iec:2382:-37:ed-3:v1:en:term:37.01.03
- Control the quality of biometric data (i.e. face images)
  "biometric sample … at any stage of processing"
  https://www.iso.org/obp/ui/en/#iso:std:iso-iec:2382:-37:ed-3:v1:en:term:37.03.06



Challenges and Security Checks

Critical factors for Face Recognition Systems (FRS):

- Presentation Attacks



Challenges and Security Checks

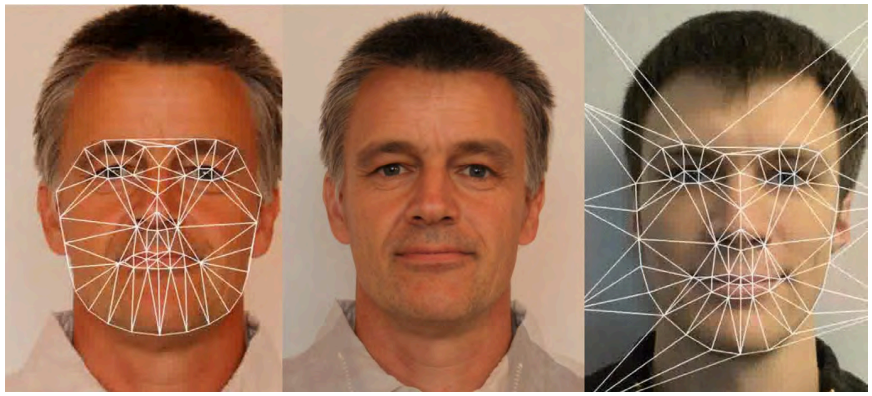
Critical factors for Face Recognition Systems (FRS):

- Presentation Attacks
- Face Image Quality

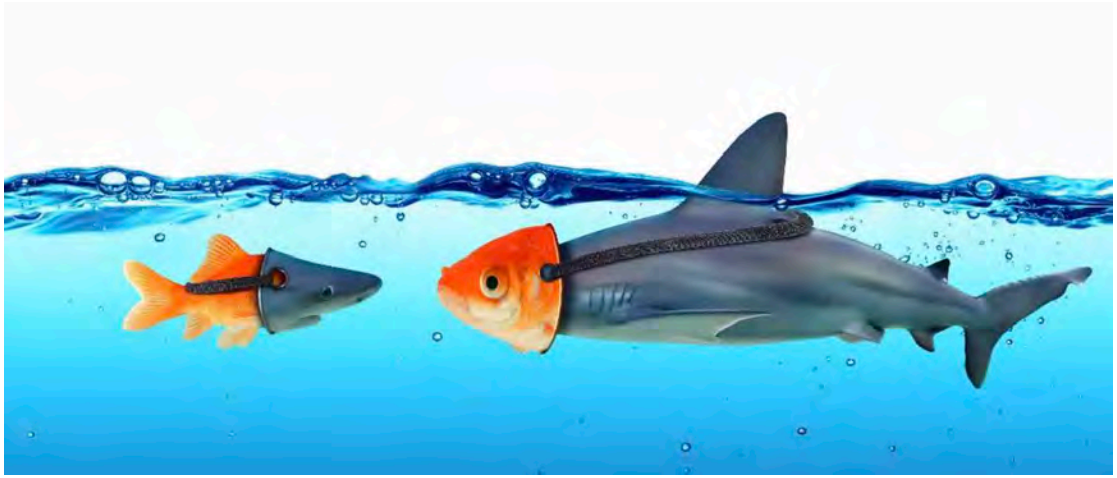
Challenges and Security Checks

Critical factors for Face Recognition Systems (FRS):

- Presentation Attacks
- Face Image Quality
- Morphing Attacks



Presentation Attack Detection



Presentation Attacks

Impostor

- Impersonation attack
  - Positive access 1:1 (two factor application)
  - Positive access 1:N (single factor application)
- Finding a look-a-like
- Artefact presentation

Concealer

- Evasion from recognition
  - Negative 1:N identification (watchlist application)
- Depart from standard pose

- Evade face detection

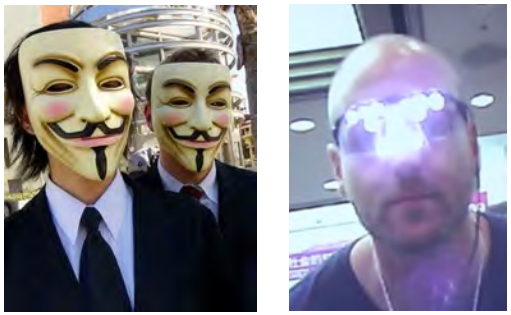


Image Source: https://www.youtube.com/watch?v=LRj8whKmN1M

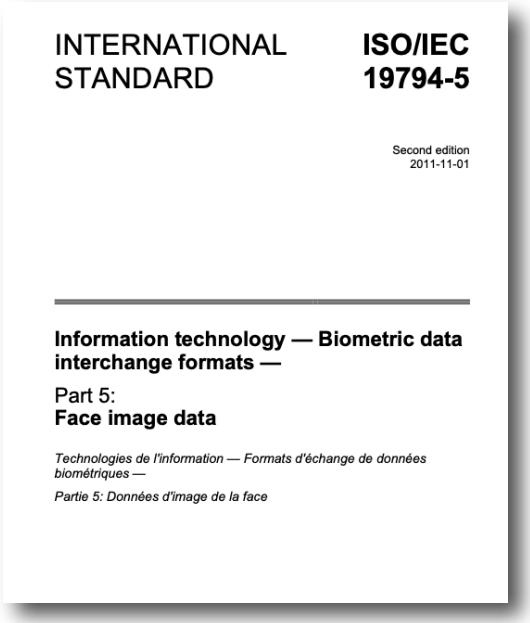
Face Image Quality

Quality Requirements for Facial Images

The requirement in EES implementing decision 2019/329

- *„The quality of the facial images, … and with the image requirements of ISO/IEC 19794-5:2011 Frontal image type*

What does that mean?


INTERNATIONAL STANDARD

ISO/IEC 19794-5

Second edition
2011-11-01

Information technology — Biometric data interchange formats —

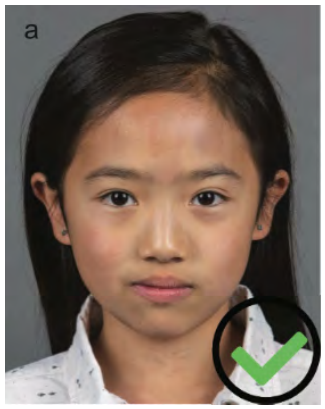
Part 5:
Face image data

Technologies de l'information — Formats d'échange de données biométriques —

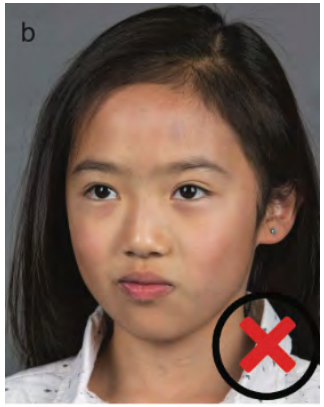
Partie 5: Données d'image de la face

Data subjects need actionable feedback

- If quality is poor, then what went wrong?



