

Challenges for Face Image Quality Assessment

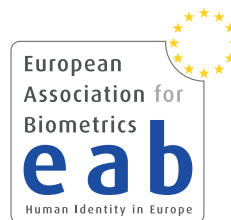
Future Directions in Biometrics
2025-11-10

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



Challenges for Face Recognition

Critical factors for Face Recognition Systems (FRS):

- Pose
- Illumination
- Expression and Ageing



2001

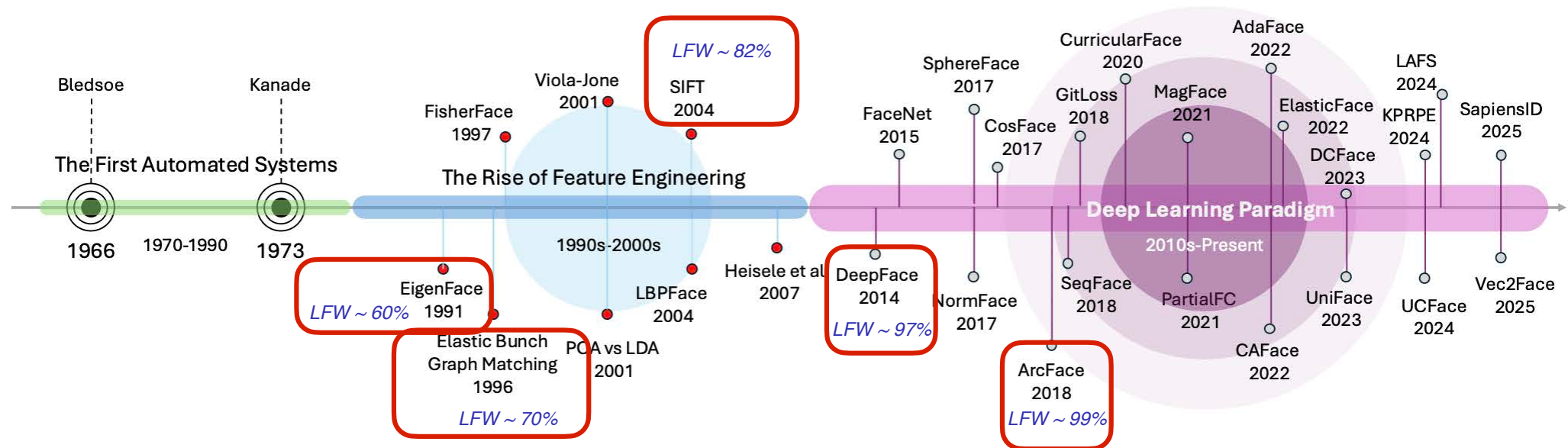
2025

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

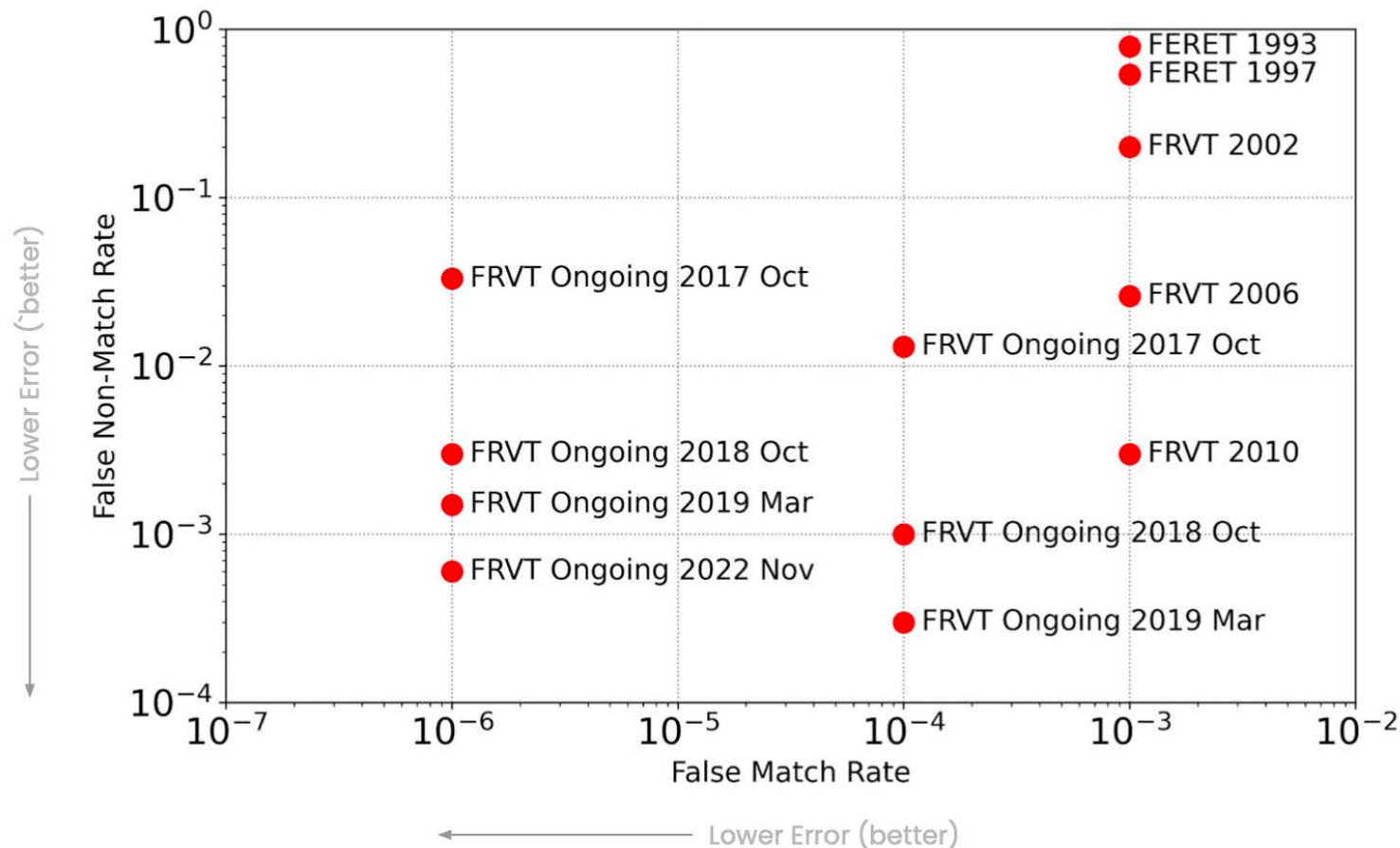


Image Source: Brendan Klare (2023)

