Challenges for Face Recognition and Sample Quality

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

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e a b
Human Identity in Europe

NTNU

Challenges for Face Recognition

Critical factors for Face Recognition Systems (FRS):
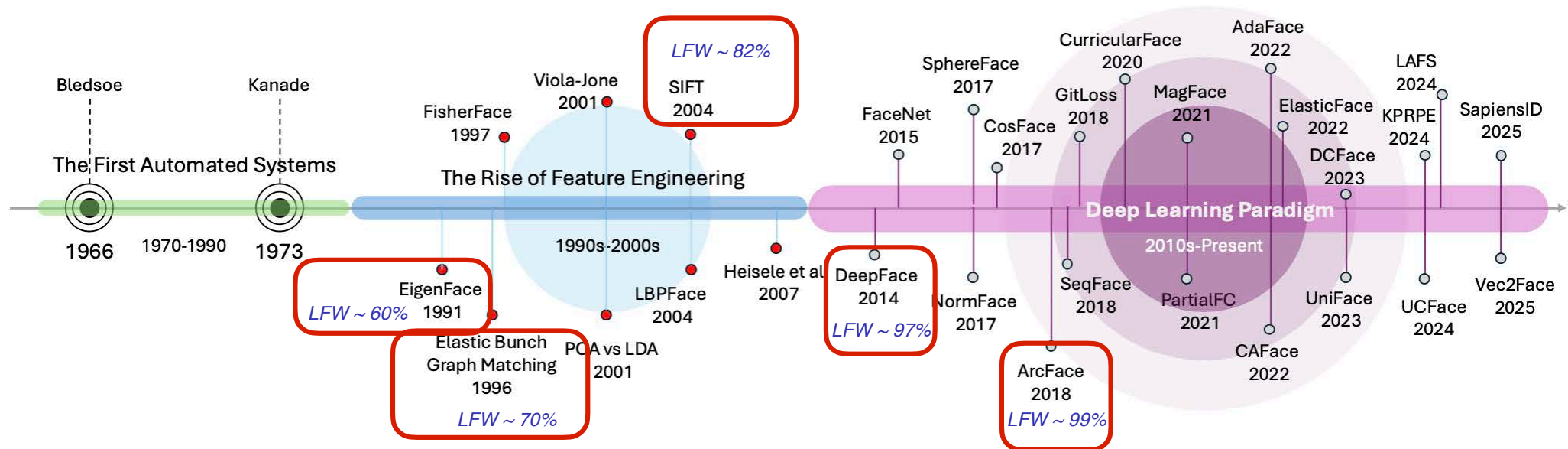
- Pose

- Illumination

- Expression and Ageing

2001   2025

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)

Progress of FR Algorithms Accuracy

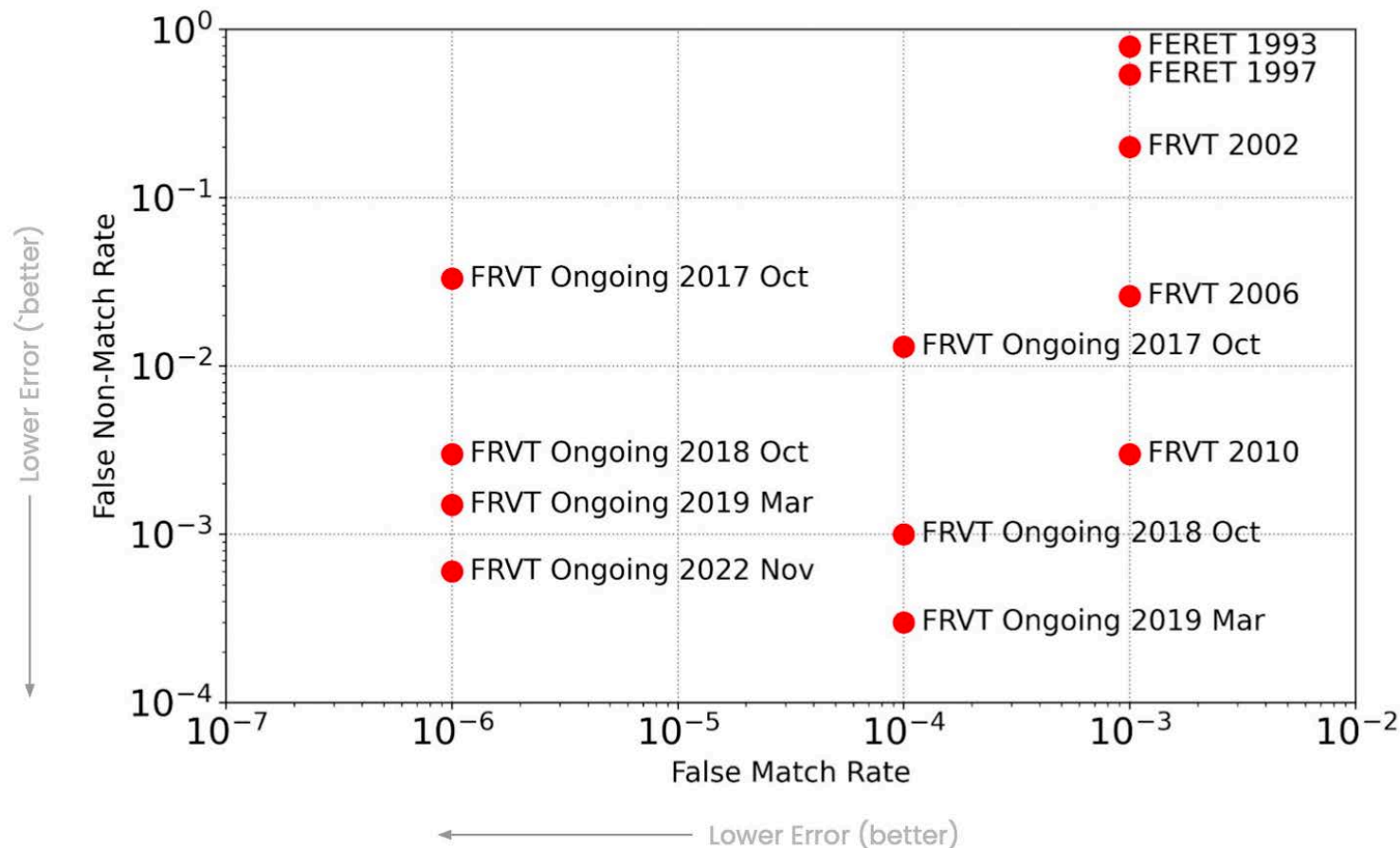## NIST: Face Recognition Technology Evaluations (FRTE)

