

Der Weg zur Robusten Gesichtserkennung

2025-11-27

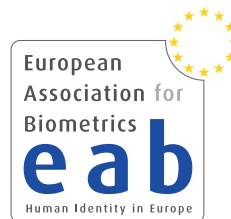
Christoph Busch

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



Challenges for Face Recognition

Critical factors for Face Recognition Systems (FRS):

- Pose
- Illumination
- Expression and Ageing



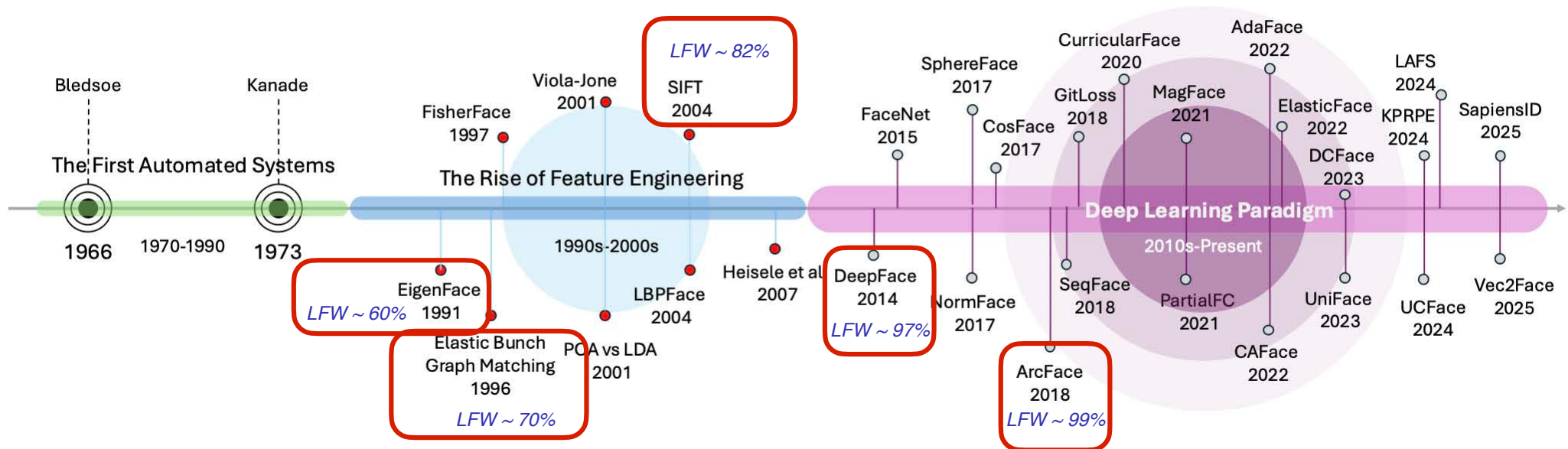
2001

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)

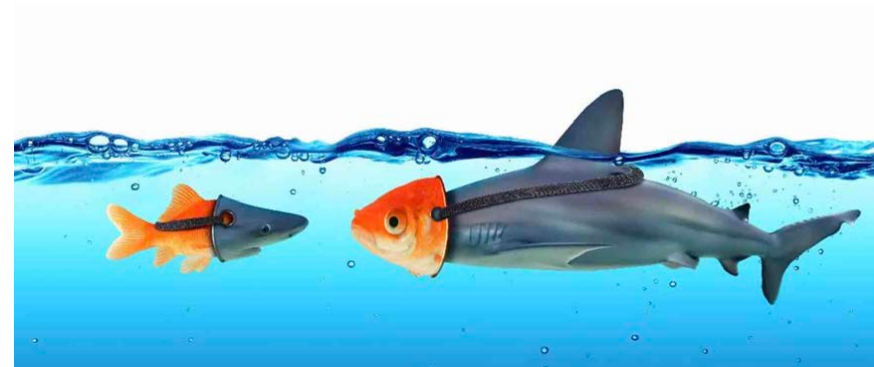
Challenges for Face Recognition

Critical factors for Face Recognition Systems (FRS):

- Pose
- Illumination
- Expression and Ageing
- Presentation Attacks



2001



Challenges for Face Recognition

Critical factors for Face Recognition Systems (FRS):

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- Face Image Quality



2001



Challenges for Face Recognition

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- Face Image Quality
- Morphing Attack Detection



2001



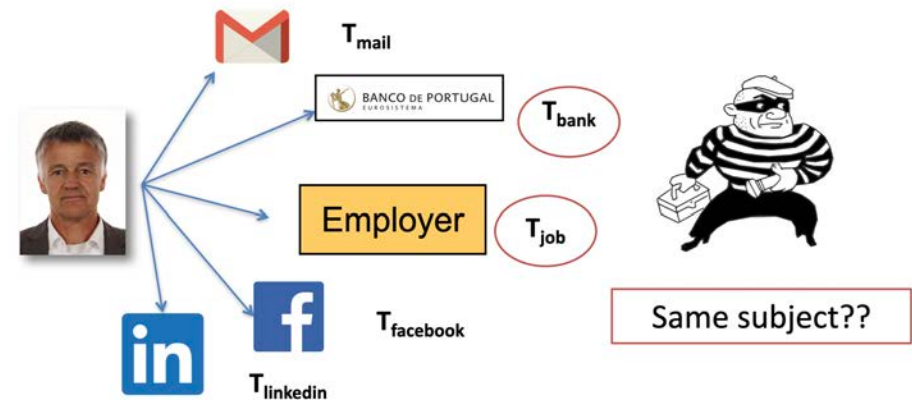
Challenges for Face Recognition

Critical factors for Face Recognition Systems (FRS):