- **NIST FRTE:**

<https://www.nist.gov/programs-projects/face-technology-evaluations-frtefate>

Challenges for Face Recognition

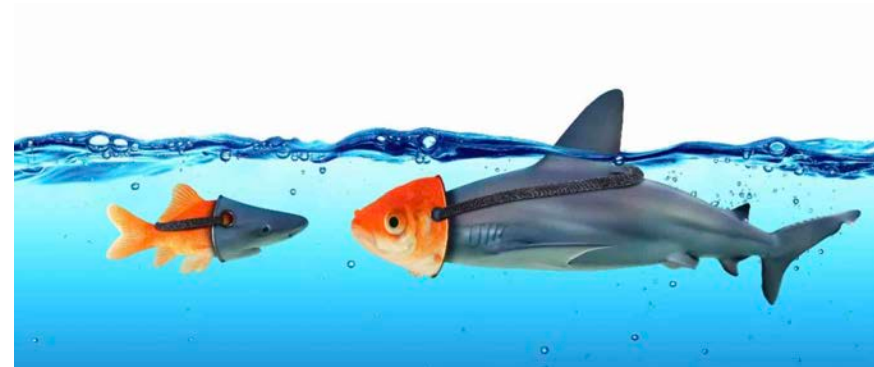
Critical factors for Face Recognition Systems (FRS):

- Pose
- Illumination
- Expression and Ageing
- Presentation Attacks



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Challenges for Face Recognition

Critical factors for Face Recognition Systems (FRS):

- Pose
- Illumination
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- Presentation Attacks
- Face Image Quality



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Challenges for Face Recognition

Critical factors for Face Recognition Systems (FRS):

- Pose
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- Face Image Quality
- Morphing Attack Detection



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Challenges for Face Recognition

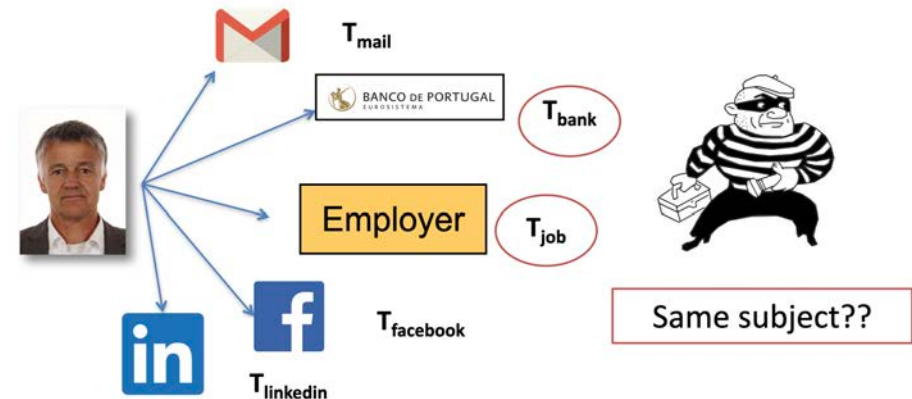
Critical factors for Face Recognition Systems (FRS):

- Pose
- Illumination
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- Face Image Quality
- Morphing Attack Detection
- Biometric Template Protection



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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



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Challenges for Face Recognition

Critical factors for Face Recognition Systems (FRS):

- Pose
- Illumination
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- Face Image Quality
- Morphing Attack Detection
- Biometric Template Protection
- Fairness of Algorithms



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[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):

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



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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



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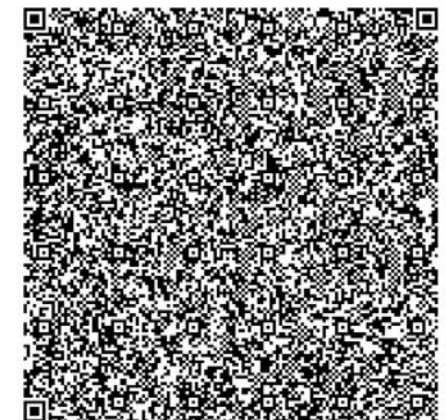


Image Source: Patrick Grother (2025)

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/exits** 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**.



Quality Requirements for Facial Images

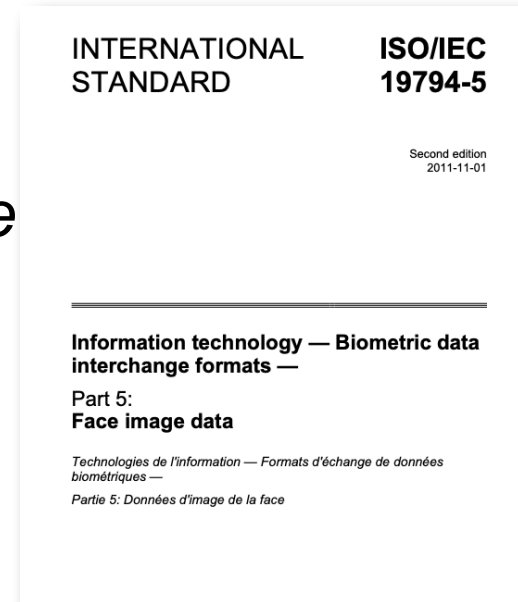
The requirement in EES implementing decision 2019/329

- „*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?



