Der Weg zur Robusten Gesichtserkennung

2025-11-27

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

ATHENE / Hochschule Darmstadt, Germany
Norwegian University of Science and Technology (NTNU), Norway

ATHENE

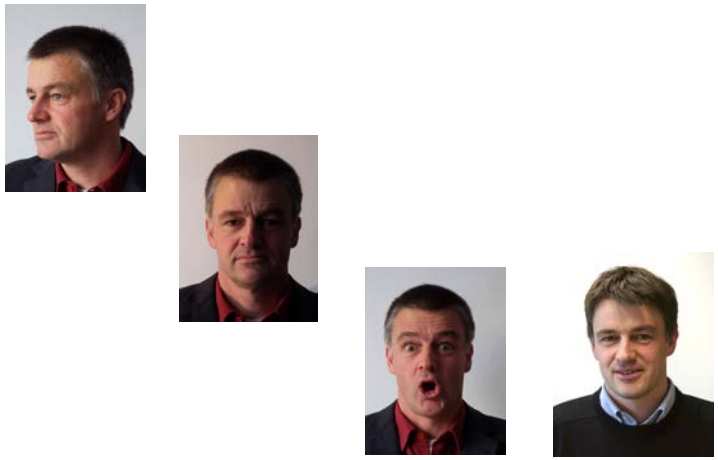
European Association for Biometrics eab Human Identity in Europe

NTNU

Challenges for Face Recognition

Critical factors for Face Recognition Systems (FRS):

- Pose
- Illumination
- Expression and Ageing

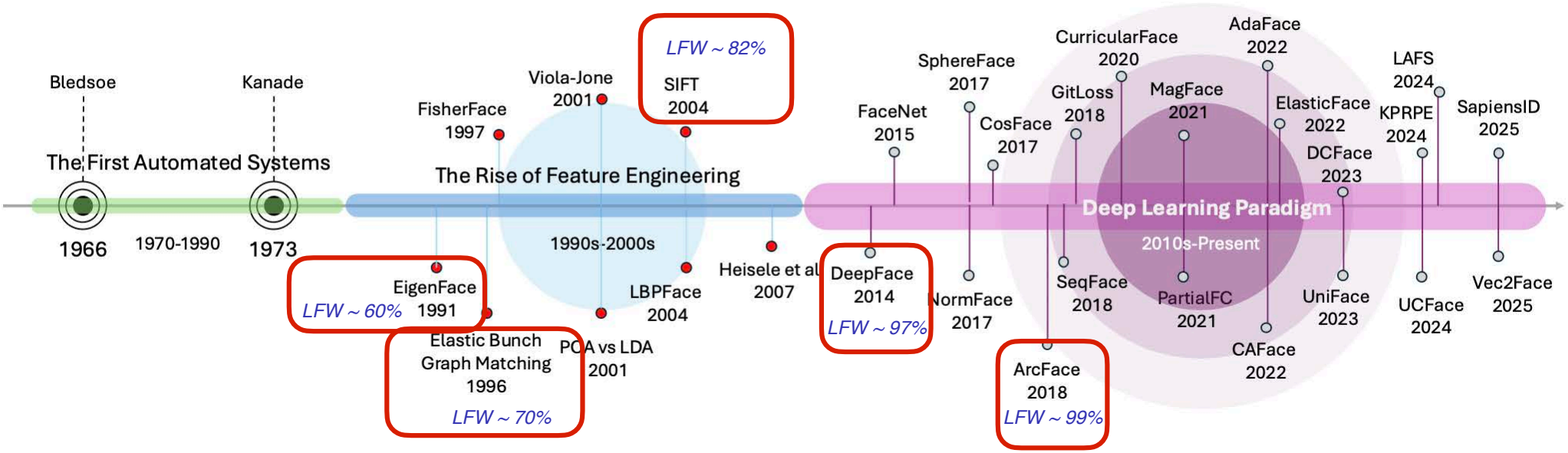


2001

Evolution of Face Recognition Algorithms

Testing on challenging facial images

- Identification rate for Labeled Faces in-the-Wild (LFW)
  http://vis-www.cs.umass.edu/lfw/



[Kim2025] M. Kim, A. Jain, X. Liu: “50 Years of Automated Face Recognition“, arXiv, (2025)

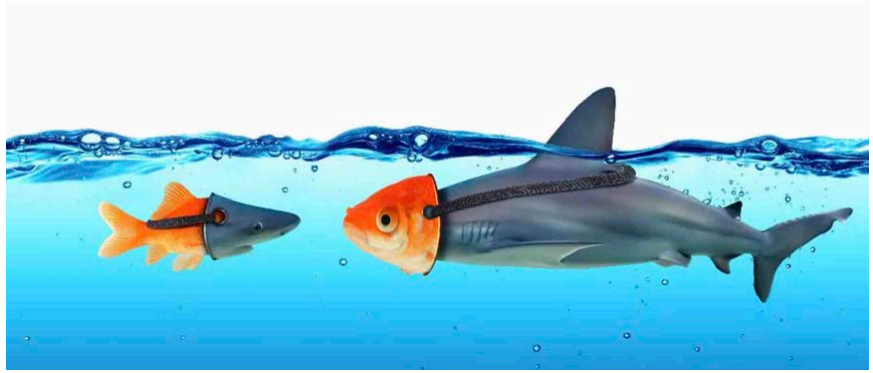
[Huang2007] G. Huang, M. Ramesh, T. Berg, E. Learned-Miller: “Labeled Faces in the Wild: A Database for Studying Recognition in Unconstrained Environments“, TR, University of Massachusetts, (2007)

Challenges for Face Recognition

Critical factors for Face Recognition Systems (FRS):

- Pose
- Illumination
- Expression and Ageing
- Presentation Attacks

2001 2025



Challenges for Face Recognition

Critical factors for Face Recognition Systems (FRS):

- Pose
- Illumination
- Expression and Ageing
- Presentation Attacks
- Face Image Quality





2001 2025



Challenges for Face Recognition

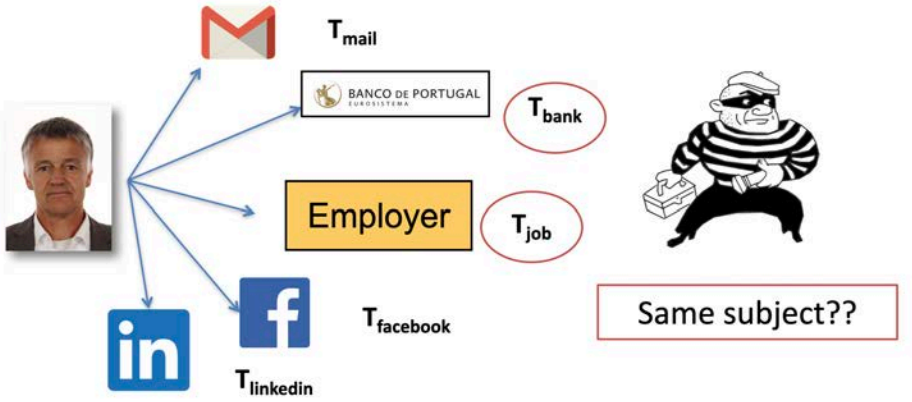
Critical factors for Face Recognition Systems (FRS):