- Reduction of error rates

Image Source: Brendan Klare (2023)

- NIST FRTE:
https://www.nist.gov/programs-projects/face-technology-evaluations-frtefate
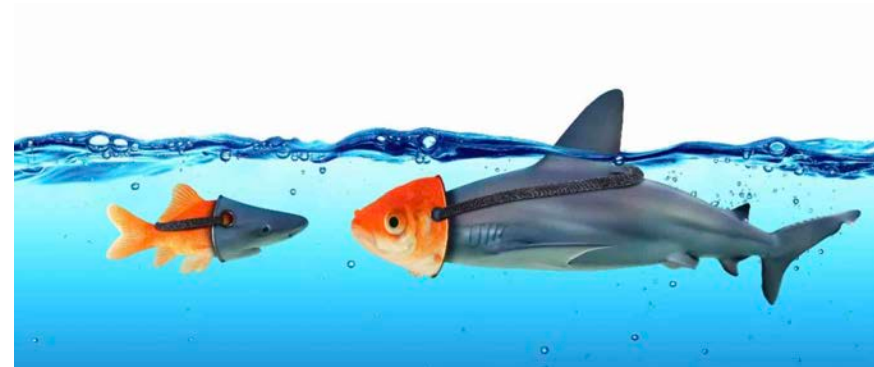
Challenges for Face Recognition

Critical factors for Face Recognition Systems (FRS):

- **P**ose

- **I**llumination

- **E**xpression and Ageing

- Presentation Attacks

2001   2025

Challenges for Face Recognition

Critical factors for Face Recognition Systems (FRS):

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- Face Image Quality

- Morphing Attack Detection
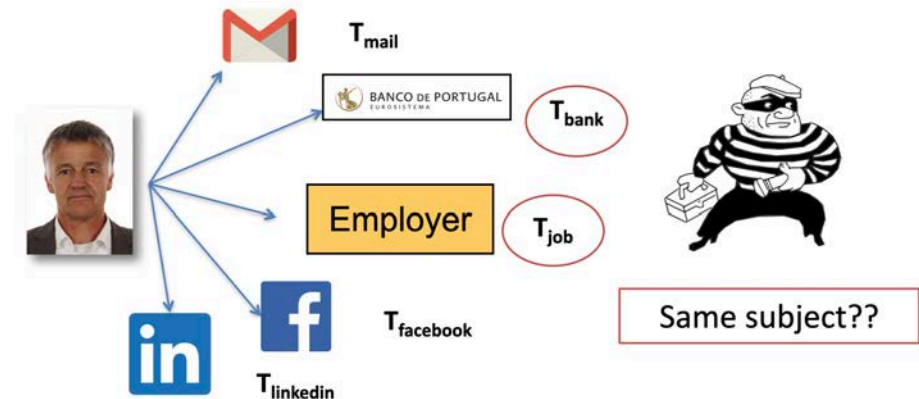

2001   2025

Challenges for Face Recognition

Critical factors for Face Recognition Systems (FRS):

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2001   2025

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- Fairness of Algorithms

2001   2025

Challenges for Face Recognition

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- Pose

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- Fairness of Algorithms

2001   2025

[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

Challenges for Face Recognition

Critical factors for Face Recognition Systems (FRS):

- **P**ose

- **I**llumination

- **E**xpression and Ageing

- Presentation Attacks

- Face Image Quality

- Morphing Attack Detection

- Biometric Template Protection

- Fairness of Algorithms

- Recognition through the windshield

2001   2025

Image Source: https://visagetechnologies.com/face-recognition-in-cars

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

- Recognition through the windshield

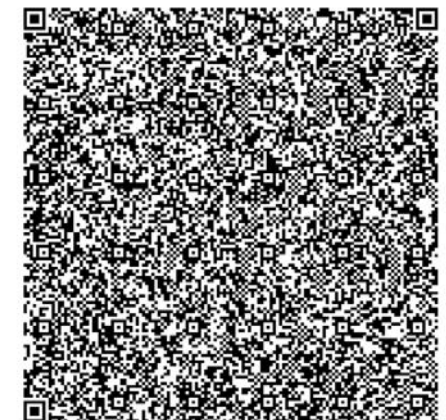- Face recognition with 1KB reference

2001   2025

Image Source: Patrick Grother (2025)

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) will start October 2025

    - Will be 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

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

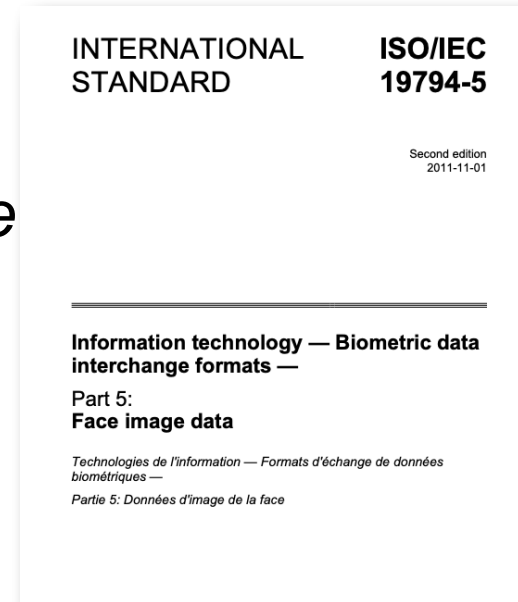Image Source: eu-LISA
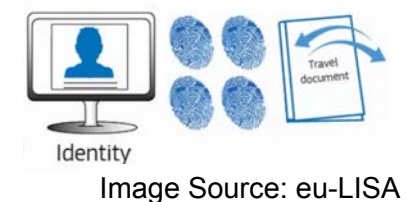
Quality Requirements for Facial Images

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?