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

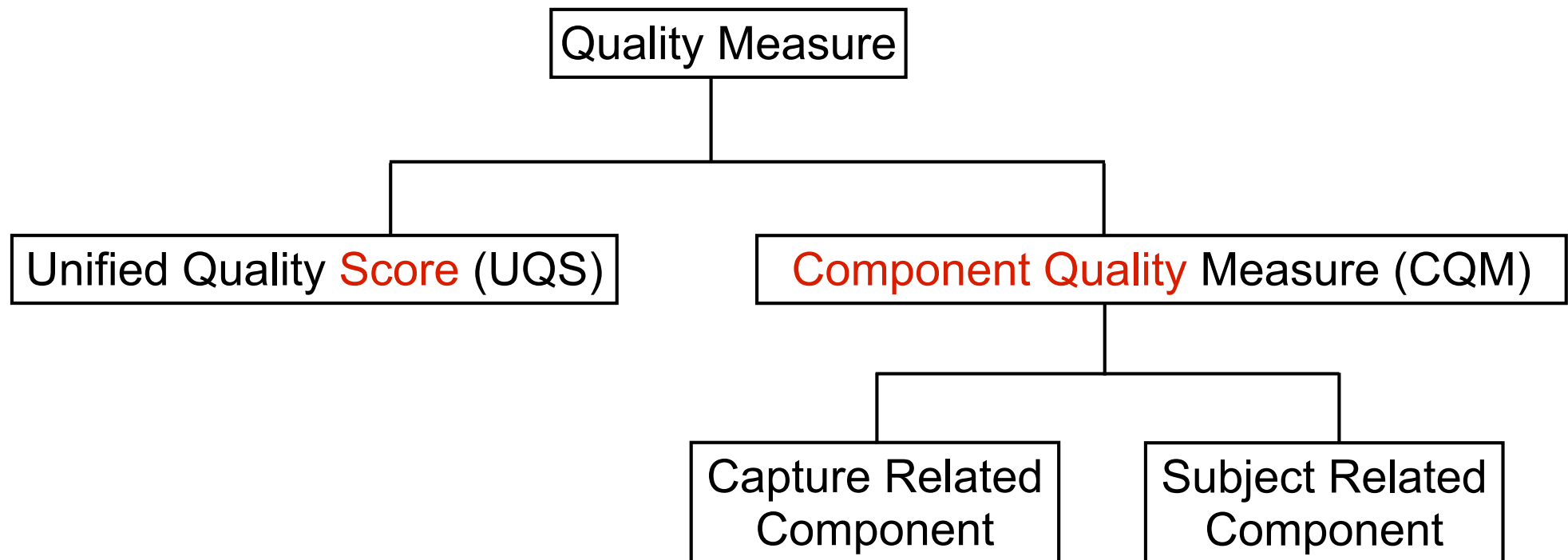
- **Standardisation**
- International Organization for Standardization, ISO/IEC 29794-5, Information technology - Biometric sample quality - Part 5: Face image data,
<https://www.iso.org/standard/81005.html>
 - ▶ Providing measures for requirements from ISO/IEC 19794-5:2011 and ISO/IEC 39794-5:2019
 - 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 <u>mean</u>
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

Explainable Quality Assessment

Subject related



Image Source: ISO/IEC 39794-5



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



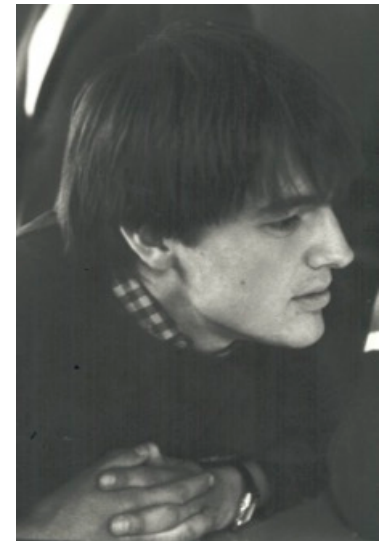
OFIQ-UQS=84



OFIQ-UQS=61



OFIQ-UQS=26



OFIQ-UQS=7

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?

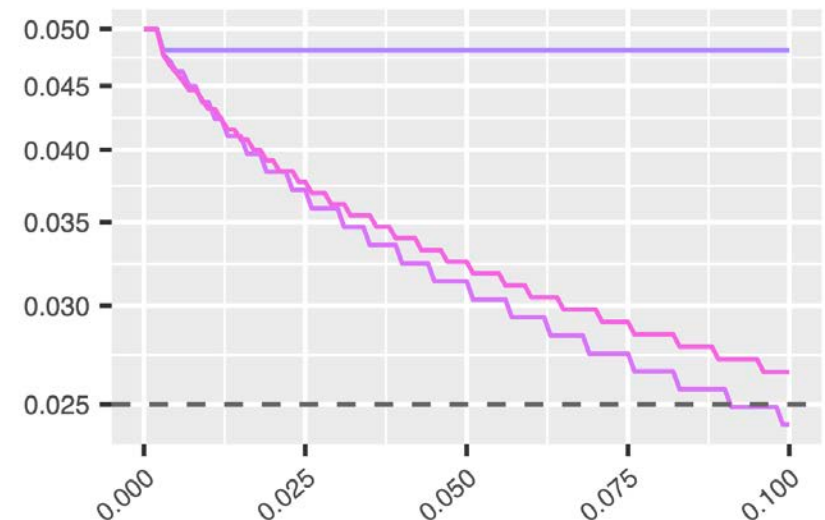
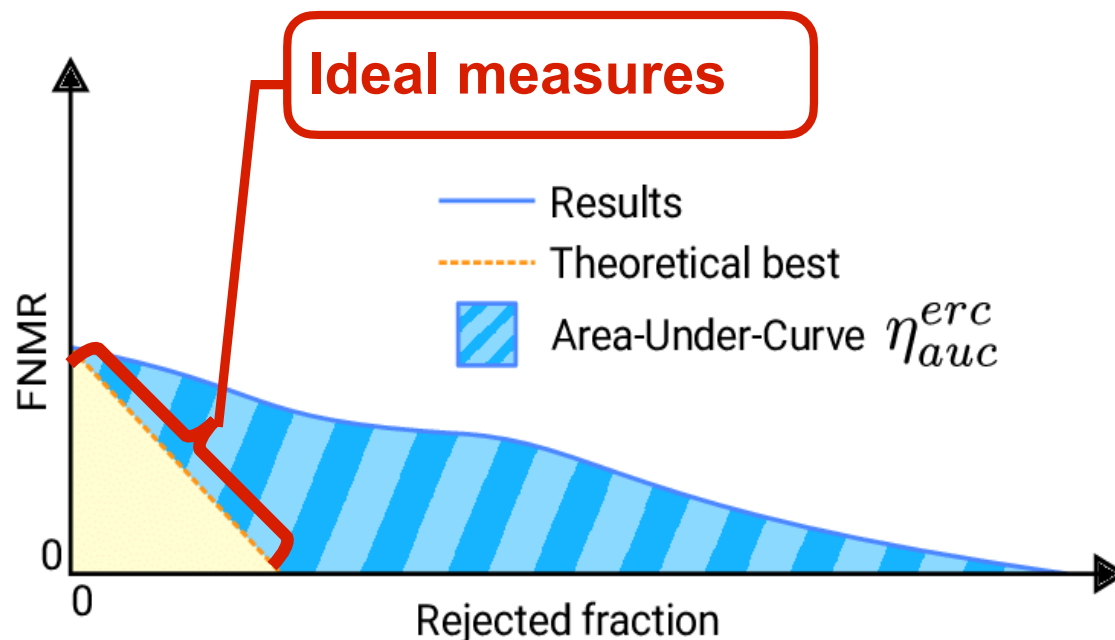