- Pose
- Illumination
- Expression and Ageing
- Presentation Attacks
- Face Image Quality
- Morphing Attack Detection

Challenges for Face Recognition

Critical factors for Face Recognition Systems (FRS):

- Pose
- Illumination
- Expression and Ageing
- Presentation Attacks
- Face Image Quality
- Morphing Attack Detection
- Biometric Template Protection



Challenges for Face Recognition

Critical factors for Face Recognition Systems (FRS):

- Pose
- Illumination
- Expression and Ageing
- Presentation Attacks
- Face Image Quality
- Morphing Attack Detection
- Biometric Template Protection
- Fairness of Algorithms





2001 2025

Challenges for Face Recognition

Critical factors for Face Recognition Systems (FRS):

- Pose
- Illumination
- Expression and Ageing
- Presentation Attacks
- Face Image Quality
- Morphing Attack Detection
- Biometric Template Protection
- Fairness of Algorithms
- Face Recognition with 1KB Reference





2001 2025

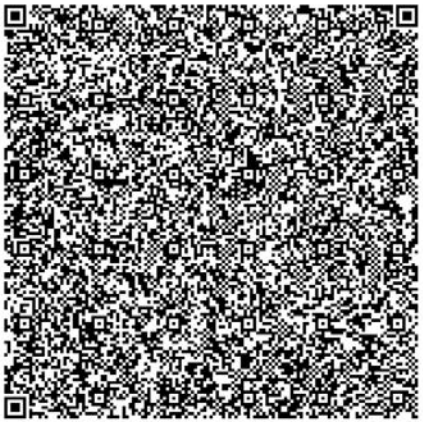
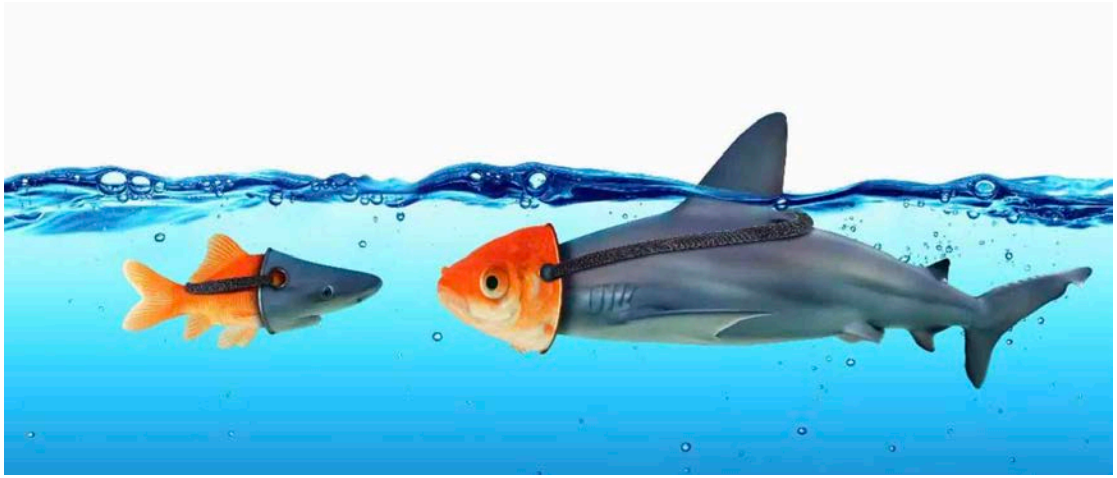



Image Source: Patrick Grother (2025)

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

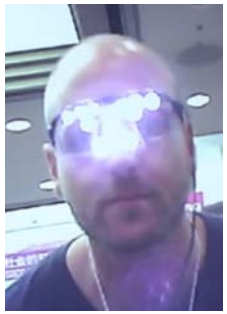



Image Source: https://www.youtube.com/watch?v=LRj8whKmN1M

Presentation Attacks

Definitions in ISO/IEC 2382-37: Vocabulary

- **Impostor**
  subversive biometric capture subject who attempts to being matched to someone else's biometric reference

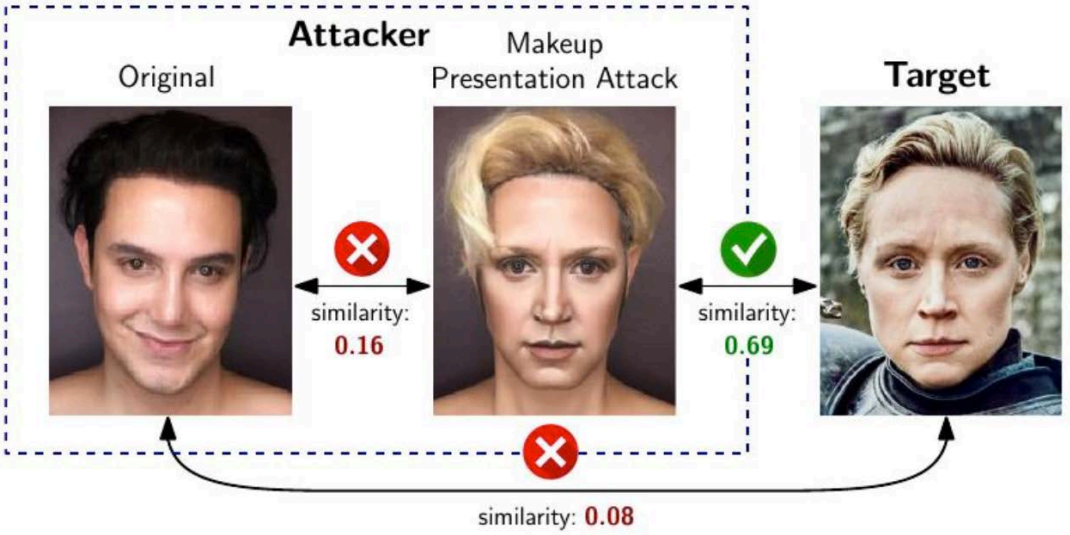
- **Identity concealer**
  subversive biometric capture subject who attempts to avoid being matched to their own biometric reference

https://www.iso.org/obp/ui/#iso:std:iso-iec:2382:-37:ed-3:v1:en

Presentation Attack Detection

Makeup for impersonation

- Liveness detection is not sufficient
- Detection difficult since bona fide users may also apply makeup



[RDB2020] C. Rathgeb, P. Drozdowski, C. Busch: "Makeup Presentation Attacks: Review and Detection Performance Benchmark", in IEEE Access, (2020)

Face Image Quality

Face Image Quality

Motivation for Face Image Quality Assessment (FIQA)