Compliant image



Pose

Eyes open

Mouth open

Inhomogenous background

Source: ISO/IEC 39794-5

Measures for Facial Images

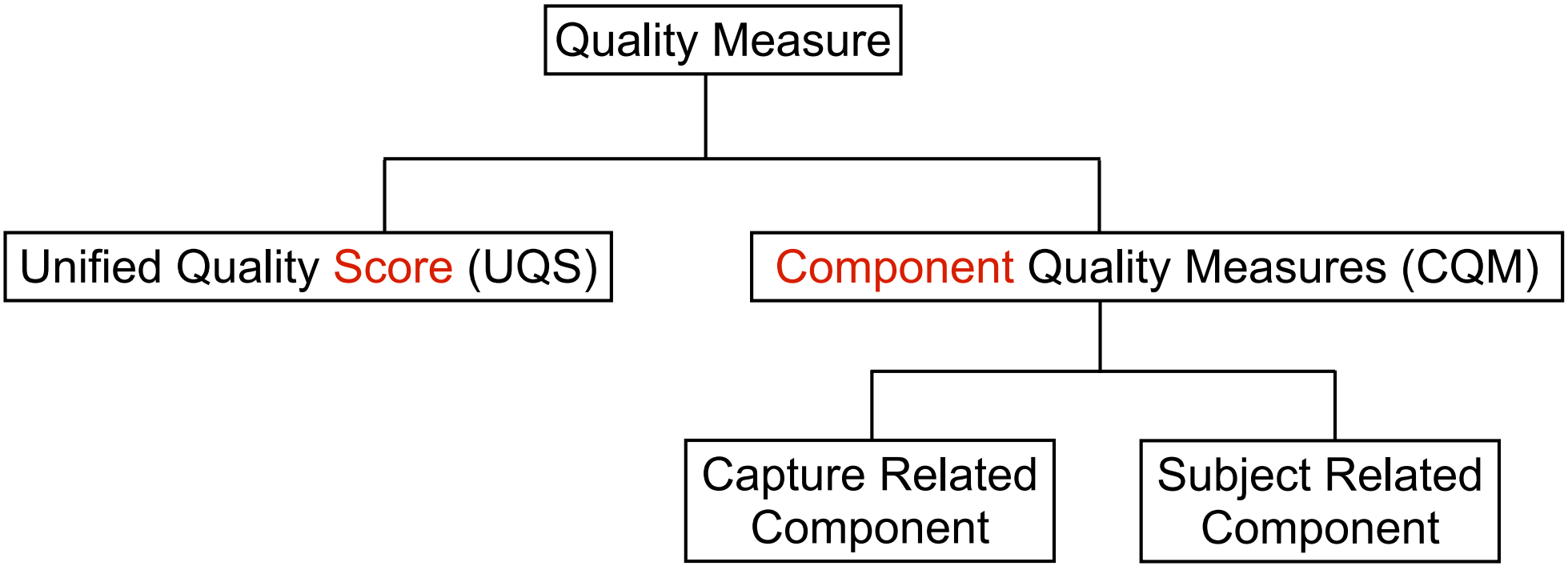
How to develop face image quality measures

- Standardisation
- International Organization for Standardization, ISO/IEC 29794-5, Information technology - Biometric sample quality - Part 5: Face image data,
  https://www.iso.org/standard/81005.html
  - Providing measures for requirements from ISO/IEC 19794-5:2011 and ISO/IEC 39794-5:2019
    - Use-1: Reference image for MRTD
    - Use-2: Reference image for Live-Enrolment at EES Kiosk
    - Use-3: Probe images (e.g. ABC gate)

Quality Measures - Framework Standard

Quality assessment algorithms

- According ISO/IEC 29794-1
  https://www.iso.org/standard/79519.html



- Higher UQS and CQM imply higher biometric utility

ISO/IEC 29794-5: Face Image Quality

ISO/IEC 29794-5 quality measures in detail

#	Face image quality measure
1.	Quality score (unified)
2.	Background uniformity
3.	Illumination uniformity
4.	Luminance mean
5.	Luminance variance
6.	Under-exposure prevention
7.	Over-exposure prevention
8.	Dynamic range
9.	Sharpness
10.	No compression artefacts
11.	Natural colour
12.	Single face present
13.	Eyes open
14.	Mouth closed
15.	Eyes visible
16.	Mouth occlusion prevention
17.	Face occlusion prevention
18.	Inter-eye distance
19.	Head size
20.	Leftward crop of face in image
21.	Rightward crop of face in image
22.	Margin above face in image
23.	Margin below face in image
24.	Pose angle yaw frontal alignment
25.	Pose angle pitch frontal alignment
26.	Pose angle roll frontal alignment
27.	Expression neutrality
28.	No head covering

Image Source:ISO/IEC 29794-5

Unified Quality Score

Capture device related

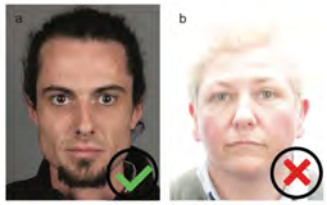


Image Source: ISO/IEC 39794-5

Explainable Quality Assessment

Subject related

Image Source: ISO/IEC 39794-5

OFIQ - Unified Quality Score

General, holistic unified quality score (OFIQ-UQS)

- Determine an overall quality score for the face image
  - CNN MagFace (iResNet 50 model)
- Shows good prediction of face recognition scores