Data subjects need actionable feedback

- If quality is poor, then what went wrong?

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

| Compliant image | Pose | Eyes open | Mouth open | Inhomogenous background |

Source: ISO/IEC 39794-5

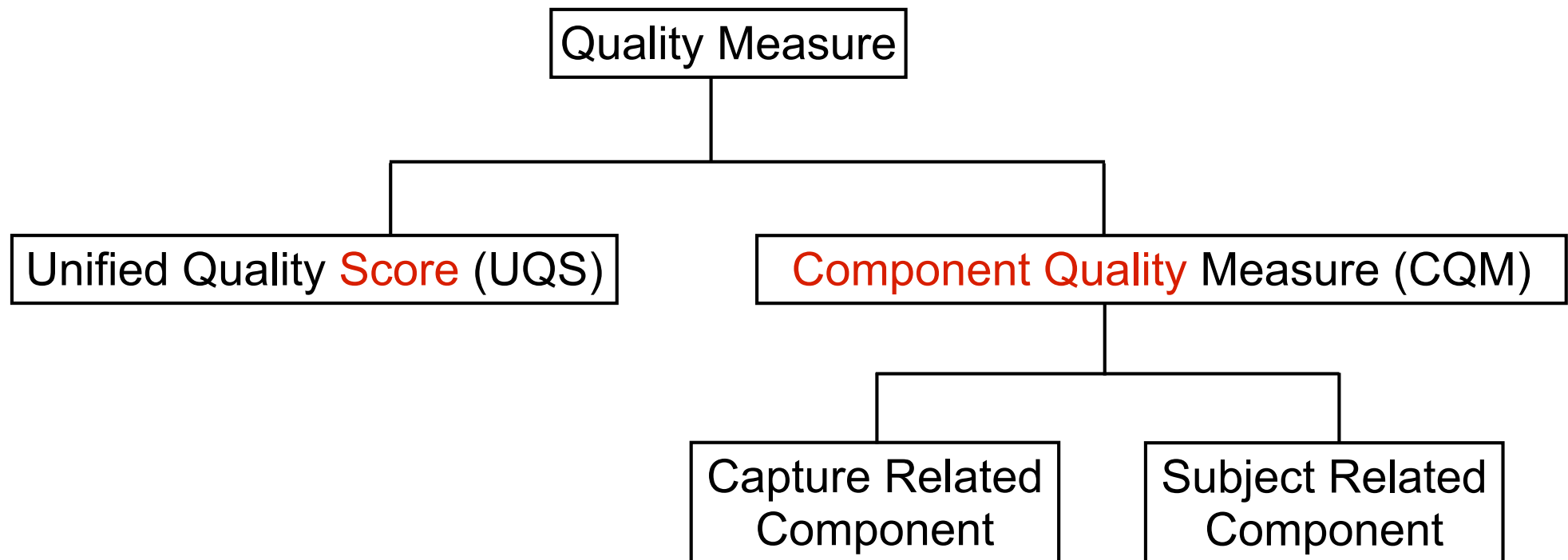# Measures for Facial Images

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

```
                    ┌─────────────────┐
                    │ Quality Measure │
                    └─────────────────┘
                             │
         ┌───────────────────┴──────────────────────┐
┌────────────────────────────┐   ┌──────────────────────────────────┐
│ Unified Quality Score (UQS) │   │ Component Quality Measure (CQM)  │
└────────────────────────────┘   └──────────────────────────────────┘
                                             │
                                  ┌──────────┴──────────┐
                          ┌─────────────────┐   ┌─────────────────┐
                          │ Capture Related │   │ Subject Related │
                          │   Component     │   │   Component     │
                          └─────────────────┘   └─────────────────┘
```

- 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

Unified Quality Score

Capture device related

Image Source: ISO/IEC 39794-5

Explainable Quality Assessment

Subject related

Image Source: ISO/IEC 39794-5

Image Source: ISO/IEC 29794-5

Open Source Face Image Quality (OFIQ)

Approach

- Library with quality assessment algorithms

- Open source https://github.com/BSI-OFIQ/OFIQ-Project

  ▸ Commercial use is enabled and foreseen

- Support for major OS platforms (including mobile OS)

  ▸ C/C++

- Serves as reference implementation of ISO/IEC 29794-5

  ▸ Providing target values for conformance tests

- Selection criteria for integrated algorithms

  ▸ Accuracy (NIST FATE SIDD evaluation)
    https://pages.nist.gov/frvt/reports/quality_sidd/frvt_quality_sidd_report.pdf

  ▸ Low computational complexity

  ▸ Liberal license (MIT or alike)

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
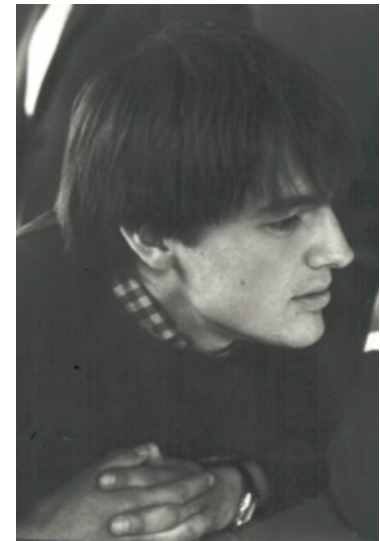
Prediction of low face recognition scores