- Quality matters, especially in large-scale databases and with diverse application scenarios.
  - The European Entry Exit System (EES) started 12th October 2025
    - Applied to all external Schengen borders
    - Central register to record all entries/exists to the Schengen area
      https://travel-europe.europa.eu/ees_en

    - For each traveller a record with facial image and fingerprint images
    - Operated by eu-LISA and 29 countries

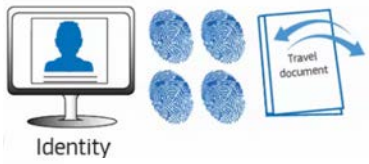


Image Source: eu-LISA

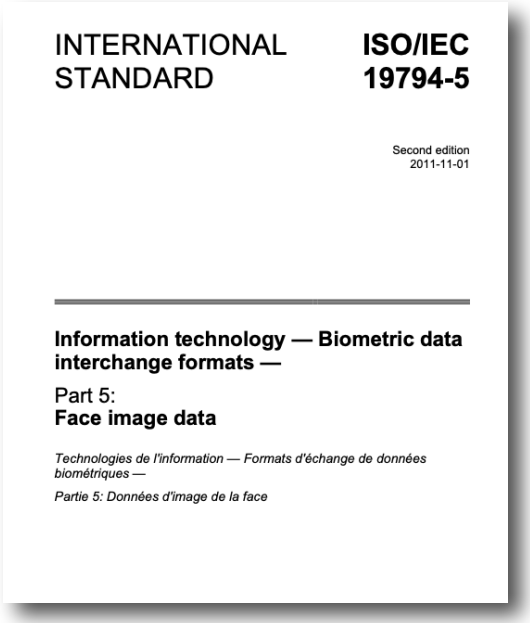
- Standardisation of minimal quality and harmonisation is essential for (semantic) interoperability.

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

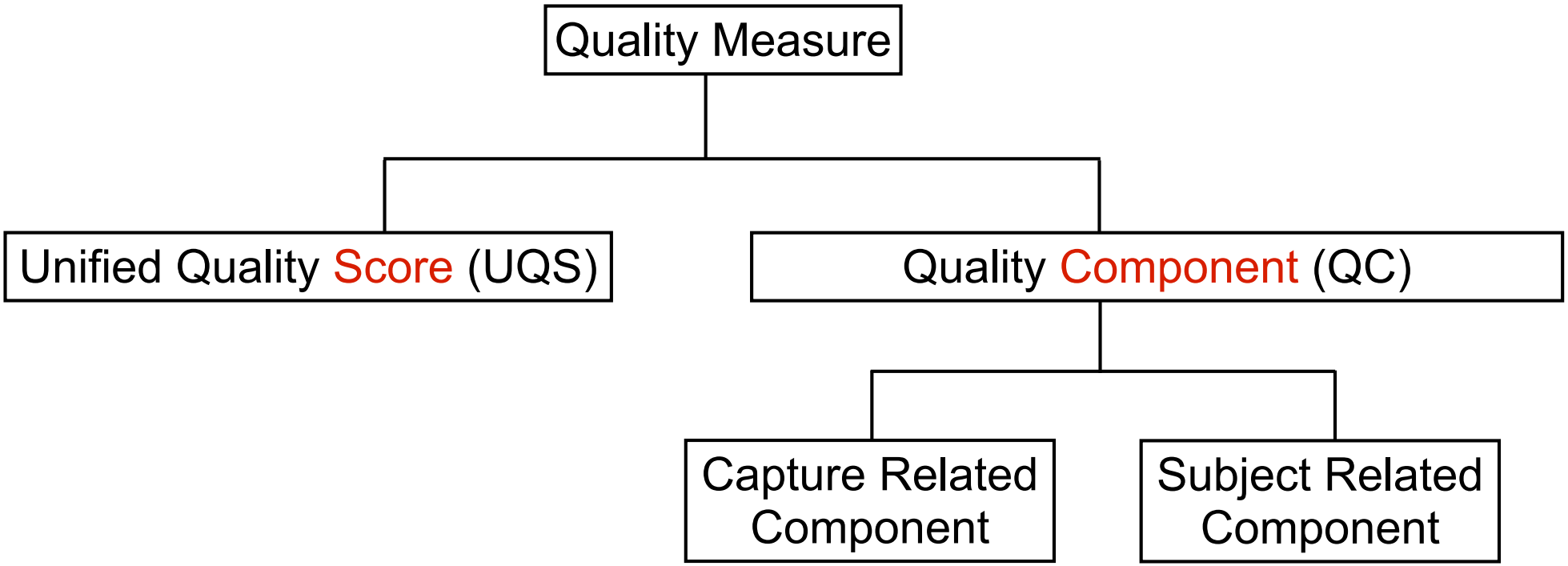
How to develop face image quality measures

- 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

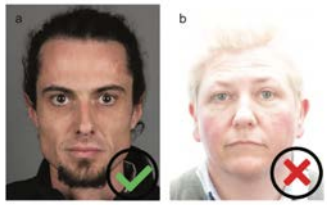


Image Source: ISO/IEC 39794-5

Explainable Quality Assessment

Subject related

Image Source: ISO/IEC 39794-5

OFIQ - Unified Quality Score

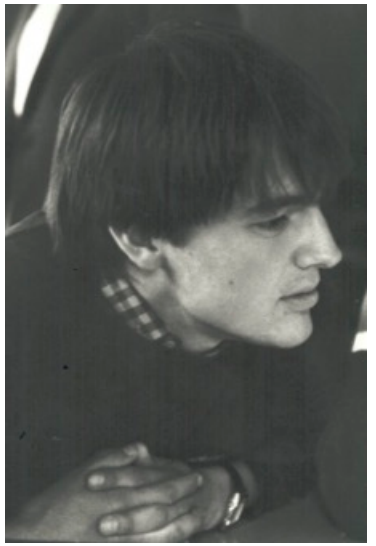
General, holistic unified quality score (OFIQ-UQS)