Image Source: NIST FATE SIDD report

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)

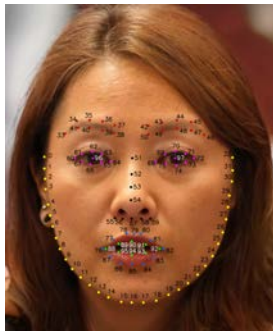
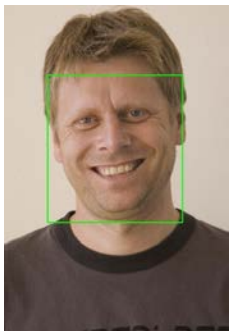


Image Source: OFIQ public report and ISO/IEC FDIS 29794-5

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

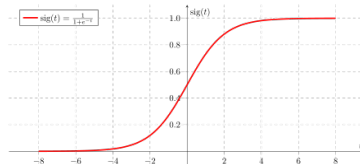
Example algorithm: Mouth Closed

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

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

- Normalized by distance T between eye's midpoint and chin
- Mouth opens aspect

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



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

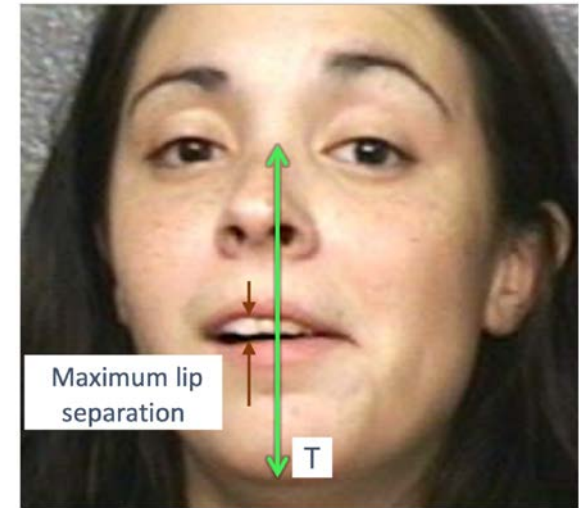


Image Source: NIST FATE SIDD report

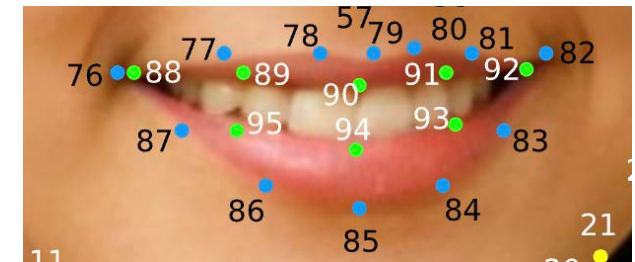
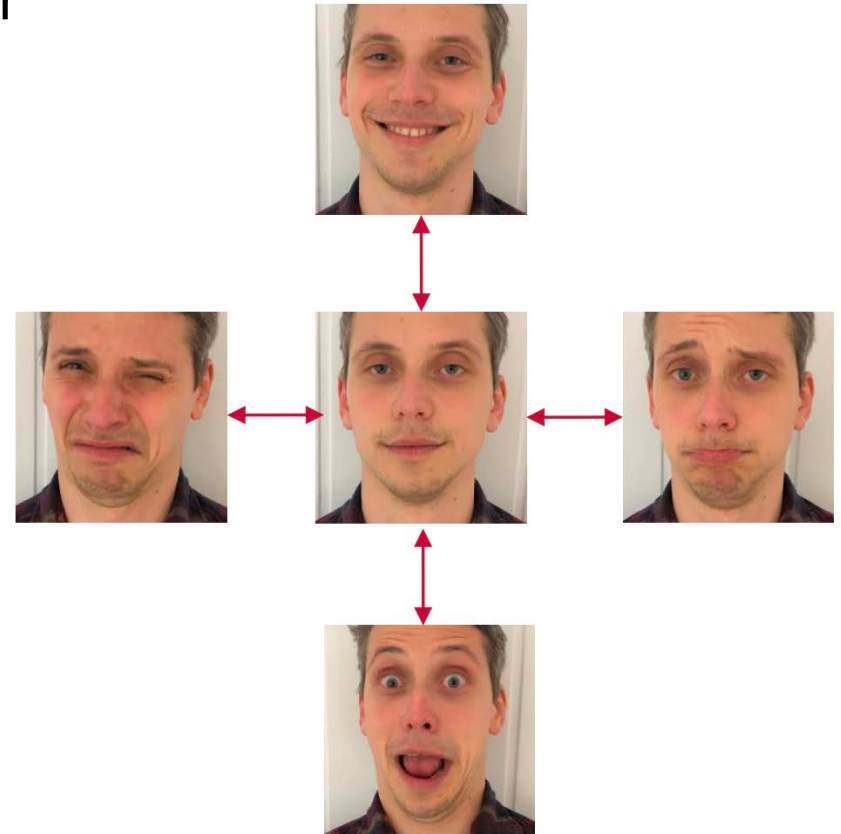