- 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?
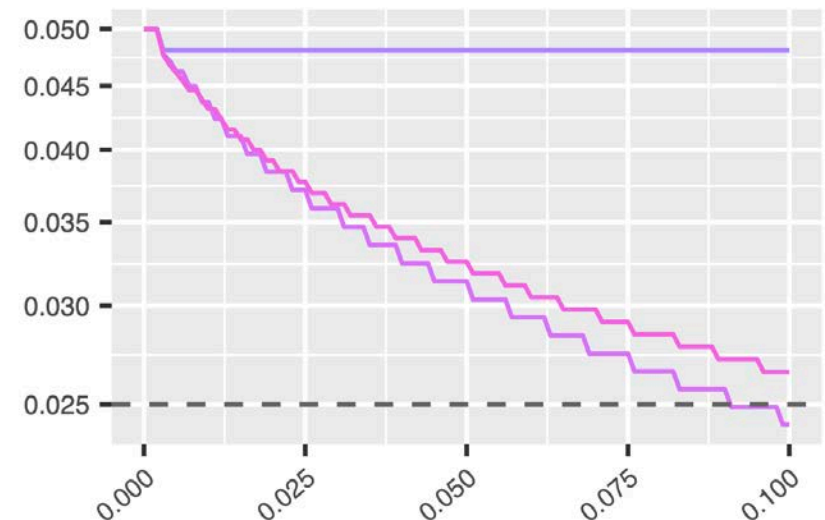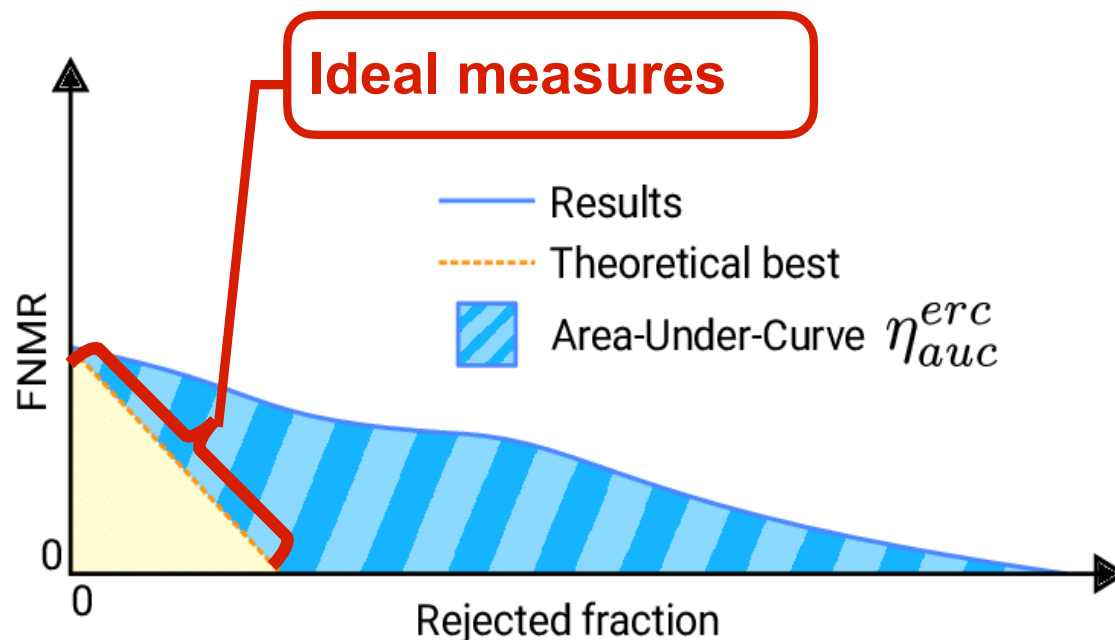
Image Source:NIST FATE SIDD report

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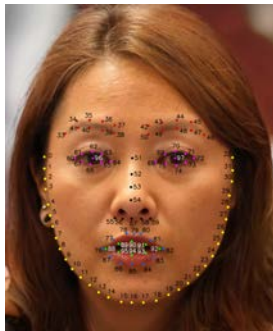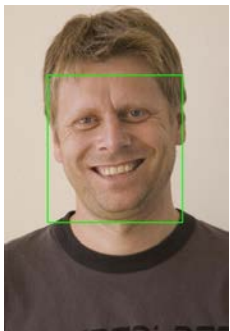
Image Source: OFIQ public report and ISO/IEC FDIS 29794-5

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

- Normalized by distance T between eye's midpoint and chin
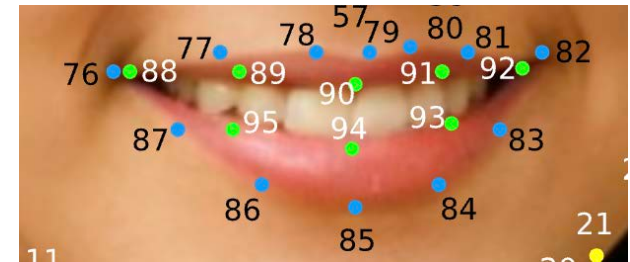
Image Source:ISO/IEC FDIS 29794-5
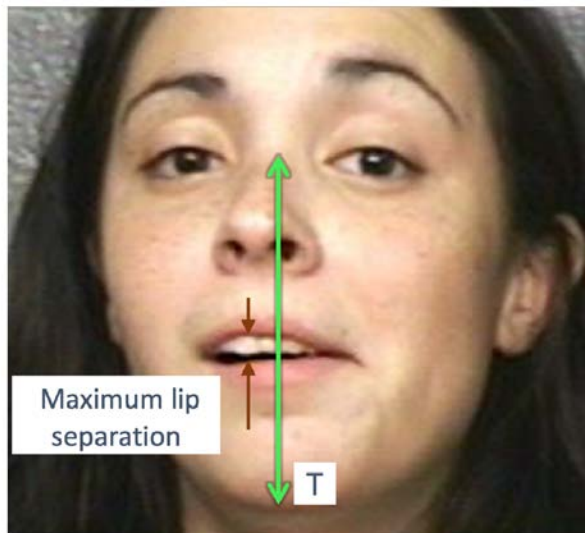
Image Source:NIST FATE SIDD report