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

OFIQ-UQS=84

OFIQ-UQS=61

OFIQ-UQS=26

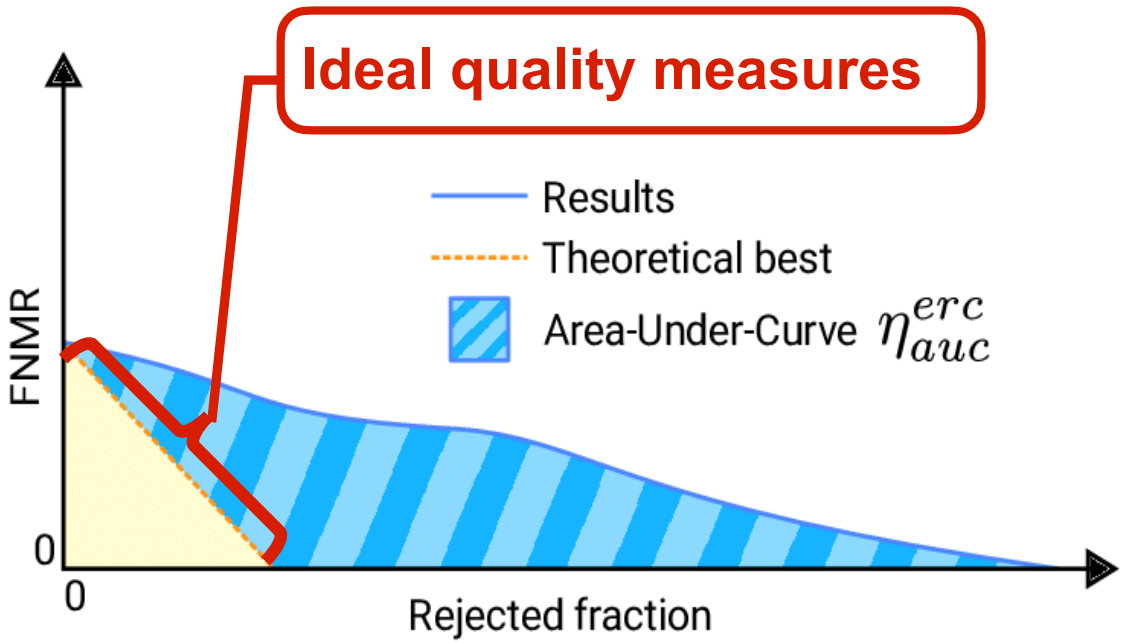


OFIQ-UQS=7

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?



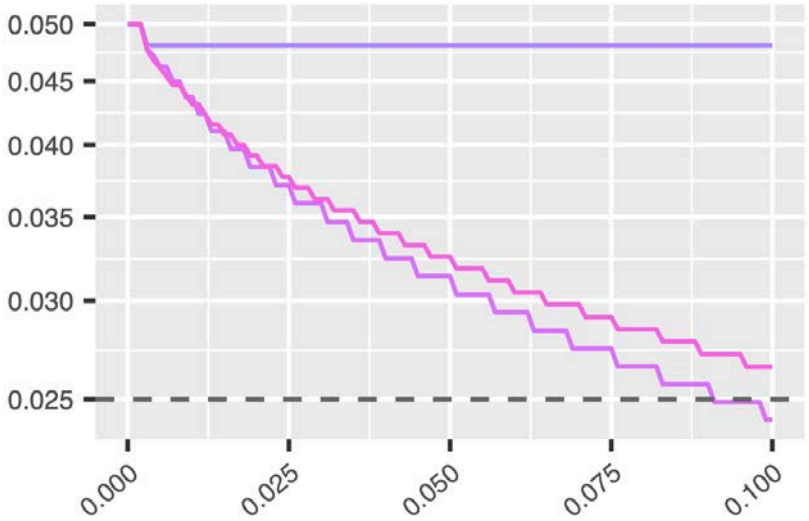


Image Source:NIST FATE SIDD report

Open Source Face Image Quality (OFIQ)

Pre-processing for quality measures

- Face Detection: bounded box of all detected faces
- Face Landmark Estimation: localization of 98 key points
- Alignment: bring eyes on the same height
- Face Occlusion Segmentation: identify un-occluded region
- Face Parsing: identify different regions of subject in the image (eyes, eye brows, nose, lips, skin / neck, ears, hair / glasses, clothes, hats, earrings, necklaces / background)

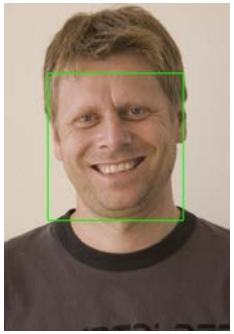
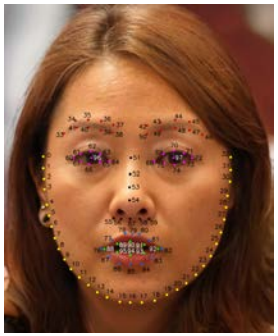




Image Source: OFIQ public report and ISO/IEC FDIS 29794-5

OFIQ - Quality Components

Example algorithm: Sharpness

- Detecting the sharpness of an image
- Is the subject in focus or the background?

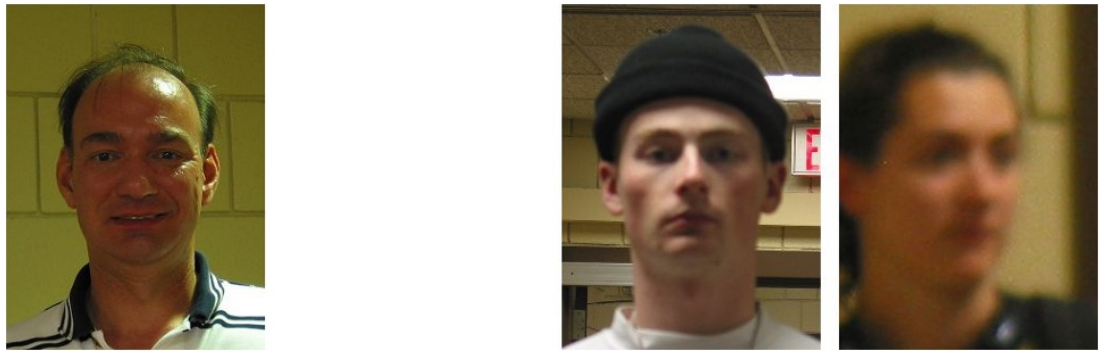


Image Source: FRGCv2 database

- Restricted to landmarked region
  - Laplacian Filter
  - Random Forest classifier

Image Source: OFIQ public report

OFIQ - Quality Components

Example algorithm: Mouth Closed

- Detecting if the most is closed
- Algorithms based on landmarks
- Maximum distance between lips

$$D_L = \max\left(\|L_{89} - L_{95}\|_2, \|L_{90} - L_{94}\|_2, \|L_{91} - L_{93}\|_2\right)$$

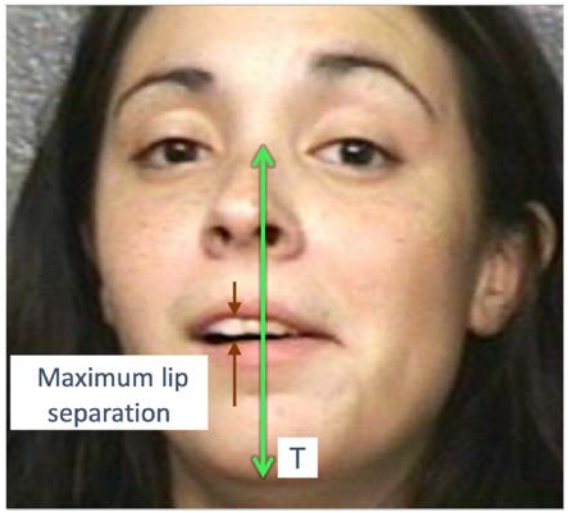
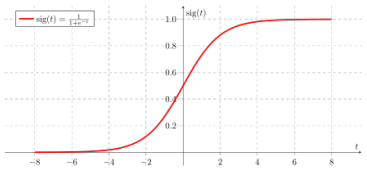