OFIQ-UQS=84

OFIQ-UQS=61

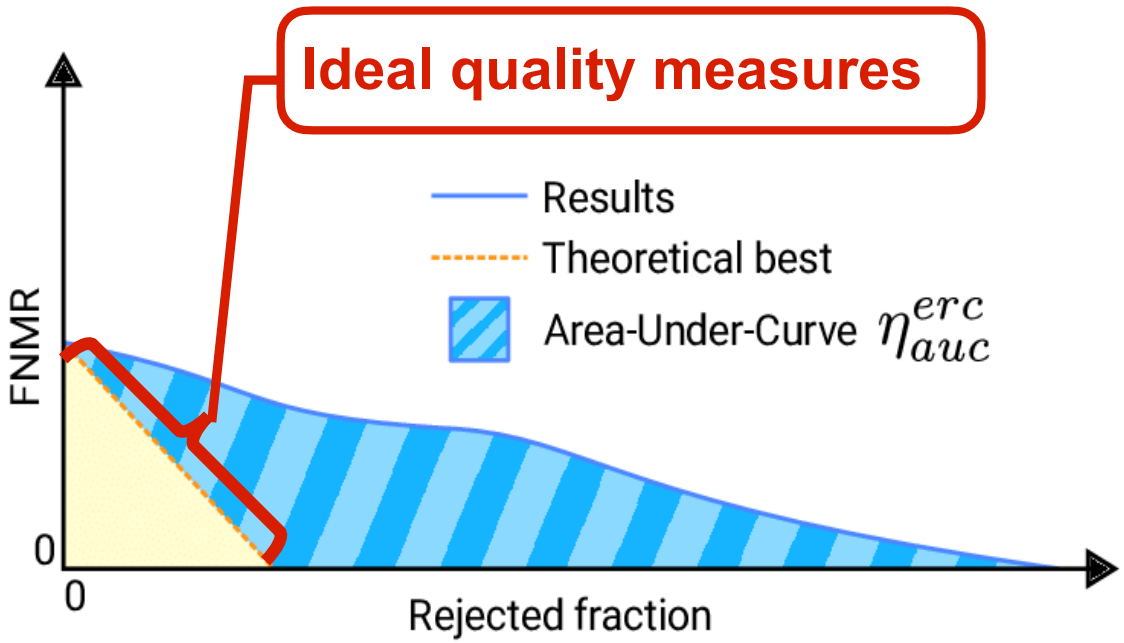
OFIQ-UQS=26

OFIQ-UQS=7

OFIQ - Unified Quality Score

Prediction of low face recognition scores

- OFIQ is the best performing algorithm in NIST SIDD
  Error versus Discard Characteristic (EDC) curves
  - How much is the FNMR reduced, when poor images are discarded/rejected?



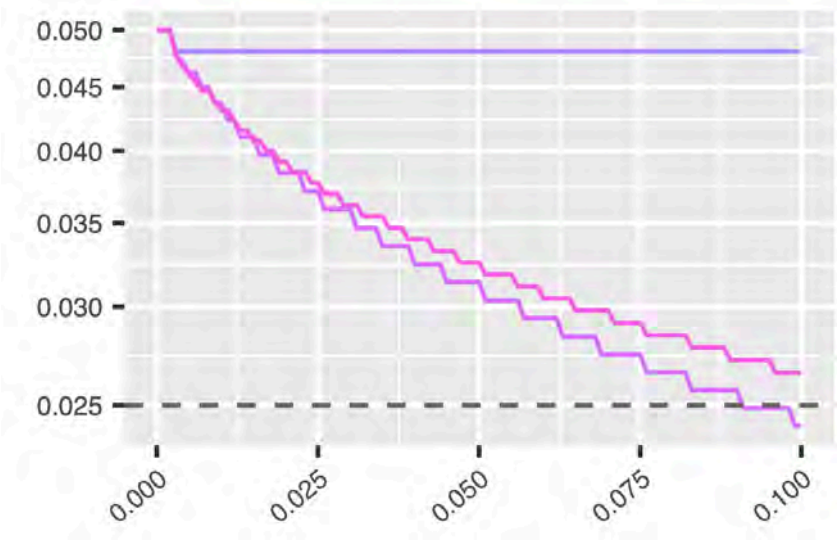


Image Source:NIST FATE SIDD report

Morphing Attack Detection

Border Security depends on an Anchor

The passport is the security anchor

- One individual - one passport

Principle of unique link of ICAO

- ICAO - International Civil Aviation Organisation
- One individual - one passport
- ICAO 9303 part 2, 2006:
  „***Additional security measures:*** *inclusion of a machine verifiable biometric feature linking the document to its legitimate holder*“

image source: https://pixabay.com/de/vectors/tick-sternchen-kreuz-rot-gr%C3%BCn-40678/

Border Security depends on an Anchor

Principle of unique link of ICAO

- One individual - one passport

We don’t want this principle of unique link to be broken

- Multiple individuals - one passport

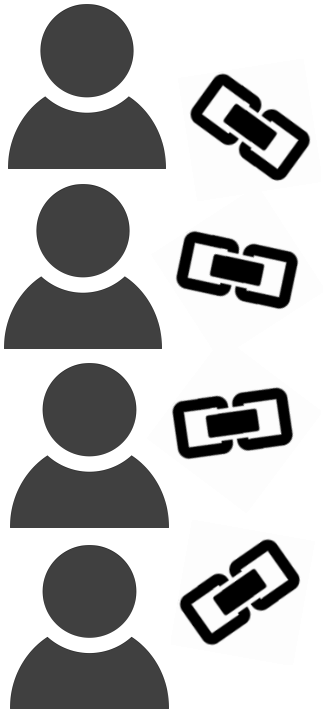


image source: https://pixabay.com/de/vectors/tick-sternchen-kreuz-rot-gr%C3%BCn-40678/

What is Morphing?

In our real world morphing can become a threat

- with a criminal and an accomplice as actors
- take the criminal
- and the accomplice
- morphing can transform one face image into the other

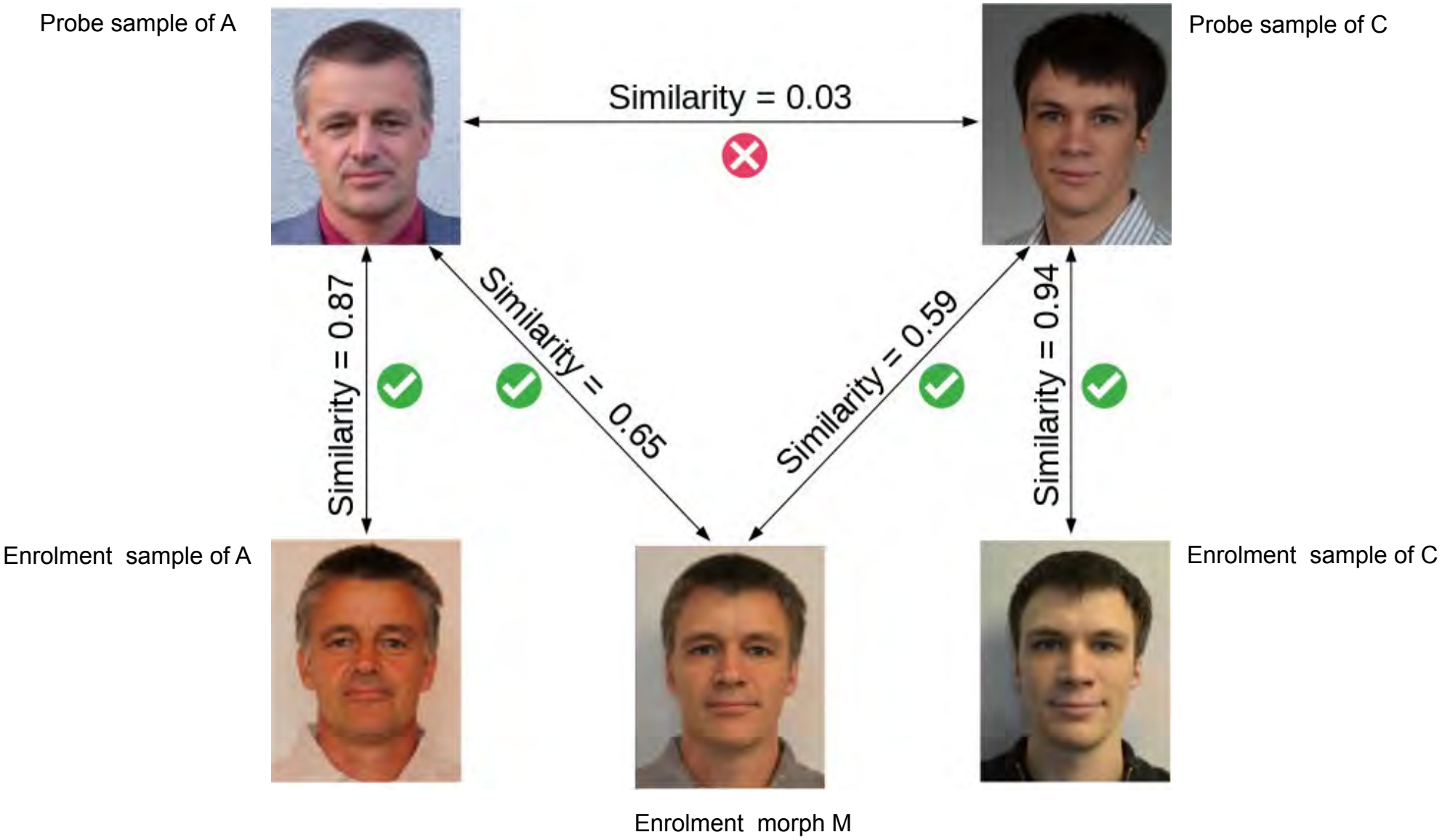
What is Morphing?