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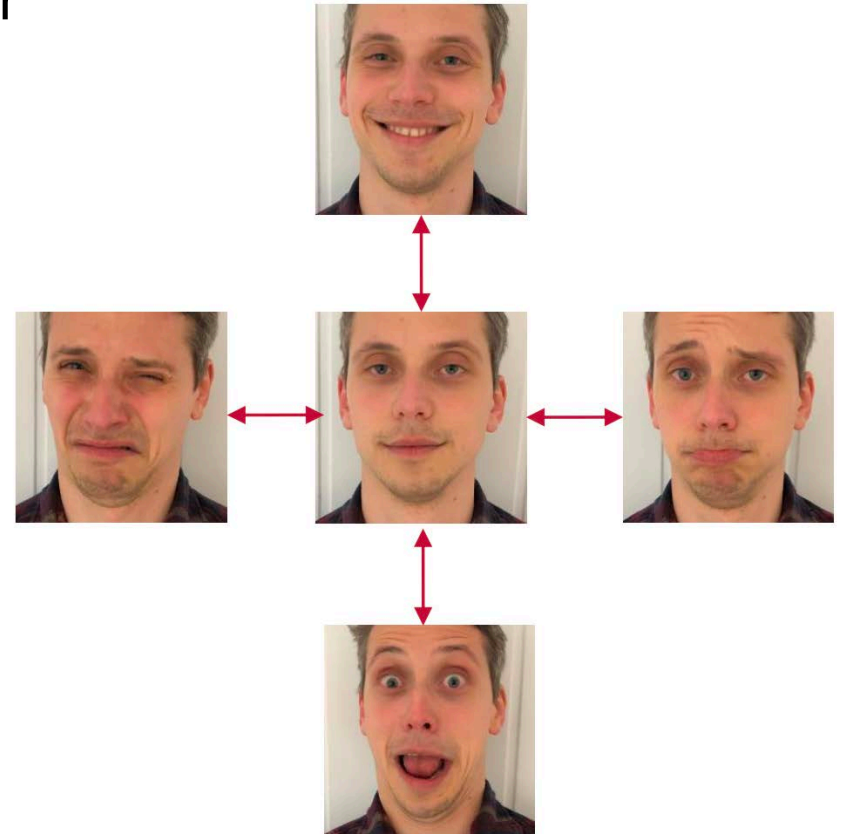
[GRVB2023] M. Grimmer, C. Rathgeb, R. Veldhuis, C. Busch: "NeutrEx: A 3D Quality Component Measure on Facial Expression Neutrality", in Proceedings of International Joint Conference on Biometrics (IJCB), (2023)

[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
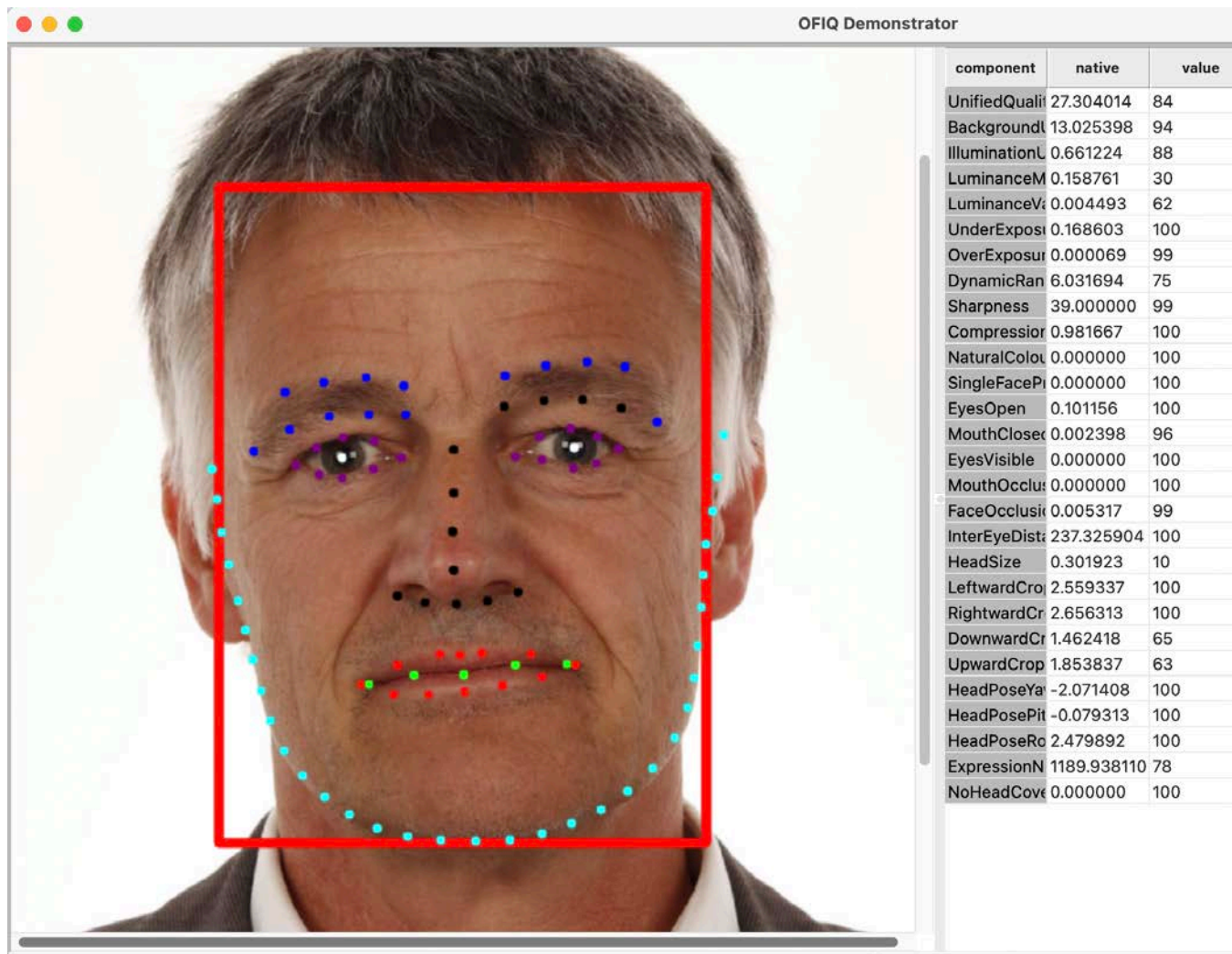
Face Image Quality - Future work