Image Source:NIST FATE SIDD report

- Normalized by distance T between eye‘s midpoint and chin
- Mouth opens aspect

$$\omega = \frac{D_L}{T}$$



$$Q = \text{ROUND}(100(1 - \text{SIGMOID}(\omega, 0.2, 0.06)))$$

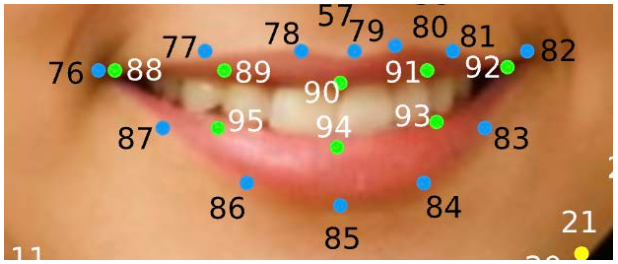


Image Source:ISO/IEC 29794-5

OFIQ - Quality Components

Quality Component: Expression Neutrality

- Expression neutrality as quality component
  - Reduced biometric performance for extreme facial expressions
- Known fact:
  - Best-possible utility through neutral expressions
- Goal:
  Quantify expression neutrality

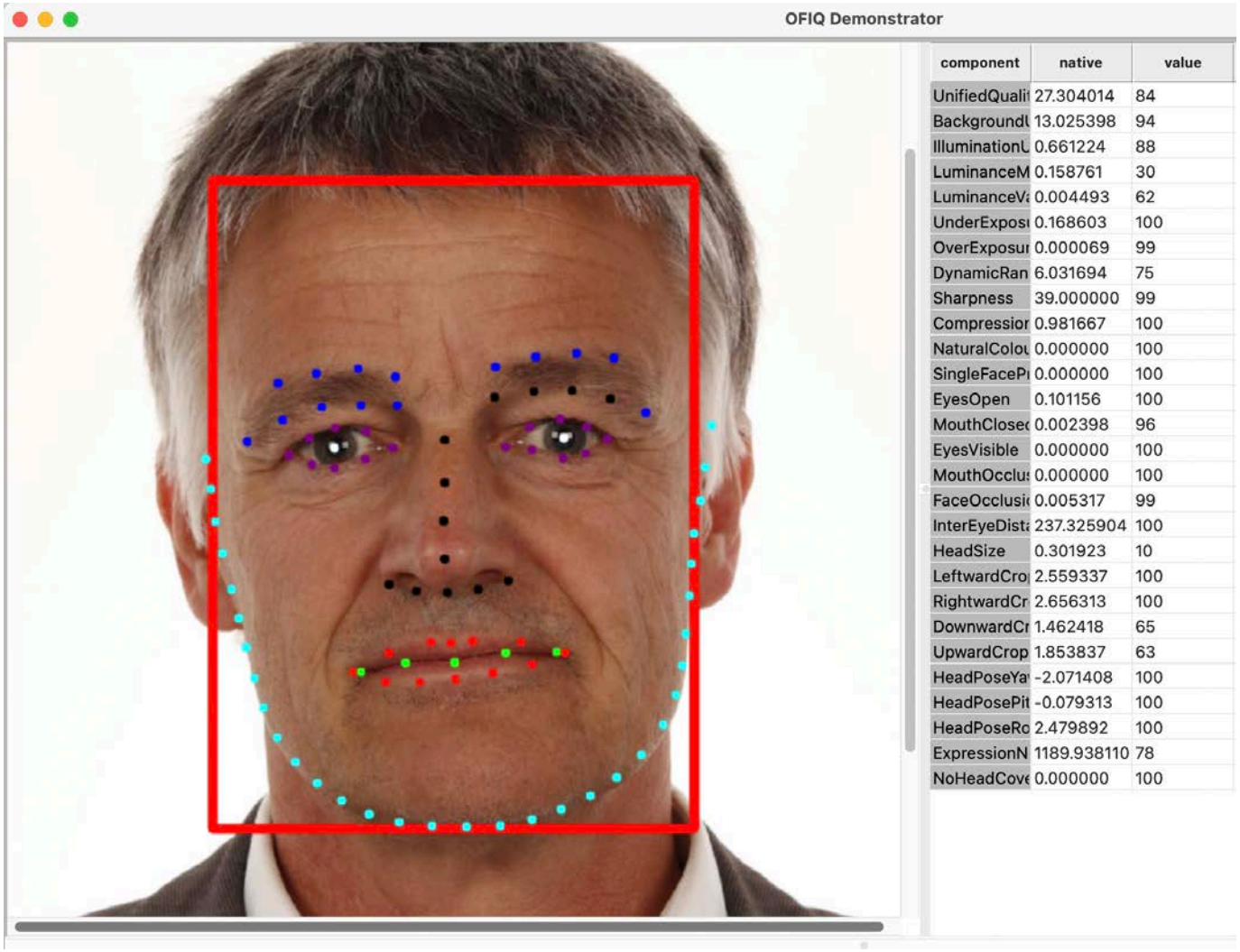
[GRVB2023] M. Grimmer, C. Rathgeb, R. Veldhuis, C. Busch: "NeutrEx: A 3D Quality Component Measure on Facial Expression Neutrality", in Proceedings of International Joint Conference on Biometrics (IJCB), (2023)

[GVB2024] M. Grimmer, R. Veldhuis, C. Busch: "Efficient Expression Neutrality Estimation with Application to Face Recognition Utility Prediction", in Proceedings of 12th International Workshop on Biometrics and Forensics, (2024)

OFIQ - Demonstrator

Demonstrator to understand the processing

- Available in GitHub:
  https://github.com/BSI-OFIQ/OFIQ-Project



Face Image Quality - Future work

Open research tasks for OFIQ 2

- Further innovation of quality measures
- Add missing components
  - Motion blur
  - Gaze estimation
  - …

Image Source: ISO/IEC 39794-5 Annex D1

- Investigate demographic variability

Outlook for OFIQ

Perspective

- OFIQ will (likely) replace the proprietary FIQA
  - wherever used
  - avoid a vendor-lock-in
- OFIQ 2.0 project has already started

Take home information on face image quality

- OFIQ open source code:
  https://github.com/BSI-OFIQ/OFIQ-Project
- OFIQ public report
  https://github.com/BSI-OFIQ/OFIQ-Project/blob/main/doc/reports/Public_Report_V1.1_2024_09_30.pdf
- NIST test report:
  https://pages.nist.gov/frvt/reports/quality_sidd/frvt_quality_sidd_report.pdf
- Face image quality website:
  https://christoph-busch.de/projects-ofiq.html
- OFIQ user group meeting - 2026-01-20:
  https://eab.org/events/program/390

Fairness of Algorithms

Image Source: https://www.flaticon.com (2020)

Demographic Factors

What is fairness?