Image Source: ISO/IEC 29794-5

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



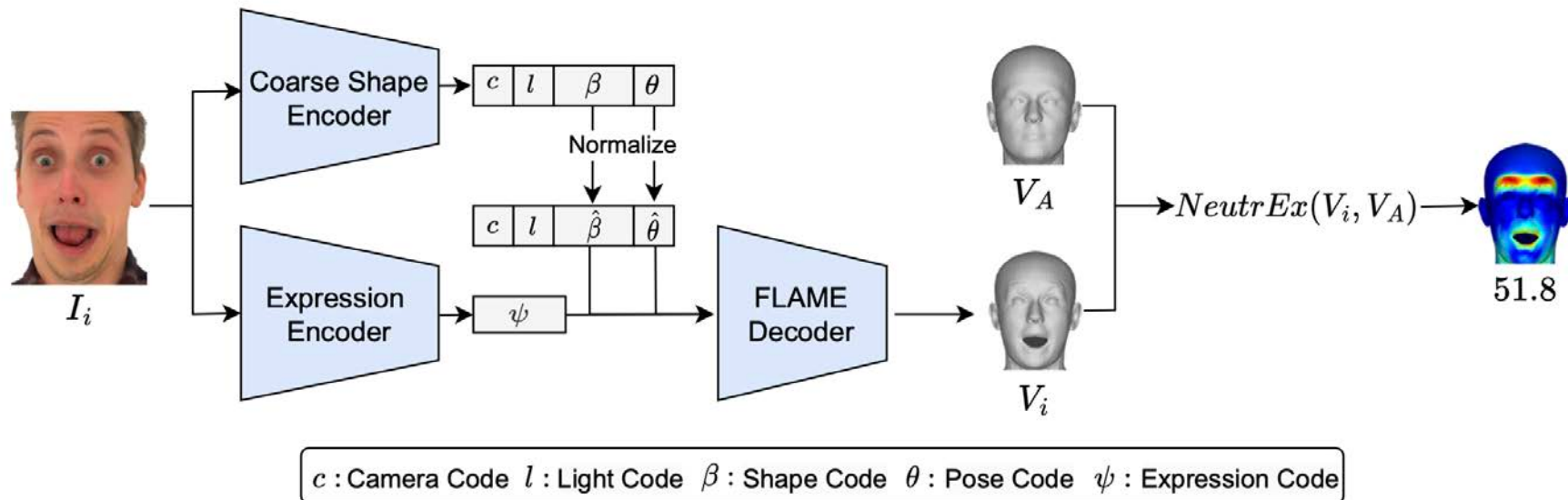
[GRVB2023] M. Grimmer, C. Rathgeb, R. Veldhuis, C. Busch: "NeutrEx: A 3D Quality Component Measure on Facial Expression Neutrality", in Proceedings of International Joint Conference on Biometrics (IJCB), (2023)

[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 - Quality Components

Example algorithm: **Expression** Neutrality

- 3D Monocular Face Reconstruction
 - ▶ Invert 2D face image into FLAME parameter space
 - ▶ Inversion achieved through Resnet50 encoders
 - Coarse Shape Encoder (DECA) and Expression Encoder (EMOCA)

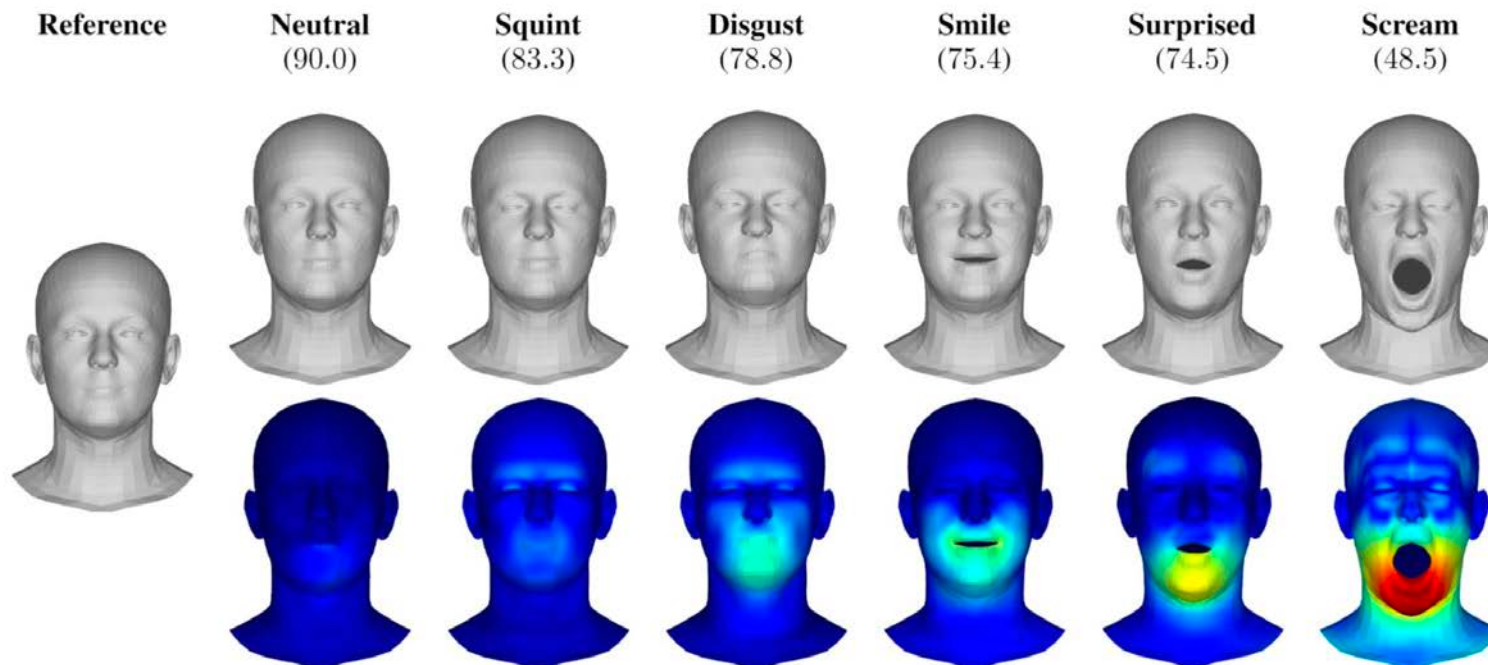


[GRVB2023] M. Grimmer, C. Rathgeb, R. Veldhuis, C. Busch: "NeutrEx: A 3D Quality Component Measure on Facial Expression Neutrality", in Proceedings of International Joint Conference on Biometrics (IJCB), (2023)