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



2001



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



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

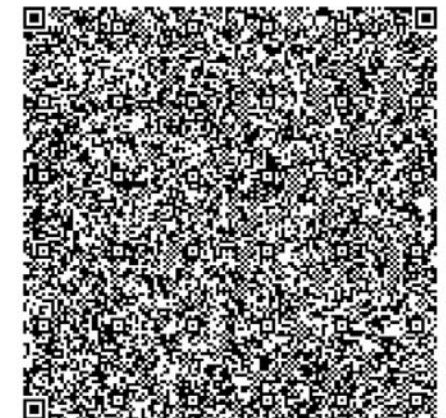
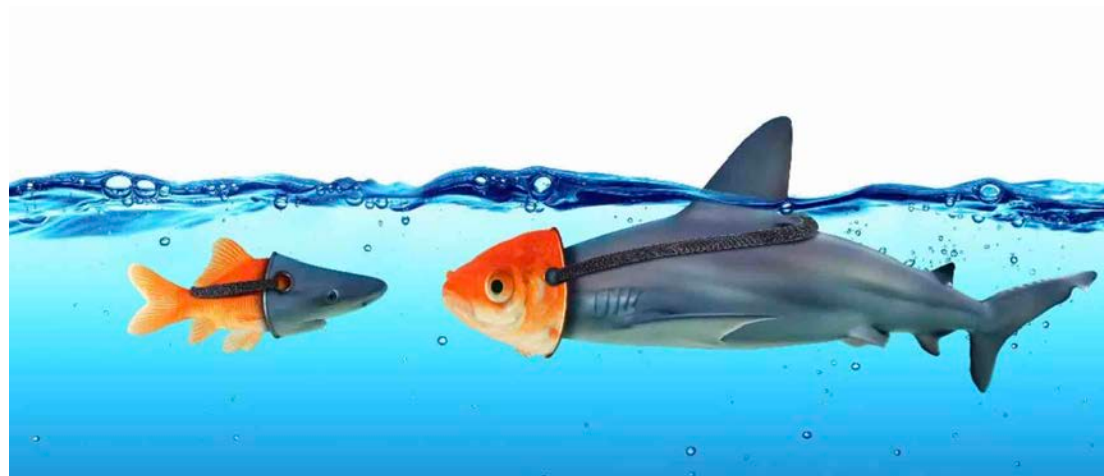


Image Source: Patrick Grother (2025)