In our real world morphing can become a threat

- with a criminal and an accomplice as actors
- take the criminal
- and the accomplice
- morphing can transform one face image into the other
- and you can stop half way in the transformation

Problem: Morphing Attacks

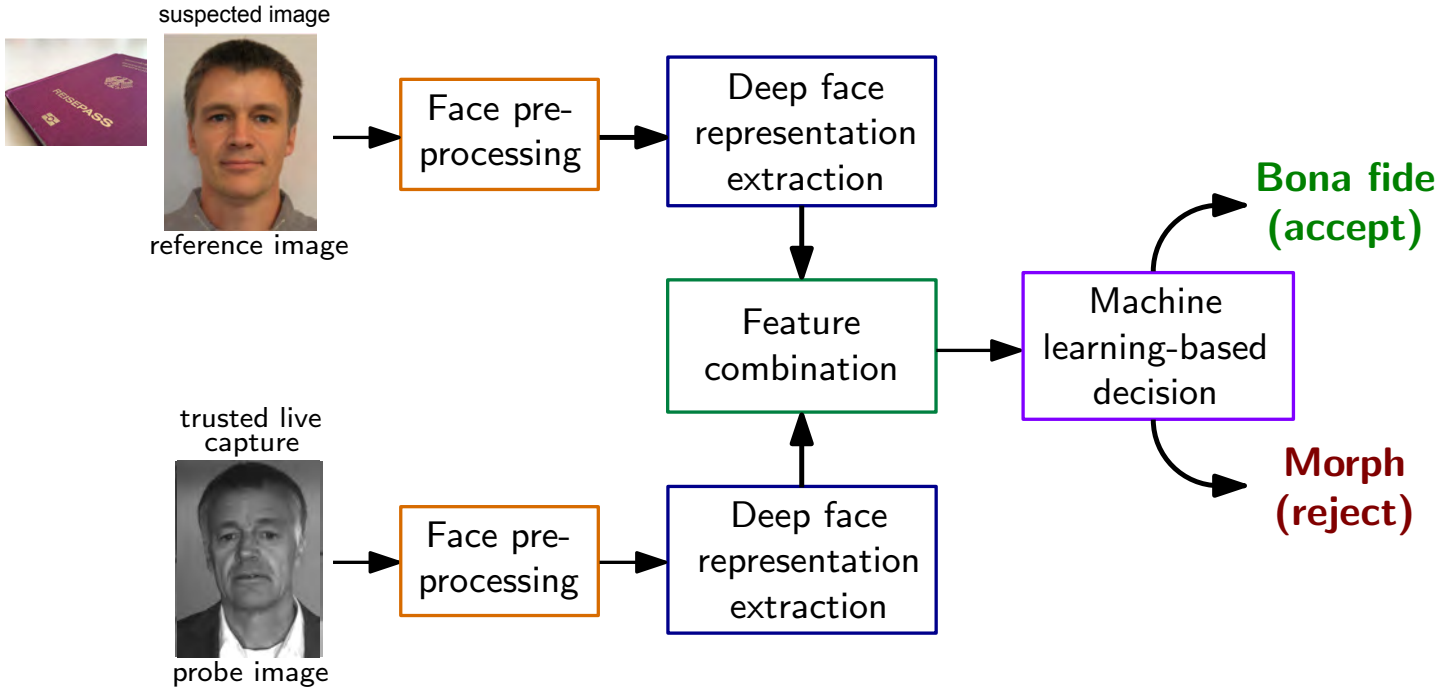
Verification against morphed facial images



Differential Morphing Attack Detection

D-MAD with deep latent vectors

- Deep Face representations of Deep CNNs



- Deep representations extracted by the neural network (on the lowest layer)
- Feature space with small dimension: 512 (for ArcFace)
- SVM with radial basis function

[SRMB2020] U. Scherhag, C. Rathgeb, J. Merkle, C. Busch: "Deep Face Representations for Differential Morphing Attack Detection", in IEEE Transactions on Information Forensics and Security (TIFS), (2020)

MAD Evaluation Methodology

Definition of detection capabilities metrics

- ISO/IEC 20059 defines testing the MAD subsystem with false-negative and false-positive errors
  https://www.iso.org/standard/86084.html

- **Morphing attack classification error rate (MACER)**
  proportion of morphed samples incorrectly classified as bona fide samples in a specific scenario
  - Formerly reported as APCER in parts of the literature