OFIQ - Quality Components

Example algorithm: Expression Neutrality

- Cumulative 2-Norm Distances: $D(V_i, V_A) = ||V_i - V_A||_2$
- NeutrEx Measure: $\text{NeutrEx}(V_i, V_A) = 100 \cdot \left(1 - \frac{D(V_i, V_A) - D_{\min}}{D_{\max} - D_{\min}}\right)$
- Quality measure between [0, 100]
- Explainability

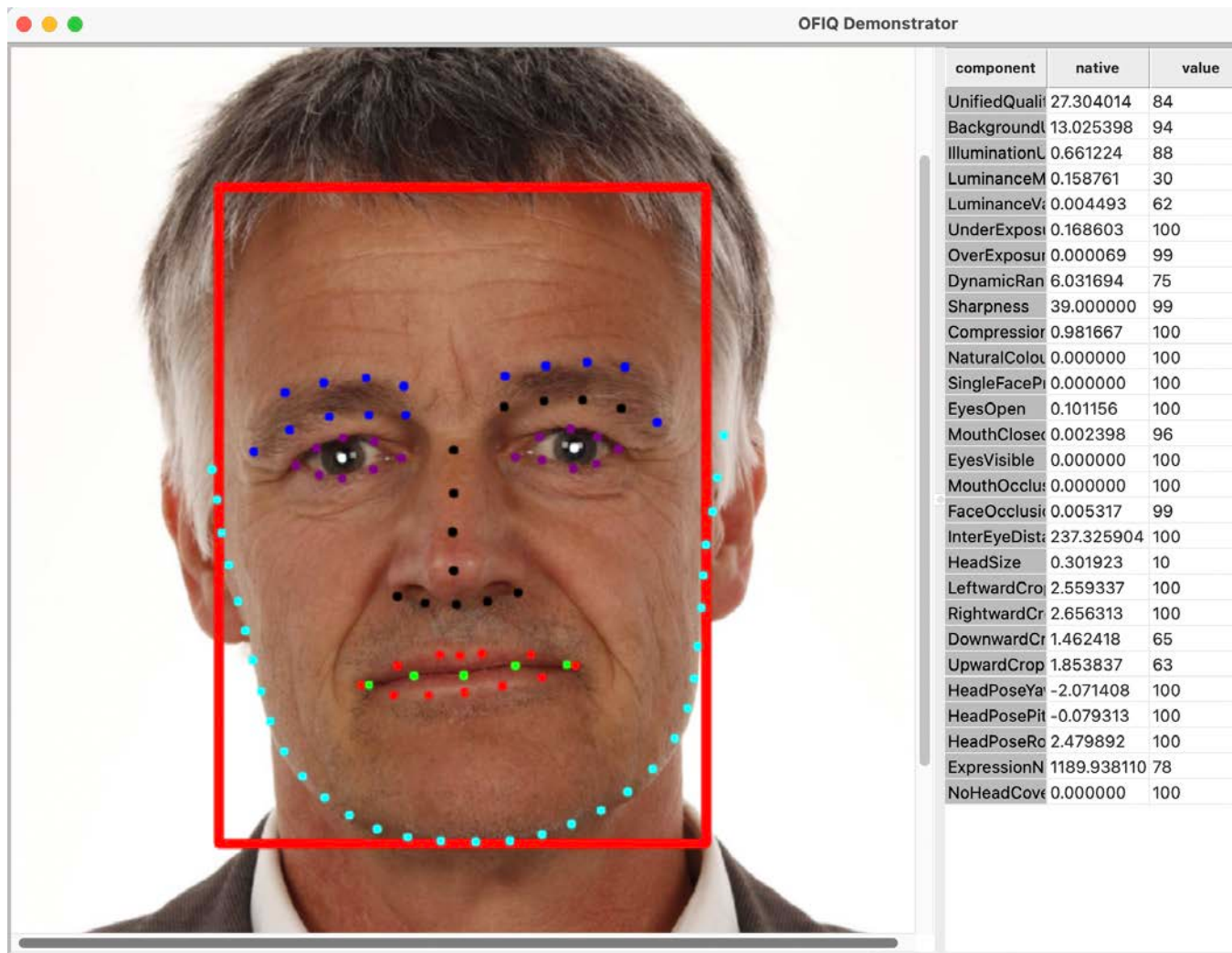


[GRVB2023] M. Grimmer, C. Rathgeb, R. Veldhuis, C. Busch: "NeutrEx: A 3D Quality Component Measure on Facial Expression Neutrality", in Proceedings of International Joint Conference on Biometrics (IJCB), (2023)

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.