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*

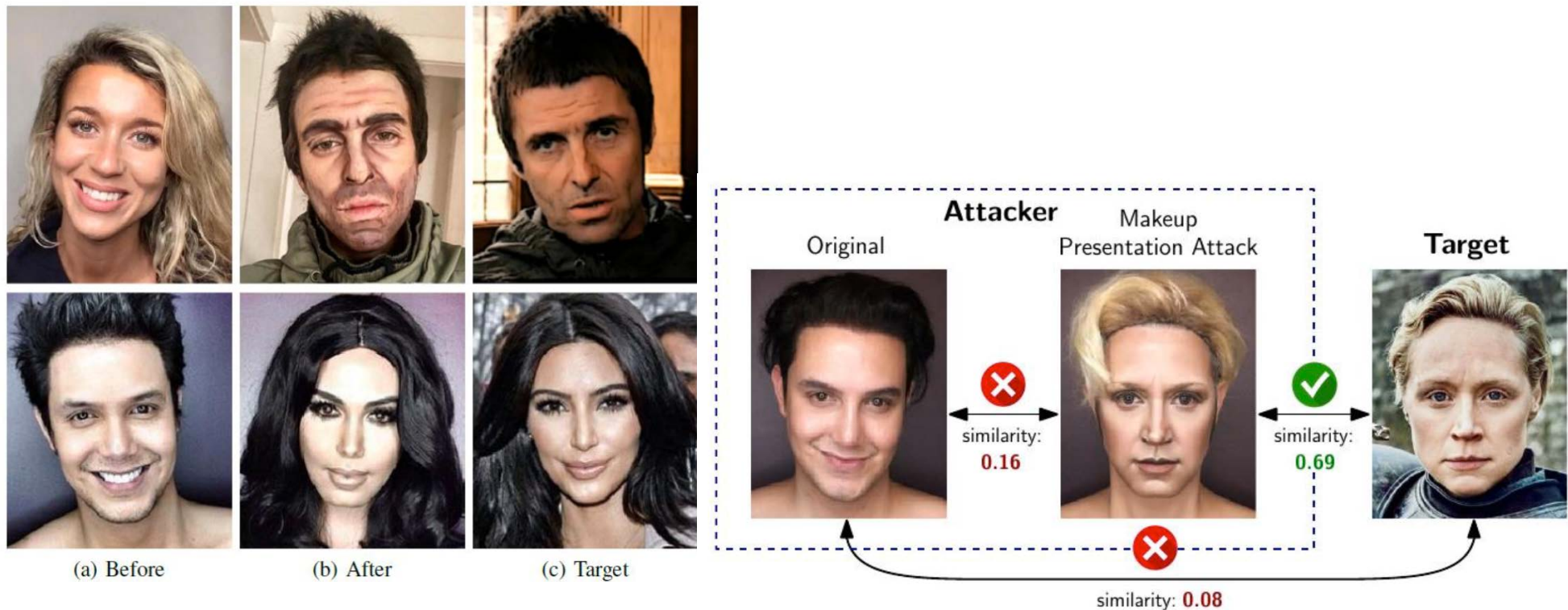


<https://www.iso.org/obp/ui/#iso:std:iso-iec:2382:-37:ed-3:v1:en>

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)

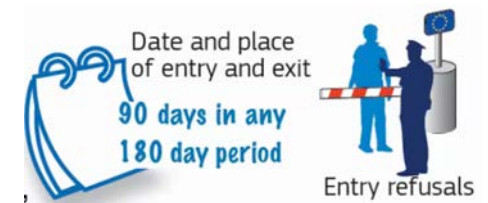
Face Image Quality



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/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

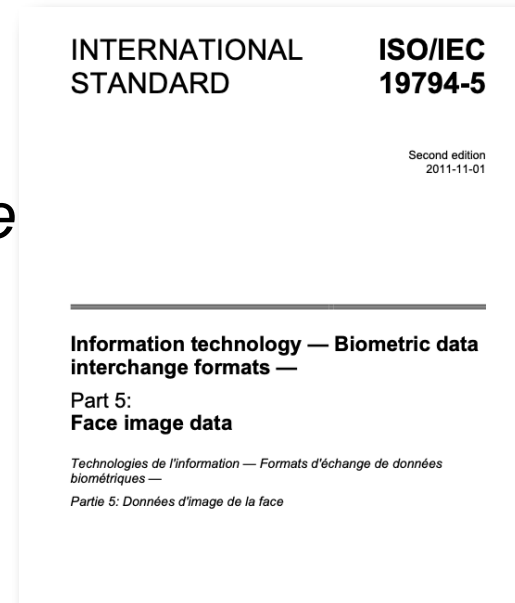
The requirement in EES implementing decision 2019/329

- „*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

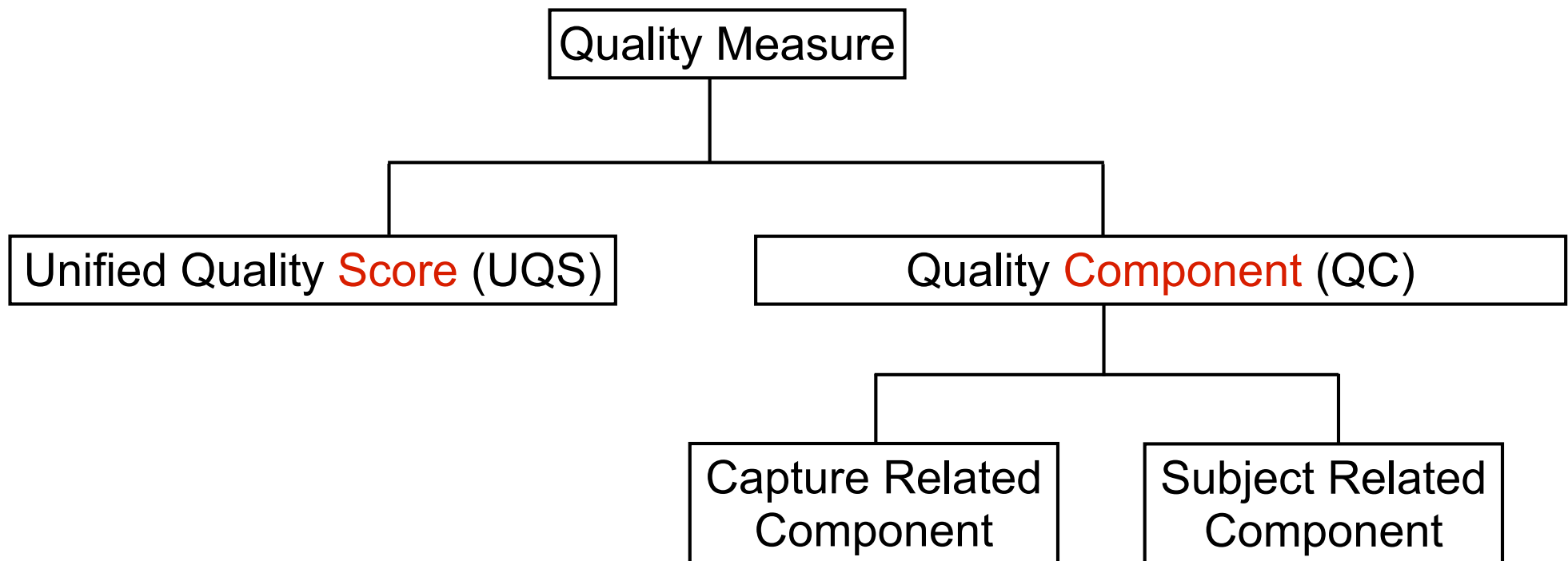
- **Standardisation**
- International Organization for Standardization, ISO/IEC 29794-5, Information technology - Biometric sample quality - Part 5: Face image data,
<https://www.iso.org/standard/81005.html>
 - ▶ Providing measures for requirements from ISO/IEC 19794-5:2011 and ISO/IEC 39794-5:2019
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

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?