- Dictionary:
  "*the quality of treating people equally or in a way that is right or reasonable*"
- Movie Coded Bias

Image Source: Netflix

An inherently ethical and social concept

- Influenced by cultural, historical, legal, religious, personal, and other factors
- Challenging to develop mathematical definitions
- However, everyone wants to be treated "fairly"

Reaching out towards group fairness

- Demographic groups: gender, age, skin tone, glasses etc.

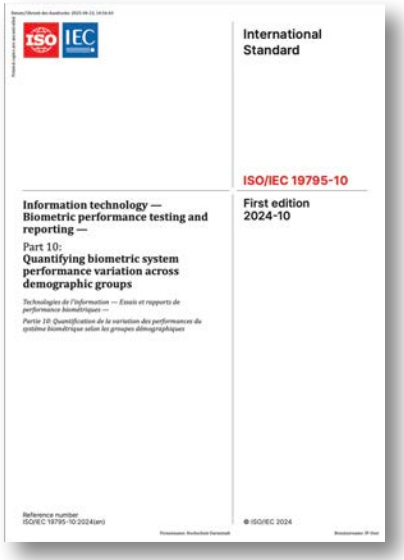
Demographic Effects

Current findings for facial biometric characteristics

- Most studies observed influence of demographic variables on biometric recognition.
  - Generally, lower biometric performance was consistently observed for females and children
  - The country of algorithm development (and hence training data) may be a large factor in this context.

International Standard

- ISO/IEC 19795-10
  https://www.iso.org/standard/81223.html

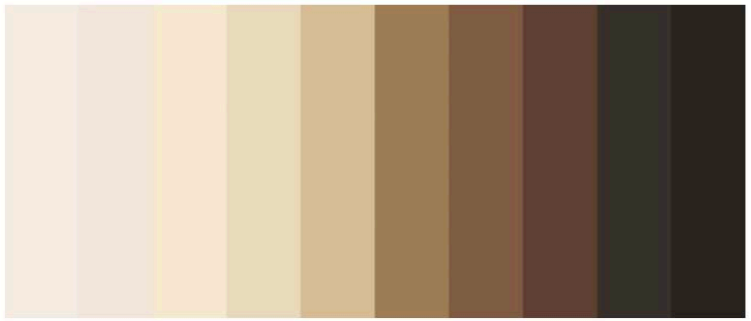


[Drozd2020] P. Drozdowski, C. Ratgeb, A. Dantcheva, N. Damer, C. Busch: "Demographic Bias in Biometrics: A Survey on an Emerging Challenge“, in IEEE Transactions on Technology and Society (TTS), (2020)

Face Image Quality - Demographics

Open research tasks

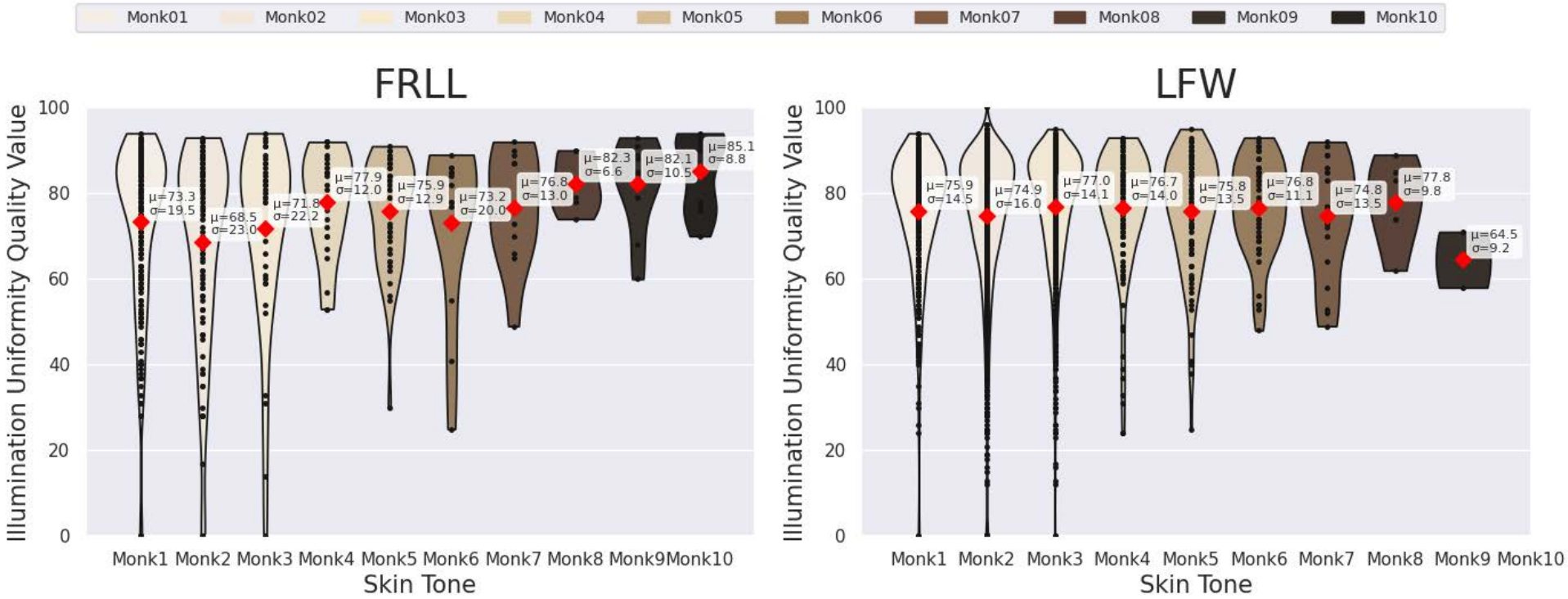
- Investigate demographic variability (DV)
- Example: skin tone variation
  Continuous demographic variable
- Collect data and organic in discrete categories
  - Monk skin tone scale (MST) vs.
  - Colorimetric skin ton (CST) vs.
  - PANTONE Skin Tone (PST)



Face Image Quality - Demographics

Open research tasks

- Investigate variability across demographic groups
  - Distribution of unified quality score (UQS)