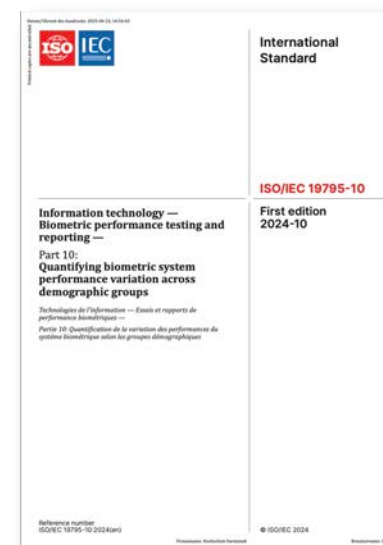
Demographic Effects

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>

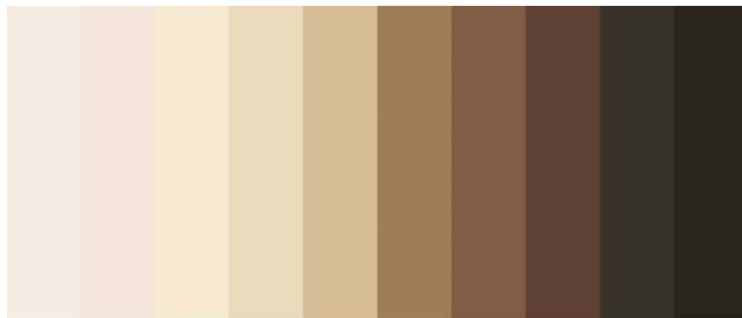


[Drozd2020] P. Drozdowski, C. Ratgeb, A. Dantcheva, N. Damer, C. Busch: "Demographic Bias in Biometrics: A Survey on an Emerging Challenge", in IEEE Transactions on Technology and Society (TTS), (2020)

Face Image Quality - Demographics

Open research tasks

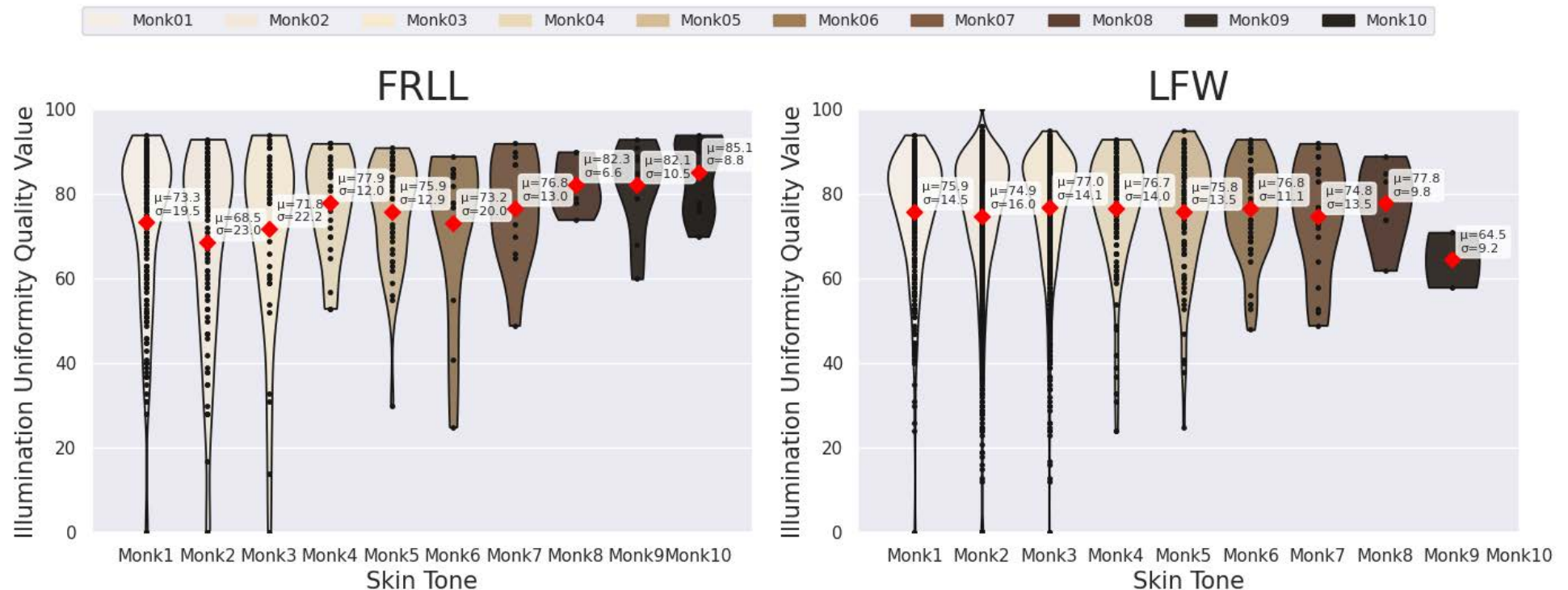
- Investigate **demographic variability** (DV)
- Example: skin tone variation
Continuous demographic **variable**
- Collect data and organize in discrete categories
 - ▶ Monk skin tone scale (MST) vs.
 - ▶ Colorimetric skin tone (CST) vs.
 - ▶ PANTONE Skin Tone (PST)