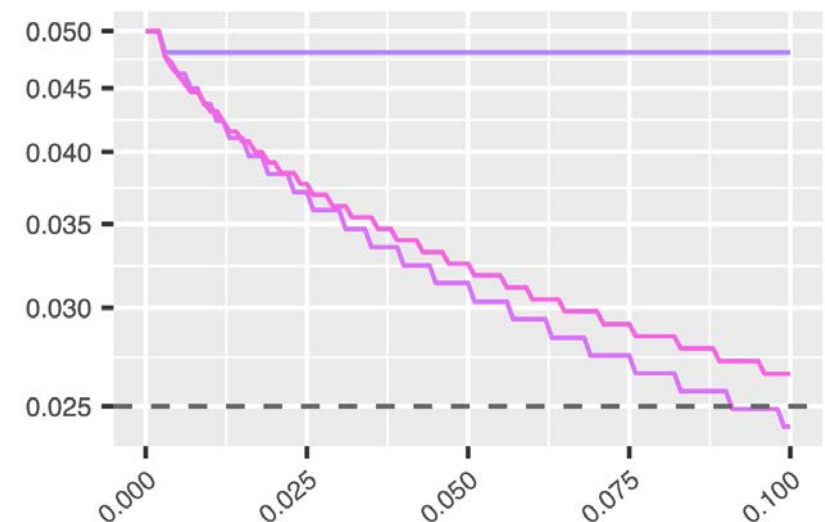
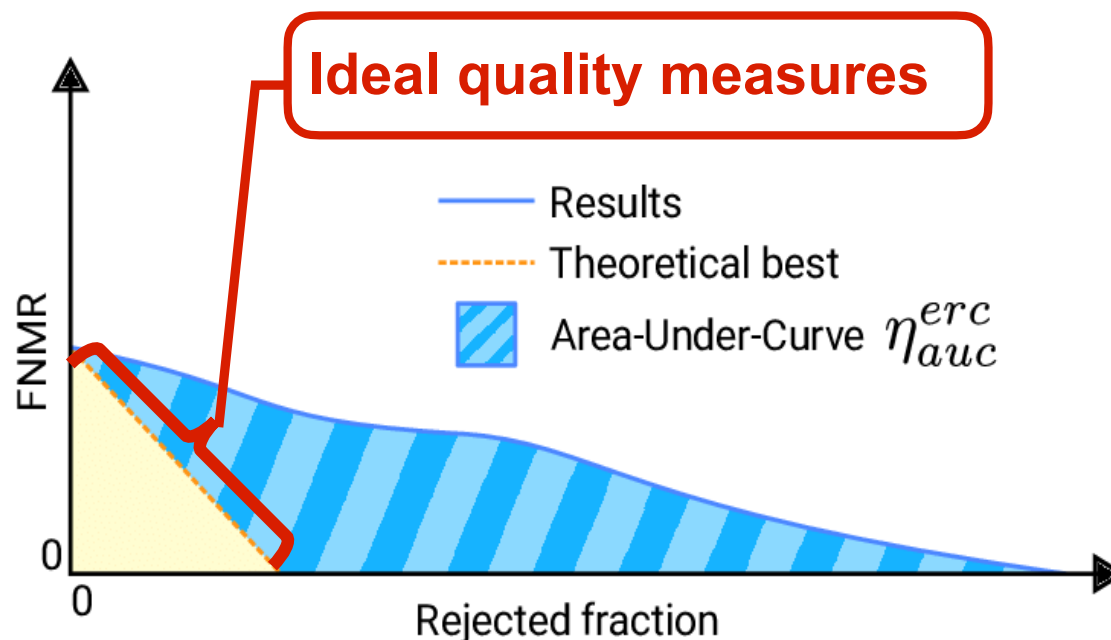


Image Source: NIST FATE SIDD report

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)

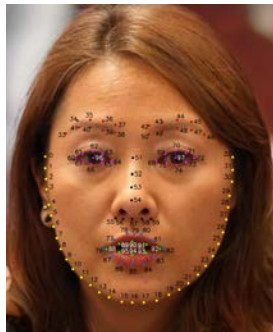
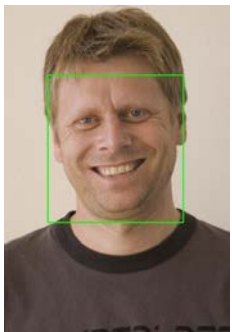