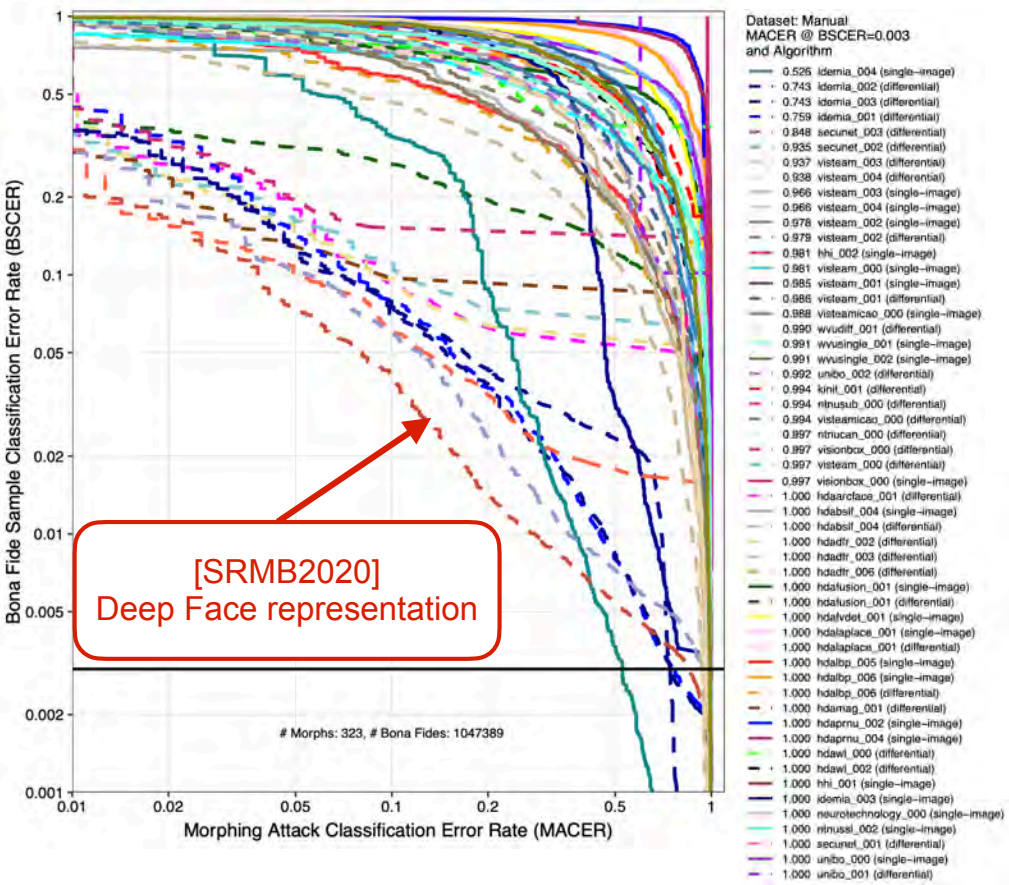
- **Bona fide sample classification error rate (BSCER)**
  proportion of bona fide samples incorrectly classified as morphed samples in a specific scenario
  - Formerly reported as BPCER in parts of the literature

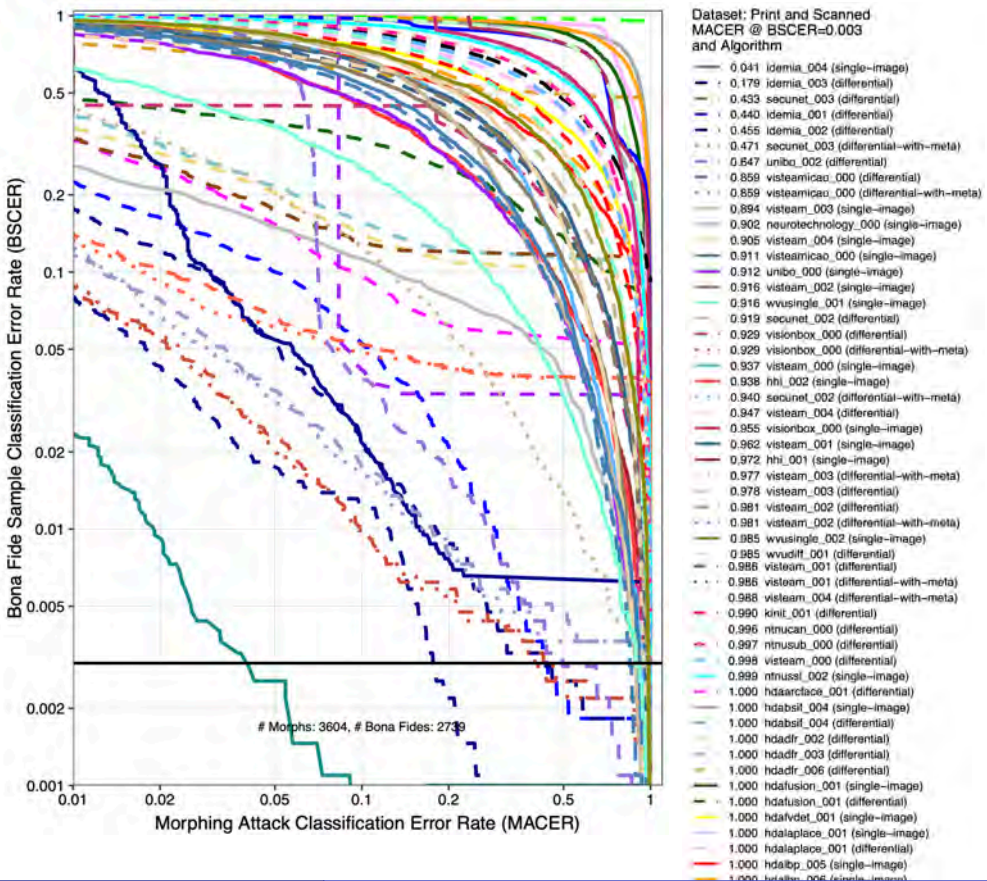
Source: ISO/IEC 20059

NIST-FATE-MORPH

NIST IR 8292 report presented June, 2025

- Performance of Automated Face Morph Detection
  https://pages.nist.gov/frvt/reports/morph/frvt_morph_report.pdf
- Results for high quality morphs versus print and scanned
  - note the low number of print and scanned images