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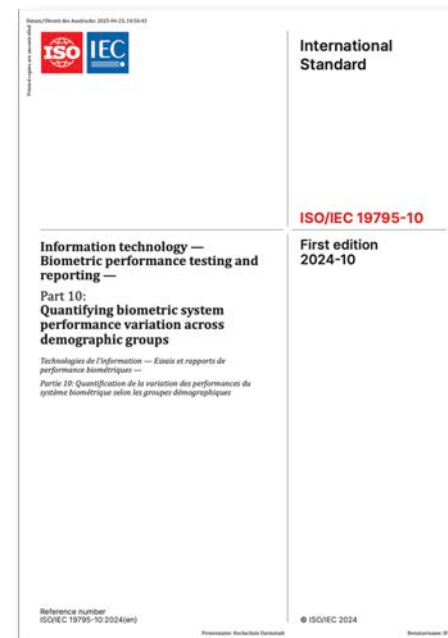
[Drozd2020] P. Drozdowski, C. Ratgeb, A. Dantcheva, N. Damer, C. Busch: "Demographic Bias in Biometrics: A Survey on an Emerging Challenge", in IEEE Transactions on Technology and Society (TTS), (2020)
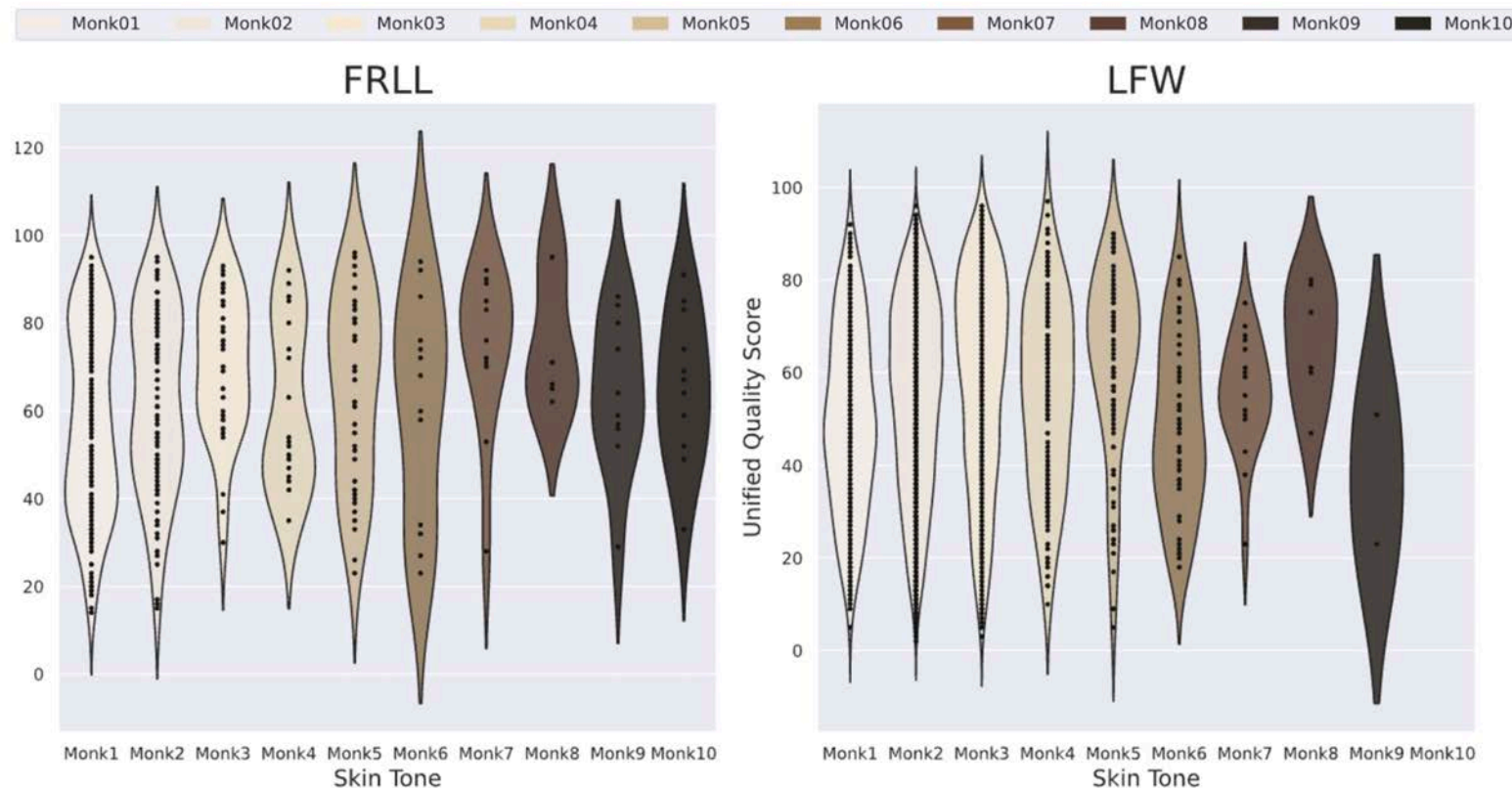
Face Image Quality - Demographics