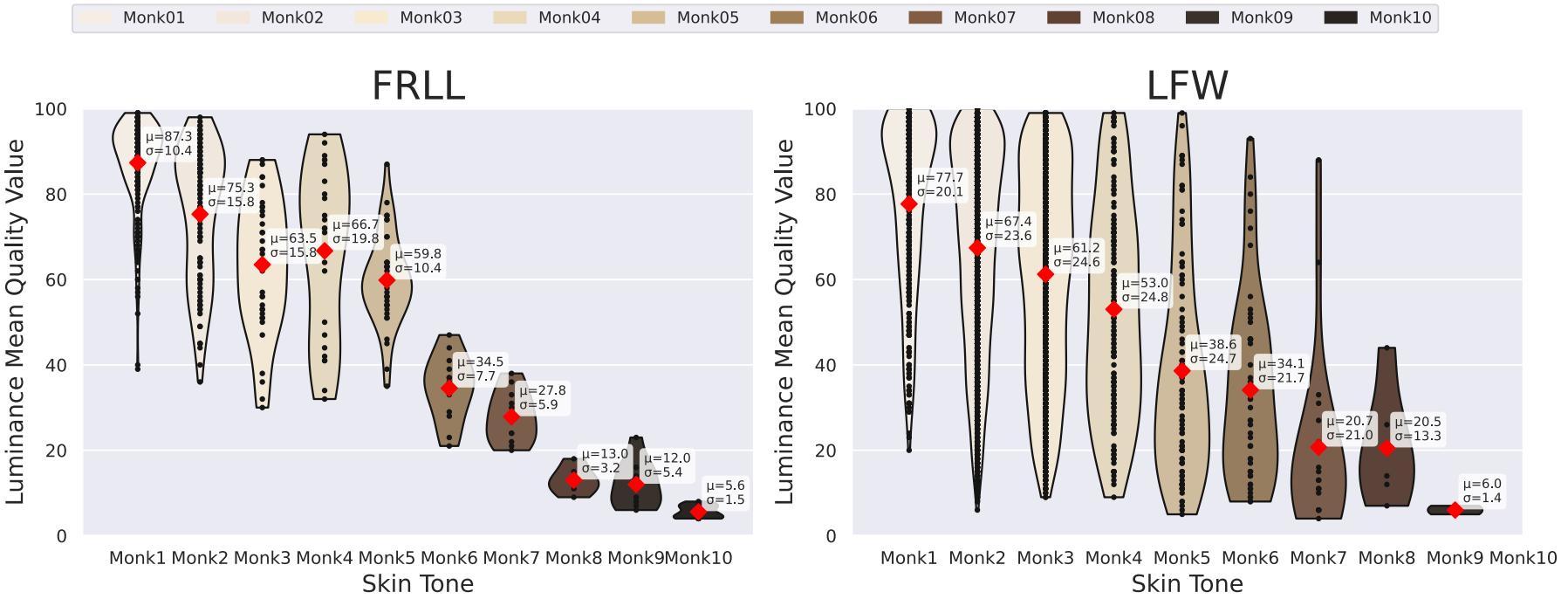


[KRRB2024] W. Kabbani, K. Raja, R. Raghavendra, C. Busch: "Demographic Differentials in Face Image Quality Measures", in Proceedings of the IEEE 23rd International Conference of the Biometrics Special Interest Group (BIOSIG), Darmstadt, September 25-27, (2024)

Face Image Quality - Demographics

Open research tasks

- Investigate variability across demographic groups
  - Distribution of component quality measures (CQM)
    Luminance Mean quality component values:

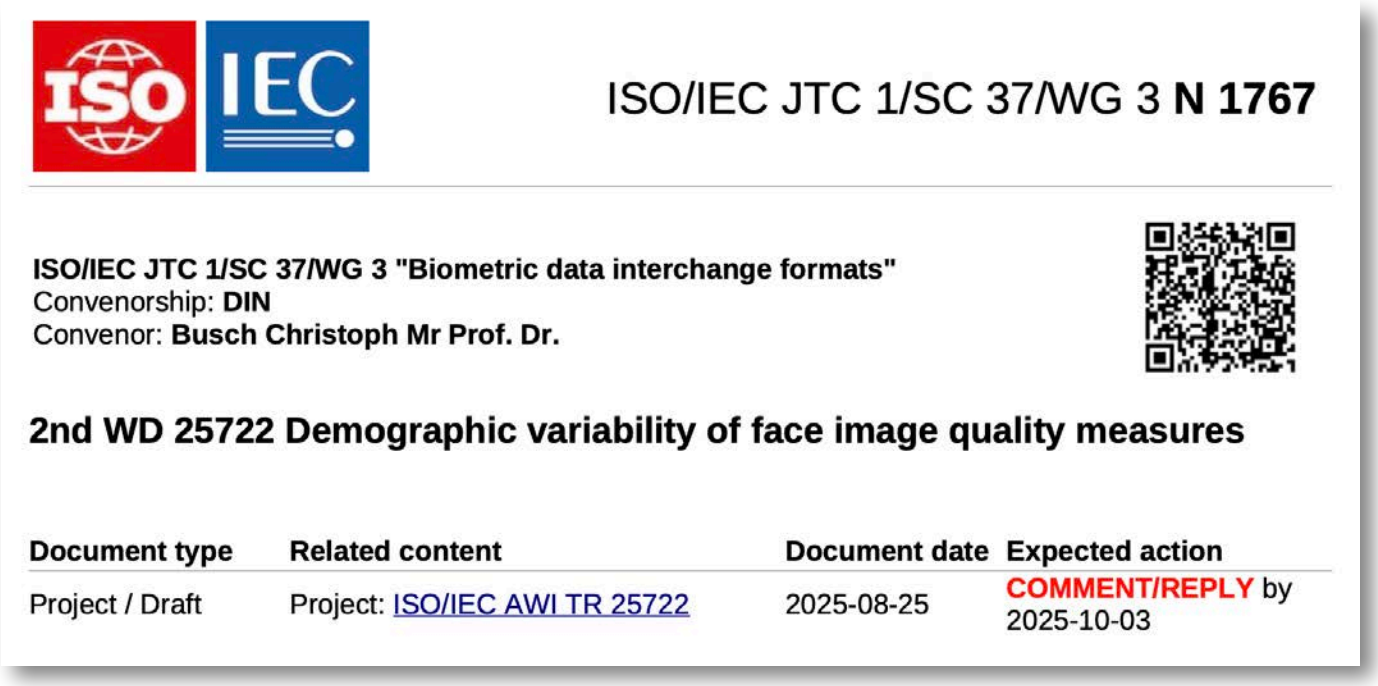


[KRRB2024] W. Kabbani, K. Raja, R. Raghavendra, C. Busch: "Demographic Differentials in Face Image Quality Measures", in Proceedings of the IEEE 23rd International Conference of the Biometrics Special Interest Group (BIOSIG), Darmstadt, September 25-27, (2024)

Face Image Quality - Demographics

Open tasks to investigate DV on operational data

- Distribution of UQS and CQM
- ISO/IEC TR 25722
  - https://www.iso.org/standard/91308.html
  - https://www.iso.org/committee/313770.html?t=pbkdp2EjRvj8aKJD_DJuyD-UVGVhaafFTG1SHYW1UKrmbchG6jLf6jqoqARosEWf&view=documents#section-isodocuments-top



ISO/IEC JTC 1/SC 37/WG 3 **N 1767**

ISO/IEC JTC 1/SC 37/WG 3 "Biometric data interchange formats"
Convenorship: **DIN**
Convenor: **Busch Christoph Mr Prof. Dr.**

2nd WD 25722 Demographic variability of face image quality measures

Document type	Related content	Document date	Expected action
Project / Draft	Project: ISO/IEC AWI TR 25722	2025-08-25	COMMENT/REPLY by 2025-10-03