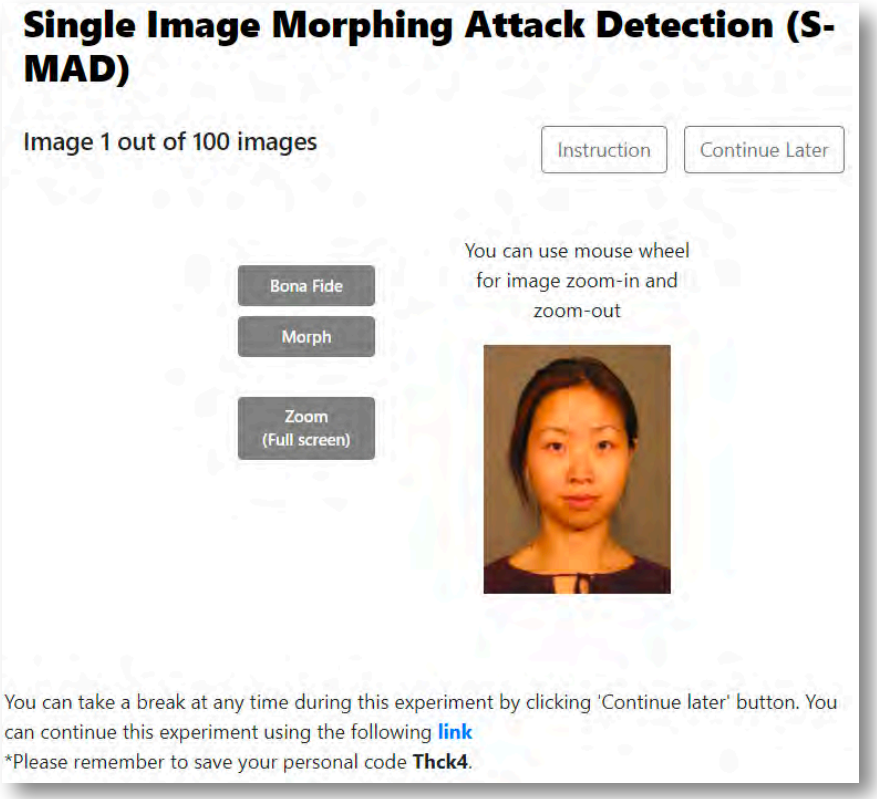


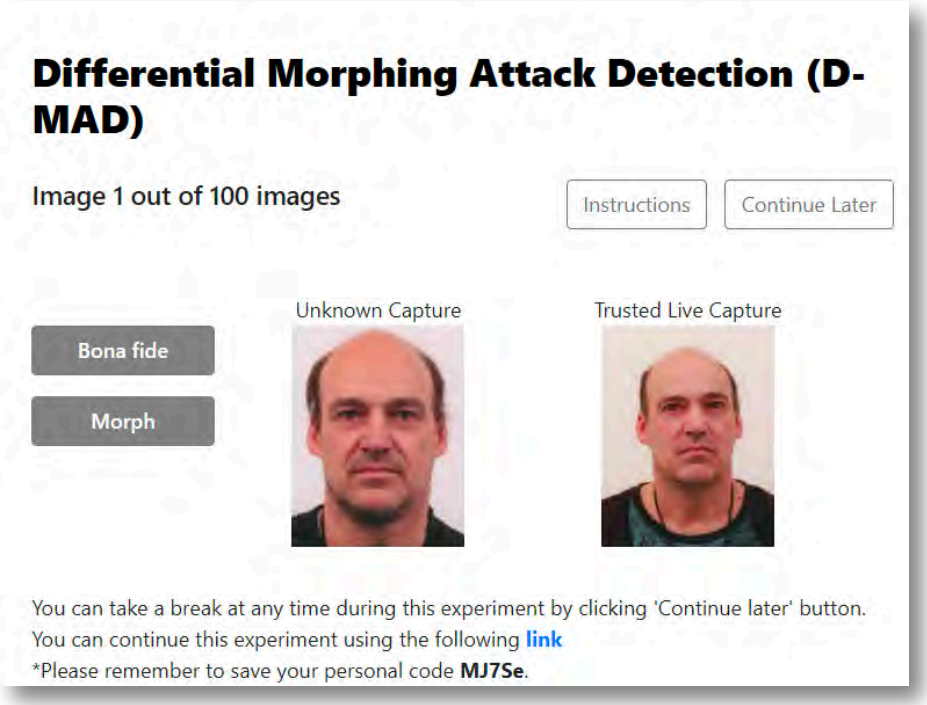


Human Observers in MAD

Border guards, case handlers, document examiners, ID experts

- S-MAD: 410 participants, 180 trials
- D-MAD: 469 participants, 400 trials (4 x 100 tasks)

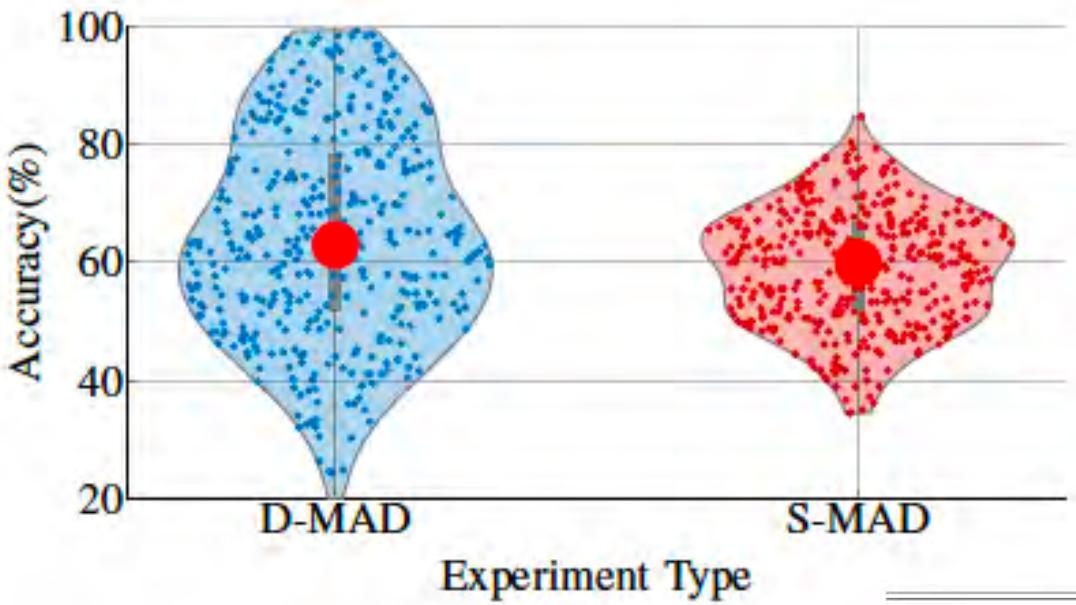




[GOD2022] S. Godage, F. Løvåsdal, S. Venkatesh, K. Raja, R. Raghavendra, C. Busch: “Analyzing Human Observer Ability in Morphing Attack Detection - Where Do We Stand?”, https://arxiv.org/abs/2202.12426