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)
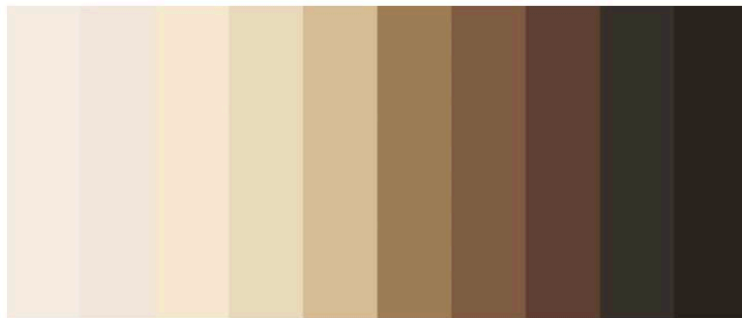
Open research tasks

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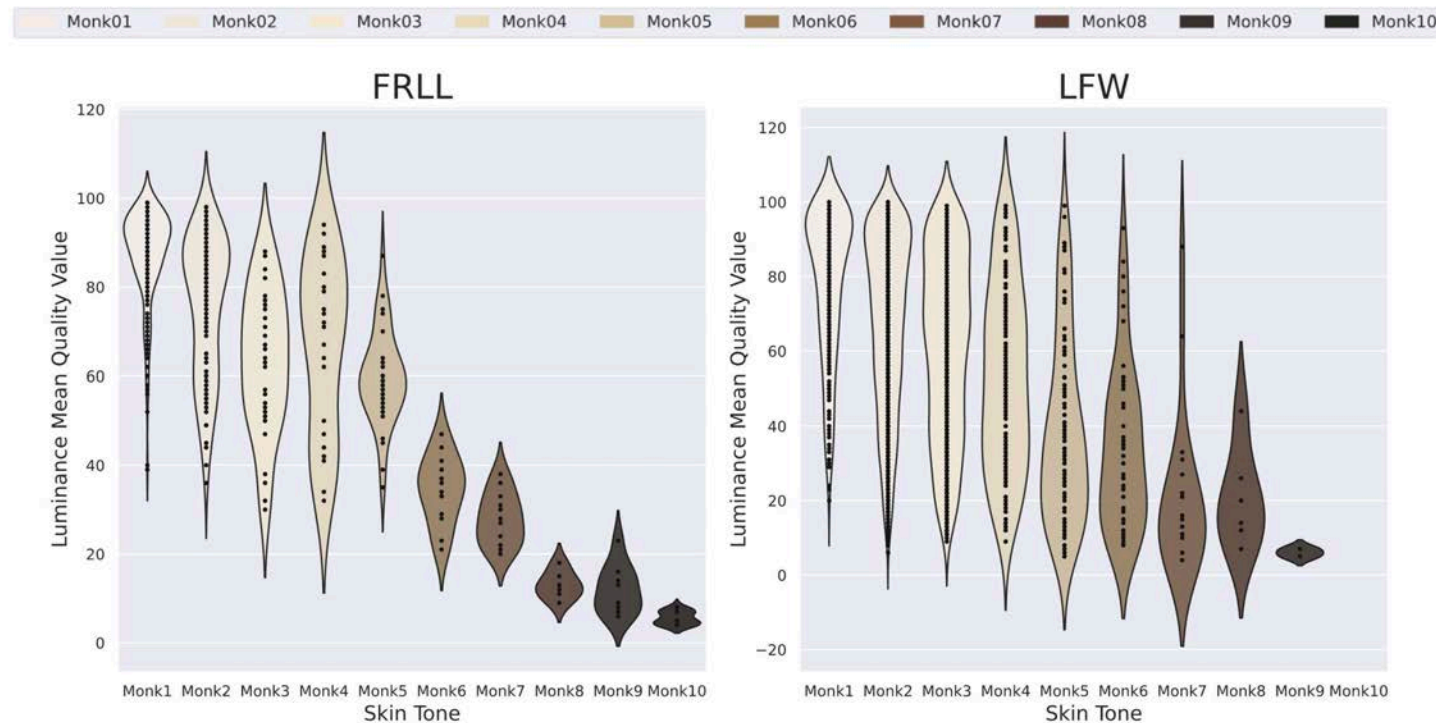 - ▸ Distribution of unified quality score (UQS)