FRS with 1KB reference Micro-Container

Compact Face Image Encoding

Containers have limited capacity

- Contact less IC Chip
  - ICAO 9303 passports
    - ISO/IEC14443
  - Target size: 32 Kbyte
- 2D Barcode
  - Temporary travel document
  - Temporary residence permit
    - ISO/IEC 18004:2024 QR code
    - ISO/IEC 16022:2024 Data Matrix
    - ISO/IEC 24778:2024 Aztec code
    - ISO/IEC 15438:2015 PDF417
    - ISO/IEC 16023:2000 Maxicode
  - Target size: 1Kbyte

Temporary eMRTD
Surname: Busch
Givename Christoph
Nationality: German
DoB: yyyymmdd
PoB: Frankfurt
DoE: yyyymmdd

Compact Face Image Encoding

Preprocessing

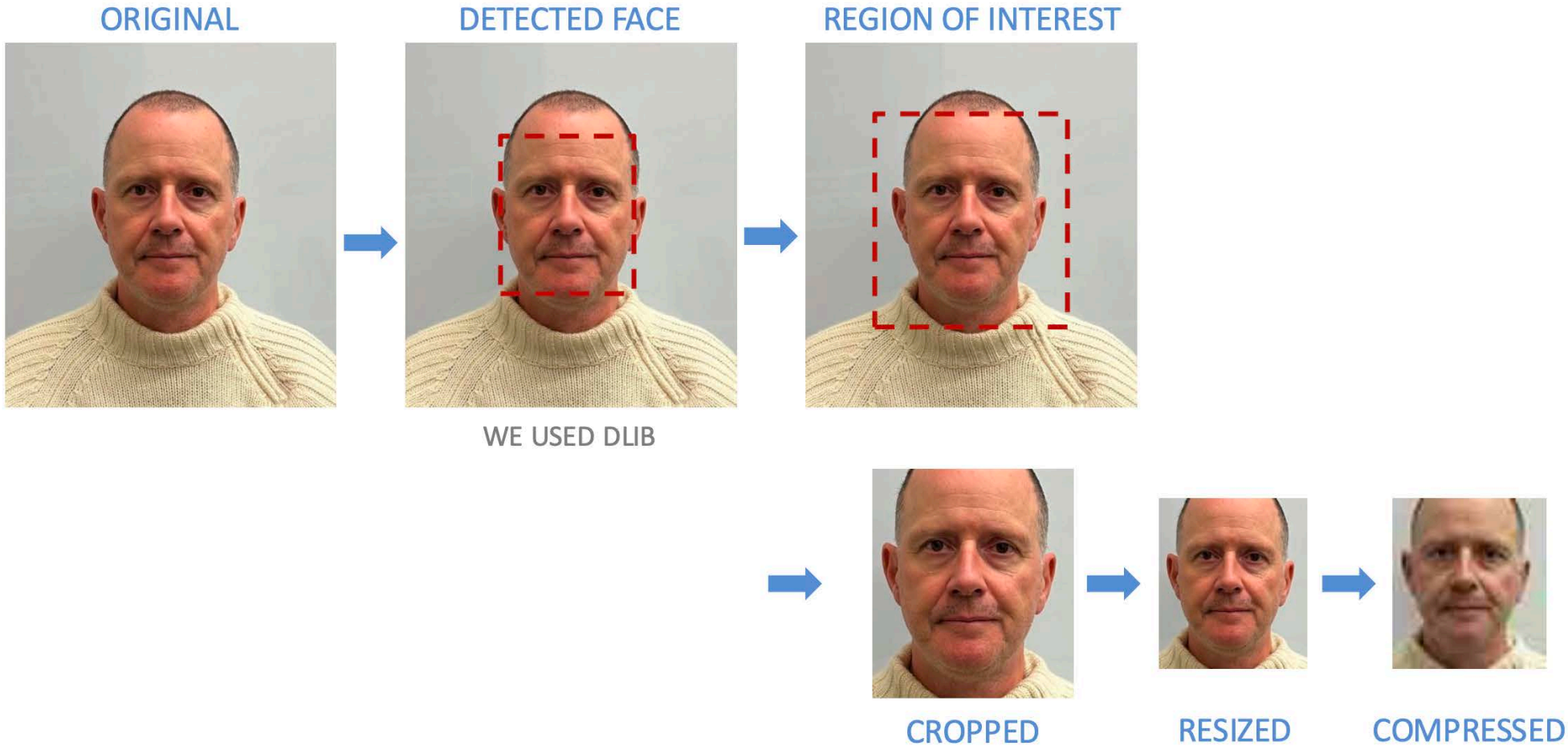
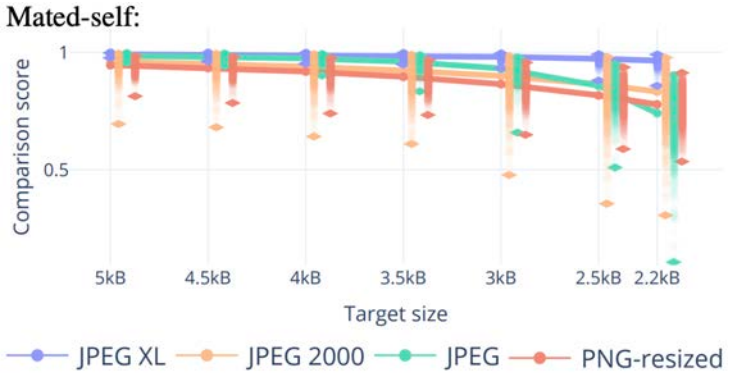


Image Source: Patrick Grother (2025)

Compact Face Image Encoding

Impact of Lossy Image Compression

- Encoding options:
  - ISO/IEC 10918 JPEG
  - ISO/IEC 15444 JPEG 2000
  - ISO/IEC 23008-12 HEIC
  - ISO/IEC 18181 JPEG-XL
  - WEBP Image Format IETF RFC 9649 2024-11-12
  - ISO/IEC 23000-22 AVIF



[Schlett2023] T. Schlett, S. Schachner, C. Rathgeb, J. Tapia, C. Busch: "Effect of Lossy Compression Algorithms on Face Image Quality and Recognition", in Proceedings of the International Conference on Acoustics, Speech and Signal Processing (ICASSP), Rhodes Island, GR, June 4-10, (2023)

https://arxiv.org/pdf/2302.12593

Compact Face Image Encoding

Impact of Lossy Image Compression

- Results with JPEG and JPEG AI

Original - RGB

Original - Monochrome

Blurred - outside region of interest

JPEG - 1KB

JPEG AI - 1KB

Conclusion

Summary

- Face image quality assessment is accurately possible with open source algorithms
  - OFIQ provides explainable feedback to the user on why a face image is of insufficient quality
- We need to investigate demographic variability of all biometric algorithms
- Face recognition with 1KB reference samples is a new challenge for research

[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