Human Observers in MAD

Overall accuracy

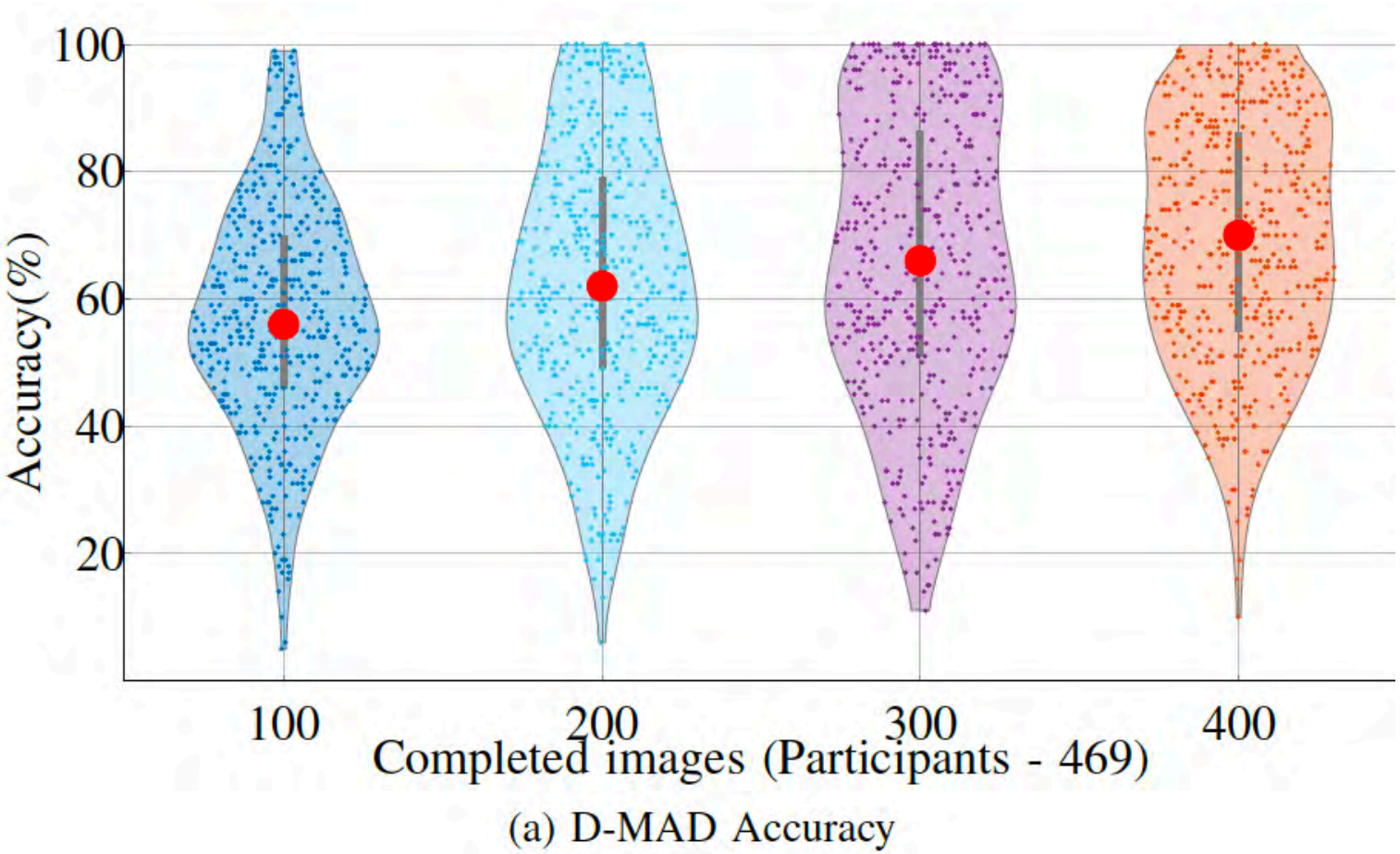


Line of work	D-MAD Number of participants	D-MAD Average Accuracy	S-MAD Number of participants	S-MAD Average Accuracy
Border Guard	30	64.66	26	55.17
Case handler- Passport, visas, ID, etc	150	63.45	137	56.65
Document examiner- 1st line	38	60.79	30	57.63
Document examiner- 2st line	40	68.64	34	62.56
Document examiner- 3rd line	30	65.74	25	61.51
Face comparison expert (Manual examination)	44	72.56	39	64.63
ID Expert	53	63.09	50	57.21
Other	84	64.66	69	55.17
Student	103	56.91	-	-
Total participants	572		410	
Experts	469		410	

[GOD2022] S. Godage, F. Løvåsdal, S. Venkatesh, K. Raja, R. Raghavendra, C. Busch: “Analyzing Human Observer Ability in Morphing Attack Detection - Where Do We Stand?”, https://arxiv.org/abs/2202.12426

Human Observers in MAD

Does exposure to morphed images help?



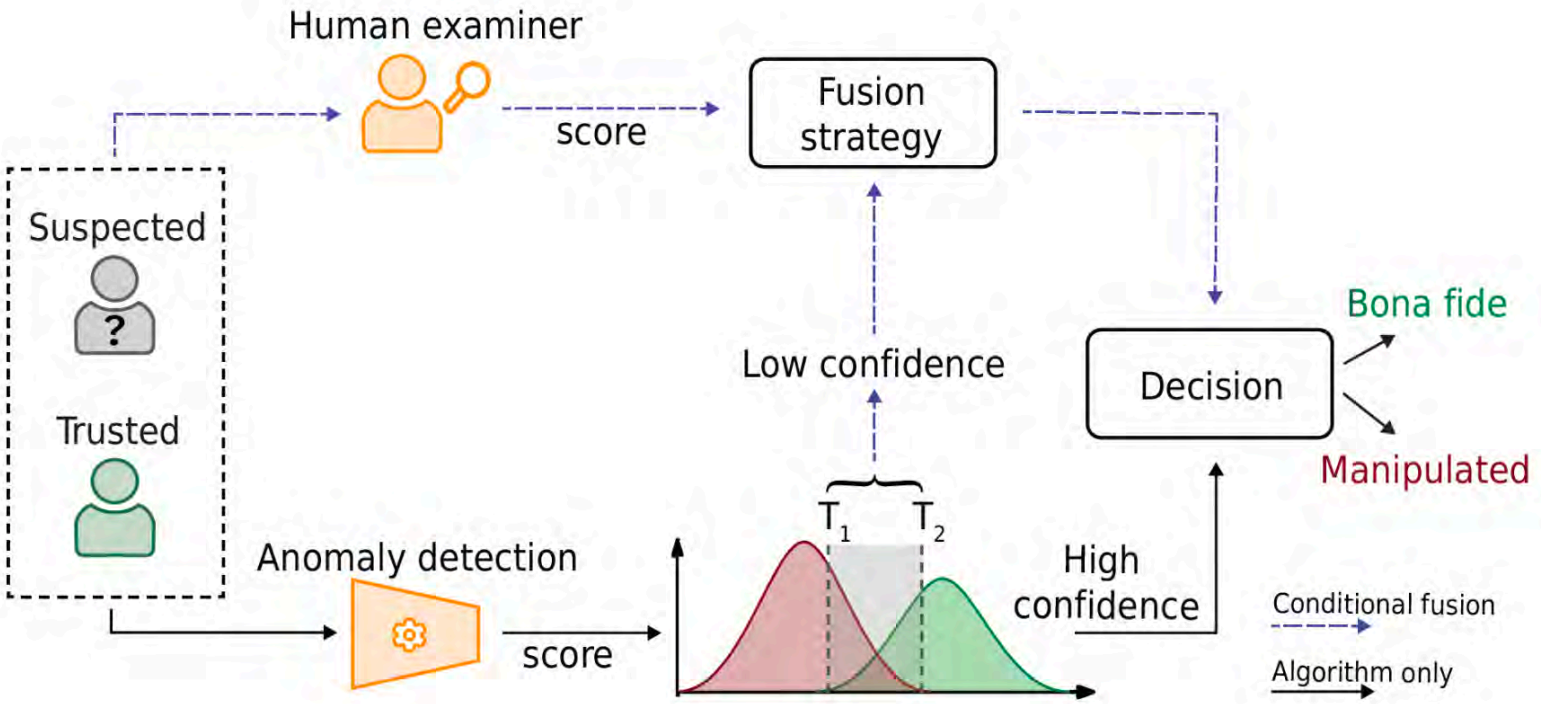
(a) D-MAD Accuracy

[GOD2022] S. Godage, F. Løvåsdal, S. Venkatesh, K. Raja, R. Raghavendra, C. Busch: “Analyzing Human Observer Ability in Morphing Attack Detection - Where Do We Stand?”, https://arxiv.org/abs/2202.12426