Image Source: OFIQ public report and ISO/IEC FDIS 29794-5

OFIQ - Quality Components

Example algorithm: Sharpness

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

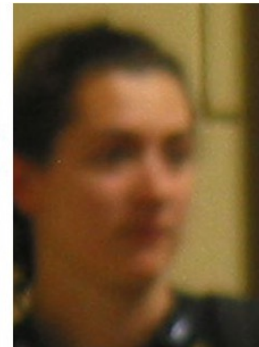


Image Source: FRGCv2 database

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



Image Source: OFIQ public report

OFIQ - Quality Components

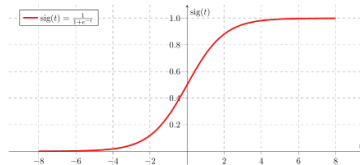
Example algorithm: Mouth Closed

- 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

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



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

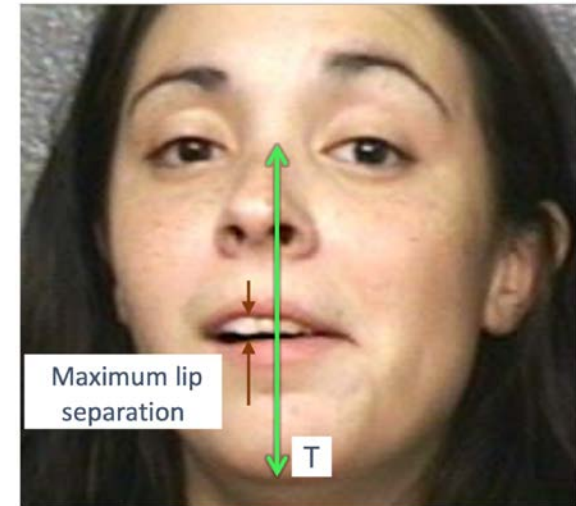


Image Source: NIST FATE SIDD report

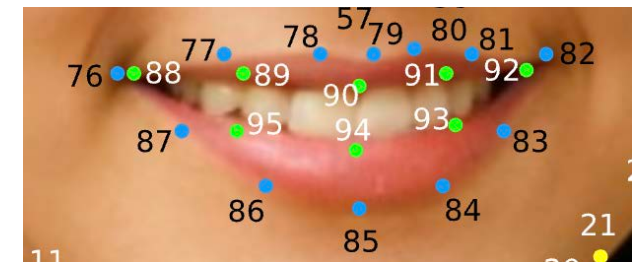


Image Source: ISO/IEC 29794-5

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



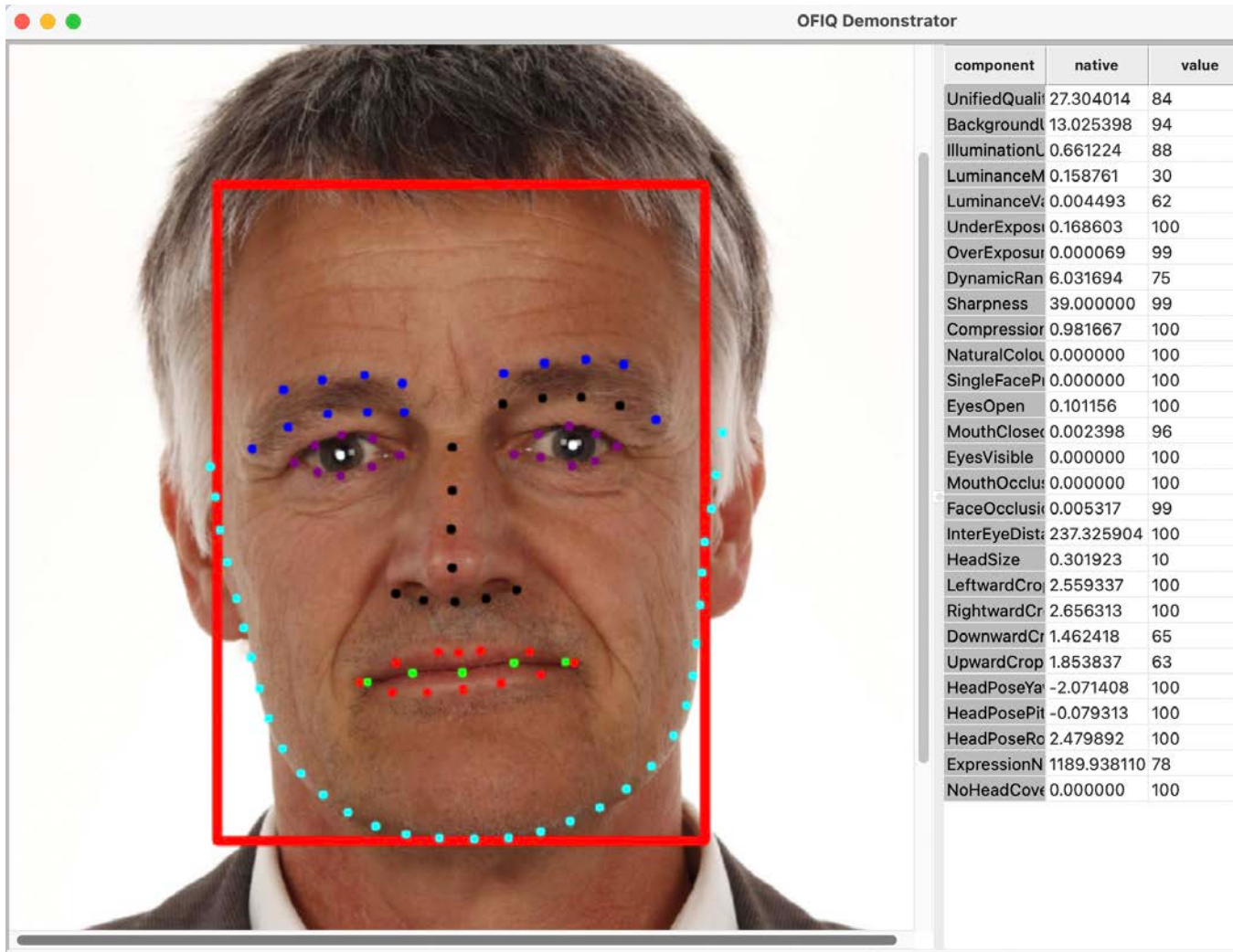
[GRVB2023] M. Grimmer, C. Rathgeb, R. Veldhuis, C. Busch: "NeutrEx: A 3D Quality Component Measure on Facial Expression Neutrality", in Proceedings of International Joint Conference on Biometrics (IJCB), (2023)