[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
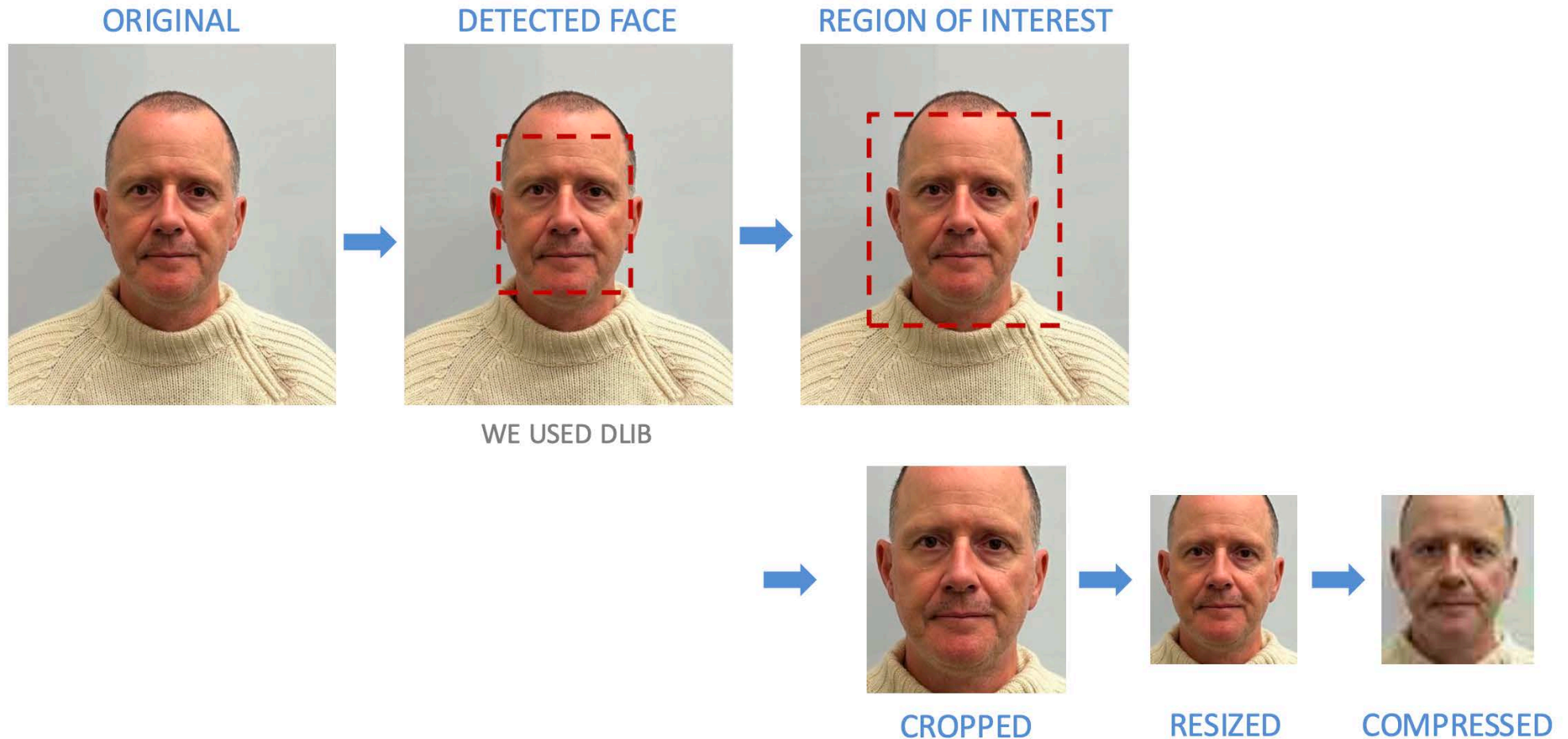

Image Source: Patrick Grother (2025)

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
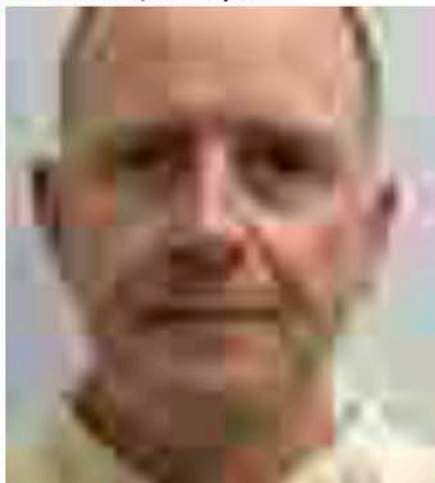

TARGET FILE SIZE: 960 BYTES

ORIG: 1205x1326
509697 bytes

JPG: 64x70, 954 bytes

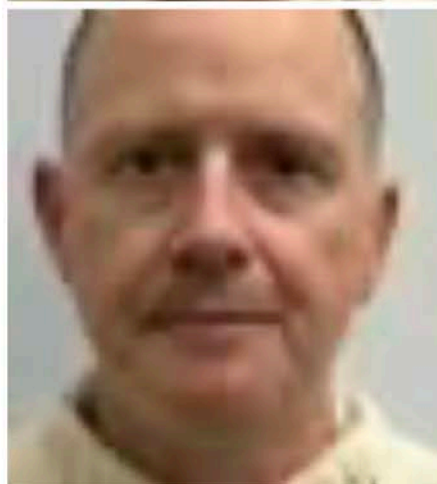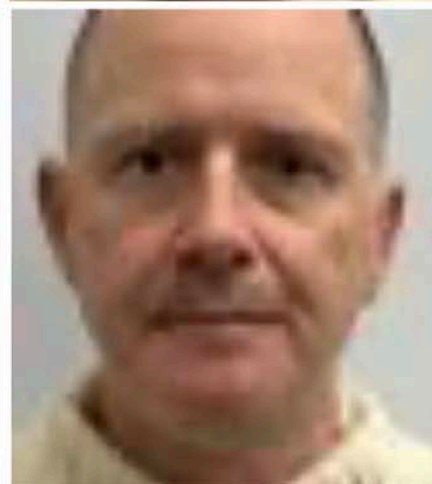JPG-LI: 64x70, 955 bytes

HEIC: 64x70, 908 bytes

WEBP: 64x70, 938 bytes

AVIF: 64x70, 919 bytes

Factors:
- Effect on FR accuracy
- Effect on human reviewer perception

- Decoder availability
- IP / License / Cost
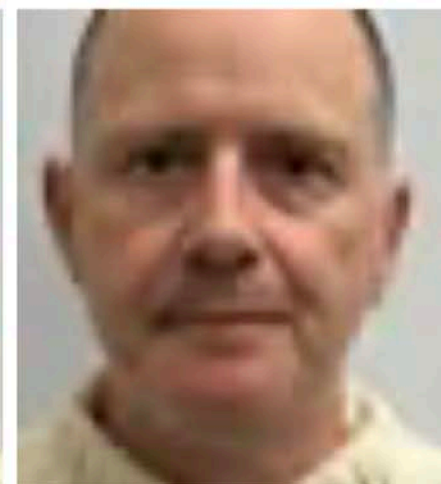
Image Source: Patrick Grother (2025)

Compact Face Image Encoding

Get involved in the standardisation

ISO/IEC JTC 1/SC 37 **N 7848**

ISO/IEC JTC 1/SC 37 "Biometrics"
Secretariat: **ANSI**
Committee manager: **Miller Michaela Ms**

Ballot text for NP 59794-5, Information technology – Compact biometric samples for 2D barcodes – Part 5: Face image data

Document type	Related content	Document date	Expected action
Ballot / Form	Ballot: ISO/IEC PWI 59794-5 (restricted access)	2025-08-11	**VOTE** by 2025-11-04

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

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

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