Humans and Algorithms in MAD

Human and Algorithm Detection Scores

- Conditional fusion



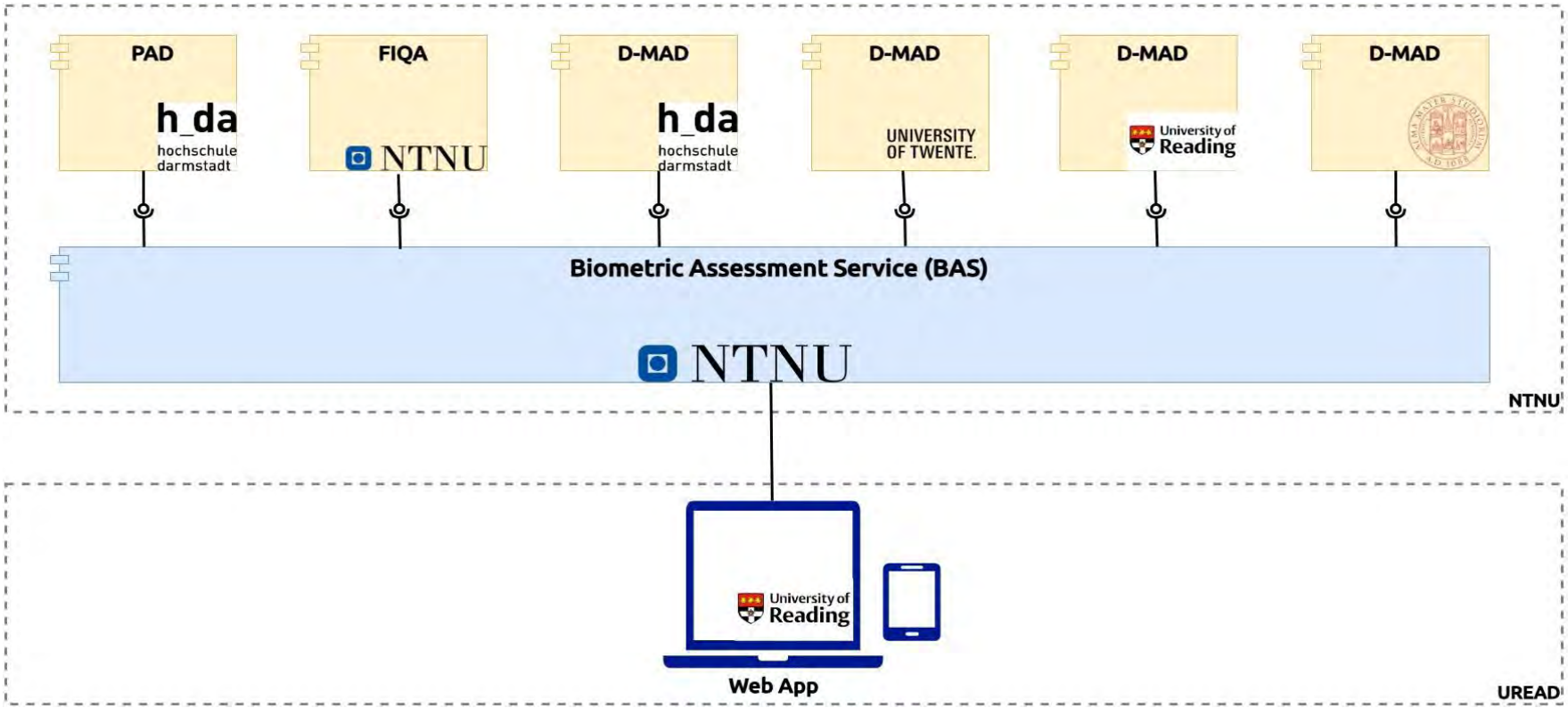
[Ibsen2024] M. Ibsen et al. “Conditional Face Image Manipulation Detection: Combining Algorithm and Human Examiner Decisions.” In: Proceedings of the Workshop on Information Hiding and Multimedia Security (IH&MMSec ’24.), (2024) https://dl.acm.org/doi/pdf/10.1145/3658664.3659649

Biometric Assessment Service (BAS)

Biometric Assessment Service (BAS)

EINSTEIN Approach

- Remote face image assessment
- BAS performs the manipulation detection and quality checks



Biometric Assessment Service (BAS)

EINSTEIN - Supporting with D-MAD check

Old passport photo

New passport photo

Facial Recognition check

Facial Recognition status: PASSED

Facial Recognition distance score (lower is better): 0.099

▸ See individual facial recognition results

BAS results:

D-MAD Detection status: NO MORPHS DETECTED

▾ See details

▾ SVM-Embeddings NO MORPH DETECTED
- Is Morphed: false
- Module Score: 1e-7

▾ ACIdA NO MORPH DETECTED
- Is Morphed: false
- Module Score: 0.000025134963

▾ SFDemorpher NO MORPH DETECTED
- Is Morphed: false
- Module Score: 0.240021

▾ StyleDemorpher NO MORPH DETECTED
- Is Morphed: false
- Module Score: 0.374662

Old passport photo

New passport photo

Facial Recognition check

Facial Recognition status: PASSED

Facial Recognition distance score (lower is better): 0.258

▸ See individual facial recognition results

BAS results:

D-MAD Detection status: MORPH DETECTED

▾ See details

▾ SVM-Embeddings NO MORPH DETECTED
- Is Morphed: false
- Module Score: 0.010862063

▾ ACIdA NO MORPH DETECTED
- Is Morphed: false
- Module Score: 0.3215394

▾ SFDemorpher MORPH DETECTED
- Is Morphed: true
- Module Score: 0.661883

▾ StyleDemorpher MORPH DETECTED
- Is Morphed: true
- Module Score: 0.592029

Conclusion

Summary

- Face image quality assessment is accurately possible with open source algorithms and explainable feedback
- Fusion improves morphing attack detection accuracy
- EINSTEIN Biometric Assessment Service provides security and quality leading to trustworthiness of ID documents
- Field Test with UK Home Office are currently conducted

Get involved

- Frøy Løvåsdal has initiated an application to implement MAD in Politiet
- Participate also in human observer experiments

[B2024] C. Busch: "Challenges for Automated Face Recognition Systems", in Nature Reviews Electrical Engineering, (2024), https://christoph-busch.de/files/Busch-NatureReview-ChallengesFRS-2024.pdf

Questions and Answers?

Take home information:

- Face image quality website:
  https://christoph-busch.de/projects-ofiq.html
- Morphing attack detection website:
  https://christoph-busch.de/projects-mad.html