[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 - Demonstrator

Demonstrator to understand the processing

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



component	native	value
UnifiedQuali	27.304014	84
BackgroundL	13.025398	94
IlluminationL	0.661224	88
LuminanceM	0.158761	30
LuminanceV	0.004493	62
UnderExposi	0.168603	100
OverExposur	0.000069	99
DynamicRan	6.031694	75
Sharpness	39.000000	99
Compressor	0.981667	100
NaturalColor	0.000000	100
SingleFaceP	0.000000	100
EyesOpen	0.101156	100
MouthClose	0.002398	96
EyesVisible	0.000000	100
MouthOcclu	0.000000	100
FaceOcclusi	0.005317	99
InterEyeDist	237.325904	100
HeadSize	0.301923	10
LeftwardCro	2.559337	100
RightwardCr	2.656313	100
DownwardCr	1.462418	65
UpwardCrop	1.853837	63
HeadPoseYa	-2.071408	100
HeadPosePi	-0.079313	100
HeadPoseRo	2.479892	100
ExpressionN	1189.938110	78
NoHeadCove	0.000000	100

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.

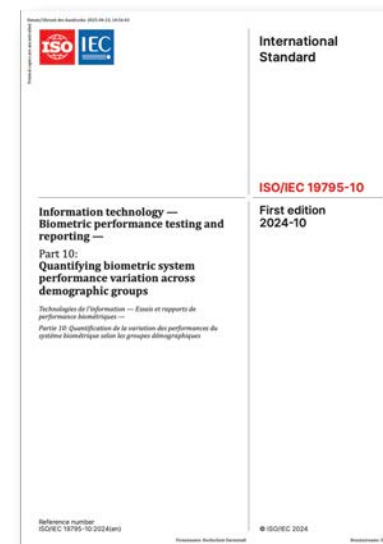
Demographic Effects

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>

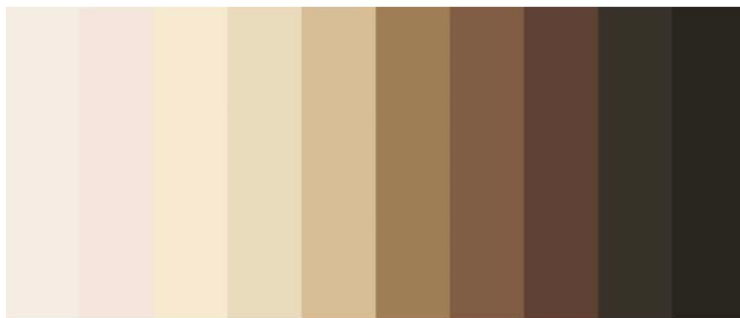


[Droz2020] P. Drozdowski, C. Ratgeb, A. Dantcheva, N. Damer, C. Busch: "Demographic Bias in Biometrics: A Survey on an Emerging Challenge", in IEEE Transactions on Technology and Society (TTS), (2020)