Face Image Quality - Demographics

Open research tasks

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

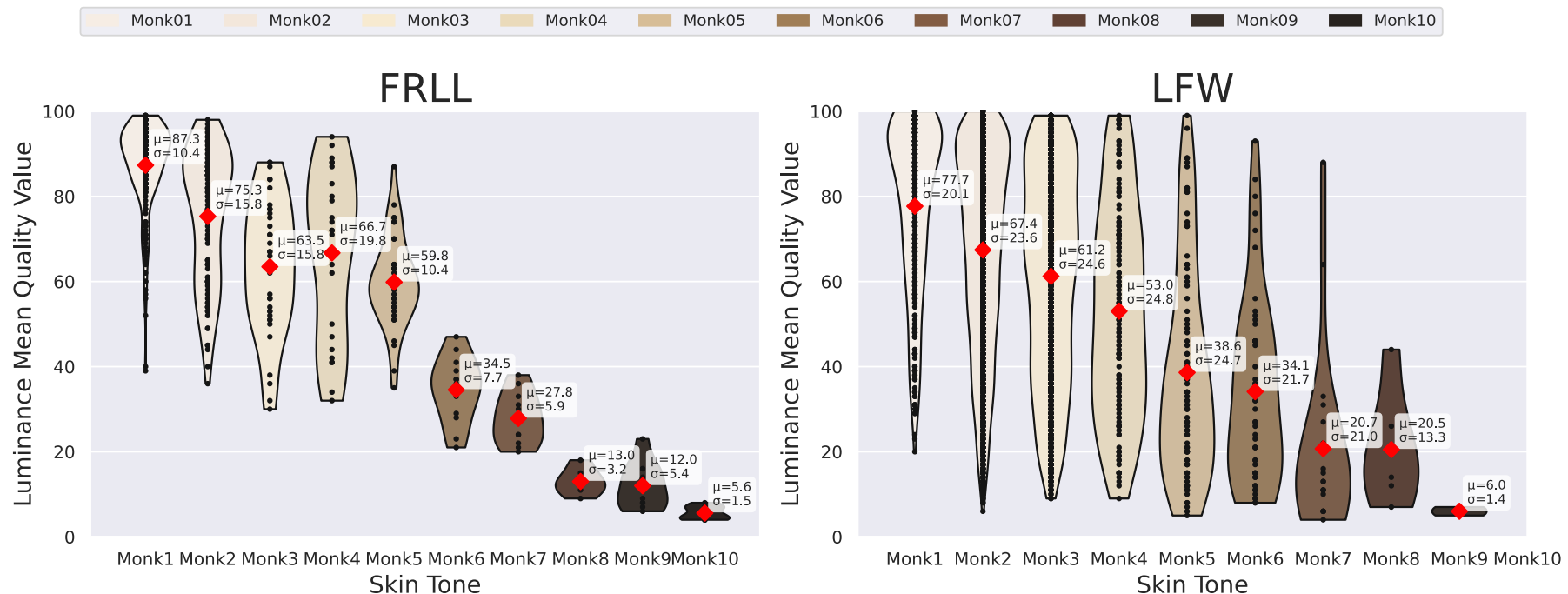


[KRRB2024] W. Kabbani, K. Raja, R. Raghavendra, C. Busch: "Demographic Differentials in Face Image Quality Measures", in Proceedings of the IEEE 23rd International Conference of the Biometrics Special Interest Group (BIOSIG), Darmstadt, September 25-27, (2024)

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
Givenname Christoph
Nationality: German
DoB: yyyyymmdd
PoB: Frankfurt
DoE: yyyyymmdd



Compact Face Image Encoding

Preprocessing

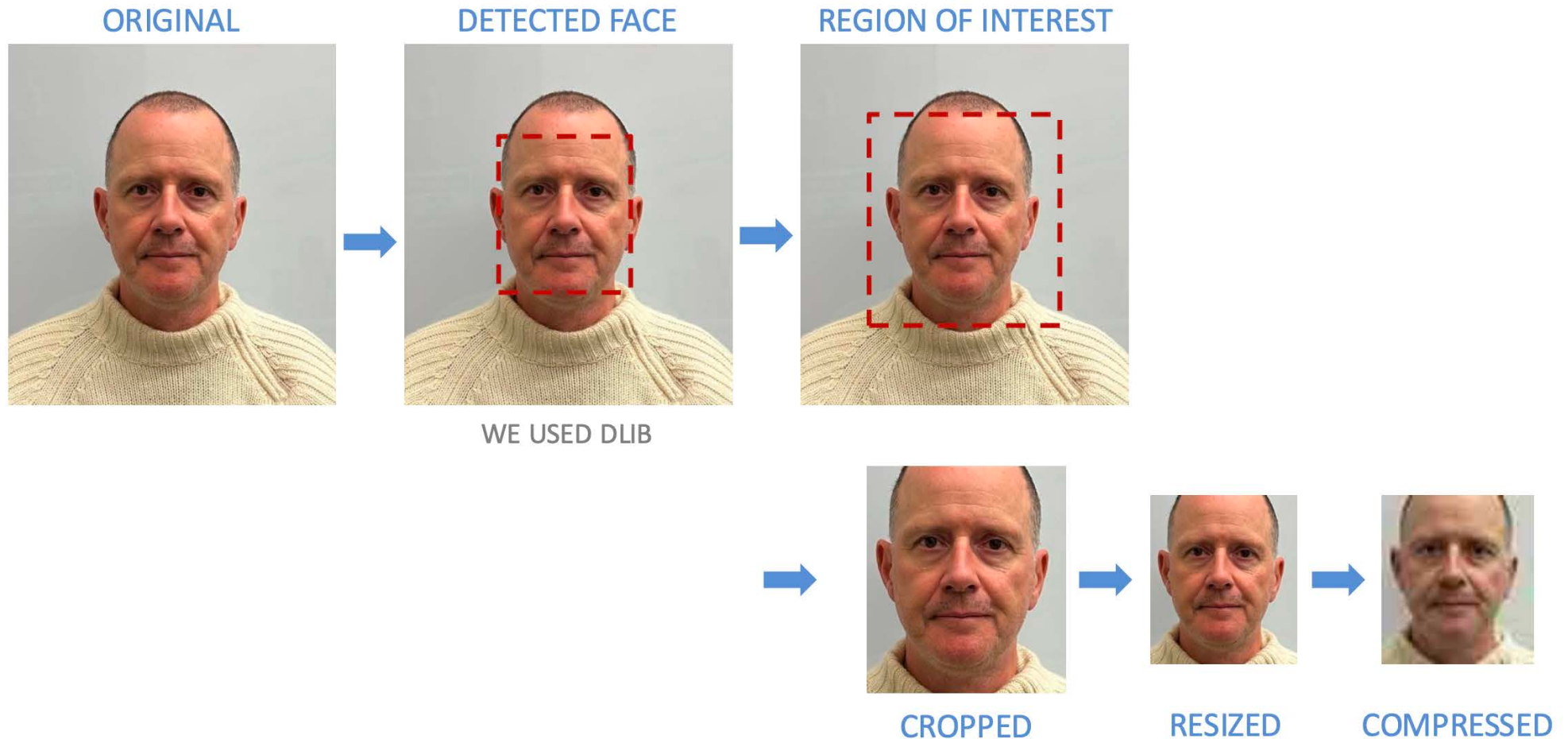


Image Source: Patrick Grother (2025)

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



Factors:

- Effect on FR accuracy
- Effect on human reviewer perception
- Decoder availability
- IP / License / Cost



HEIC: 64x70, 908 bytes



WEBP: 64x70, 938 bytes



AVIF: 64x70, 919 bytes

5

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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for Applied Cybersecurity

**h_da**
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