Face Image Quality - Demographics

Open research tasks

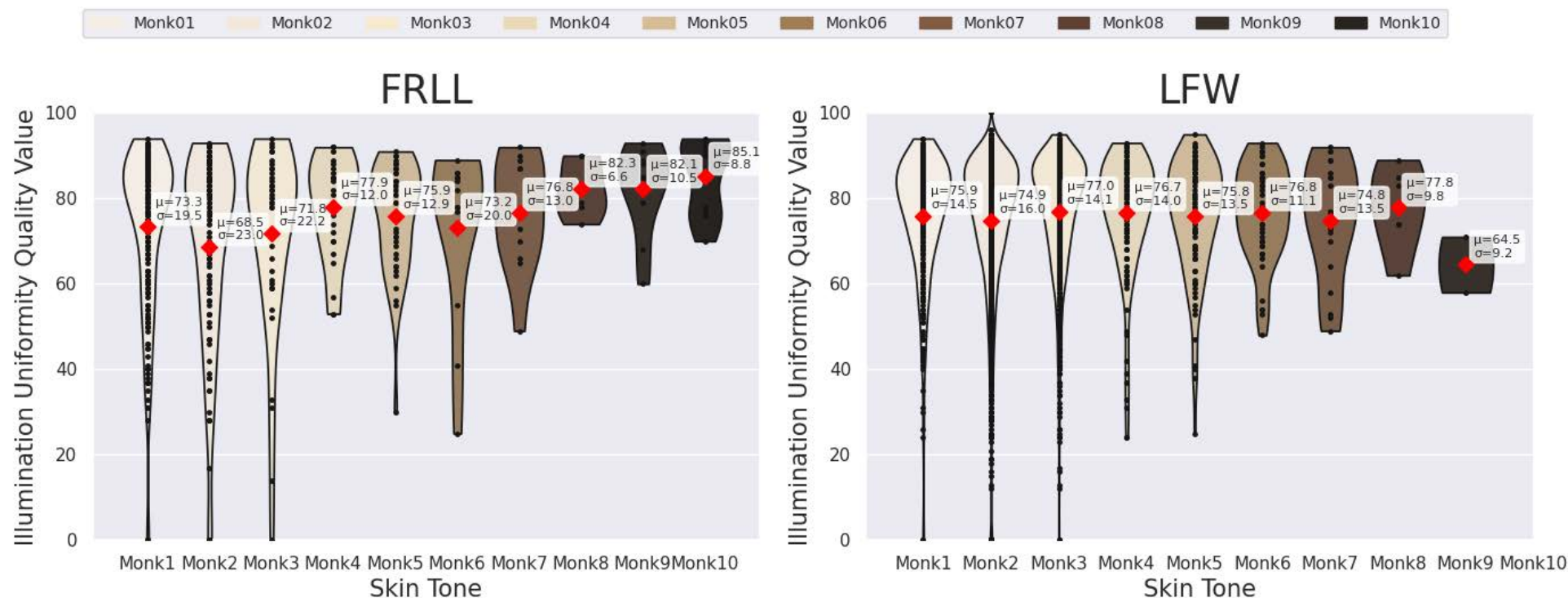
- Investigate **demographic variability** (DV) of quality measures
- Skin tone variation is a **continuous** demographic **variable**
- Collect data and organize in discrete categories
 - ▶ Monk skin tone scale (MST) vs.
 - ▶ Colorimetric skin tone (CST) vs.
 - ▶ PANTONE Skin Tone (PST)



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)

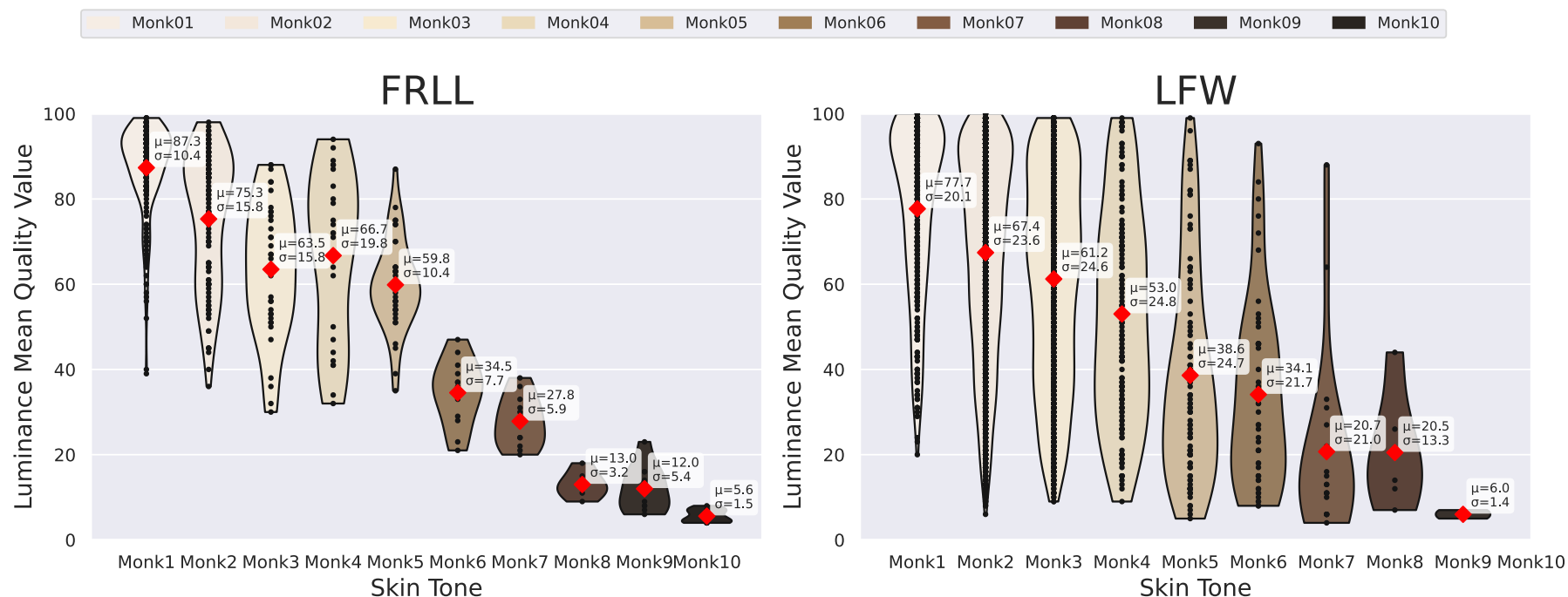
Face Image Quality - Demographics

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

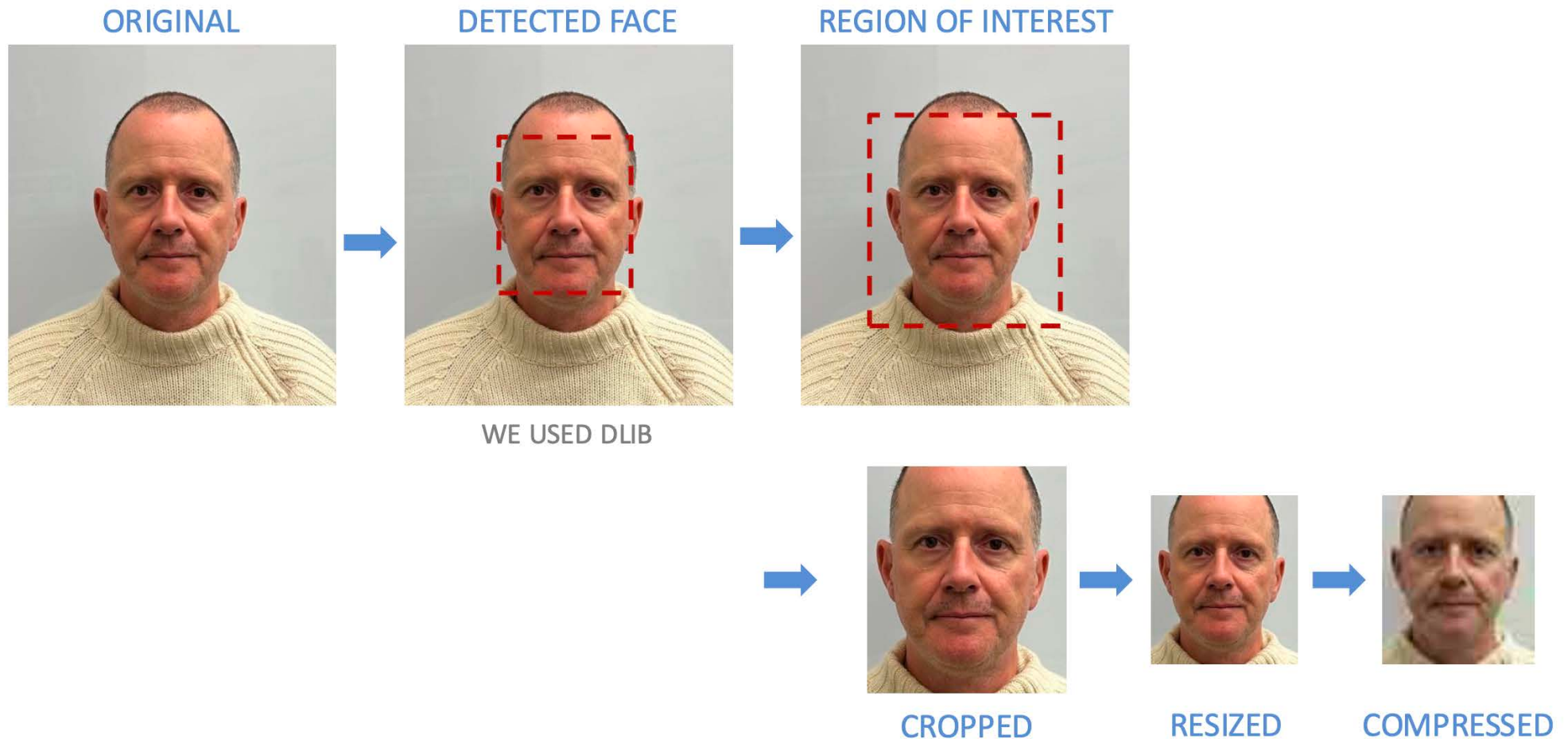


Image Source: Patrick Grother (2025)

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



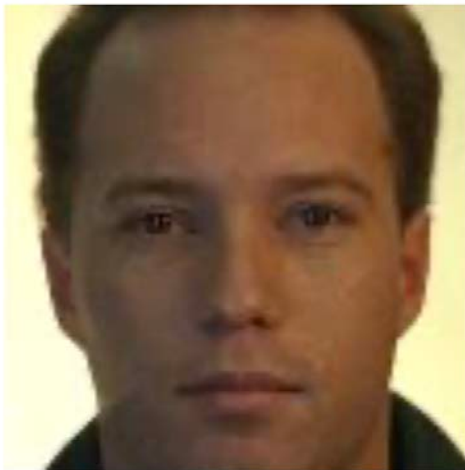
[Schlett2023] T. Schlett, S. Schachner, C. Rathgeb, J. Tapia, C. Busch: "Effect of Lossy Compression Algorithms on Face Image Quality and Recognition", in Proceedings of the International Conference on Acoustics, Speech and Signal Processing (ICASSP), Rhodes Island, GR, June 4-10, (2023)

<https://arxiv.org/pdf/2302.12593>

Compact Face Image Encoding

Impact of Lossy Image Compression

- 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>

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