

Biometric Sample Quality: Status and Challenges for Face Recognition Systems

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23rd Summer school for advanced studies on biometrics

Christoph Busch

copy of slides available at:

<https://christoph-busch.de/about-talks-slides.html>



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 - ▶ Andre Dörsch
 - ▶ Daniel Fischer
 - ▶ Fabian Stockhardt
 - ▶ Florian Bayer
 - ▶ Gregor Grote
 - ▶ Hans Geißner
 - ▶ Philipp Srock
 - ▶ Robert Nichols
 - ▶ Samuel Wolf
 - ▶ Torsten Schlett



2025

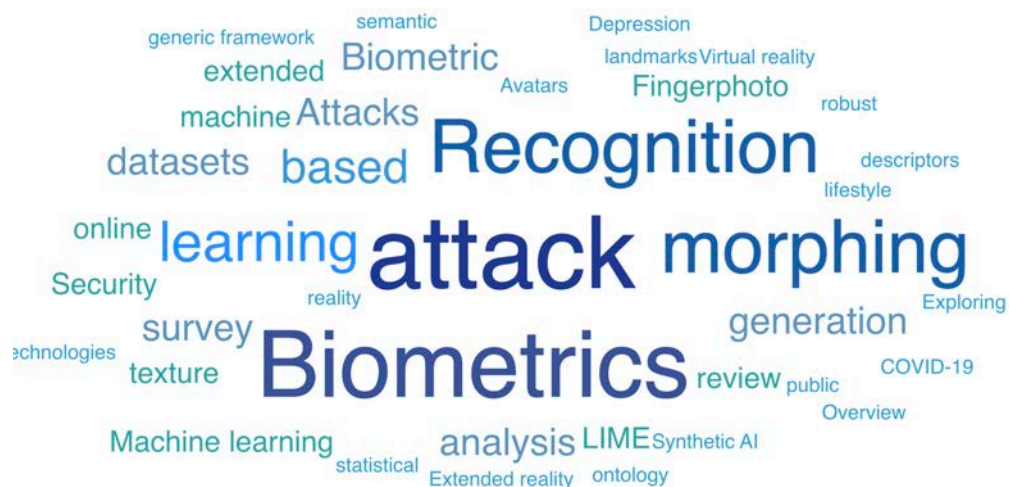


<https://dasec.h-da.de/>

- Key-factors - since 2009:
 - ▶ 8 European funded projects,
 - ▶ 10 German funded projects
 - ▶ 5 research projects funded by the German BSI,
 - ▶ 2 industrial projects,
 - ▶ cooperated with > 30 research partners
 - ▶ more than **700 peer-reviewed publications**

Norwegian Biometrics Laboratory (NBL)

- Faculty-Members / PostDocs:
 - ▶ Christoph Busch
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 - ▶ Raymond Veldhuis
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 - ▶ Tabita Tobing
 - ▶ Wassim Kabbani



- 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>



Challenges

Critical factors for Face Recognition Systems (FRS):

- **P**ose
- **I**llumination
- **E**xpression and Ageing



2001

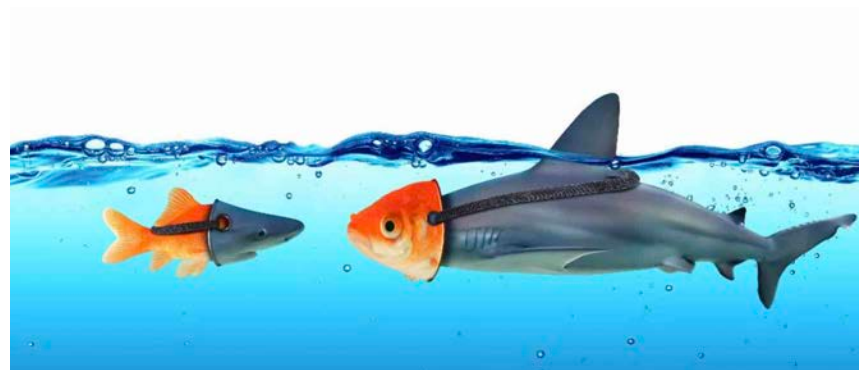
Challenges

Critical factors for Face Recognition Systems (FRS):

- Pose
- Illumination
- Expression and Ageing
- Presentation Attacks



2001



Challenges

Critical factors for Face Recognition Systems (FRS):

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



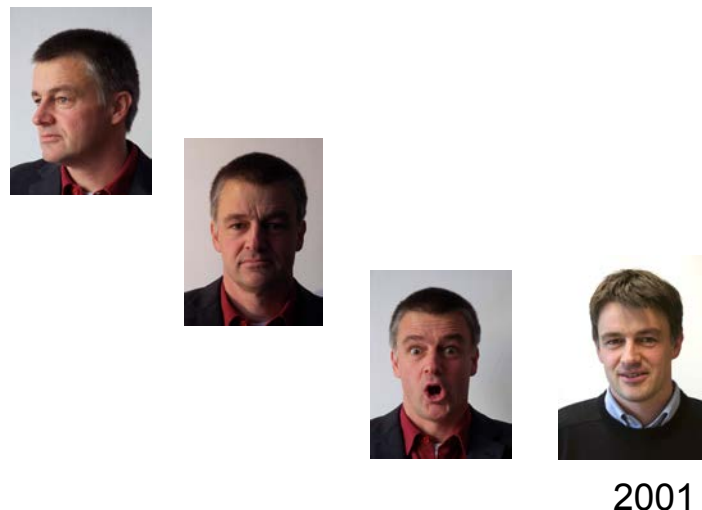
2001



Challenges

Critical factors for Face Recognition Systems (FRS):

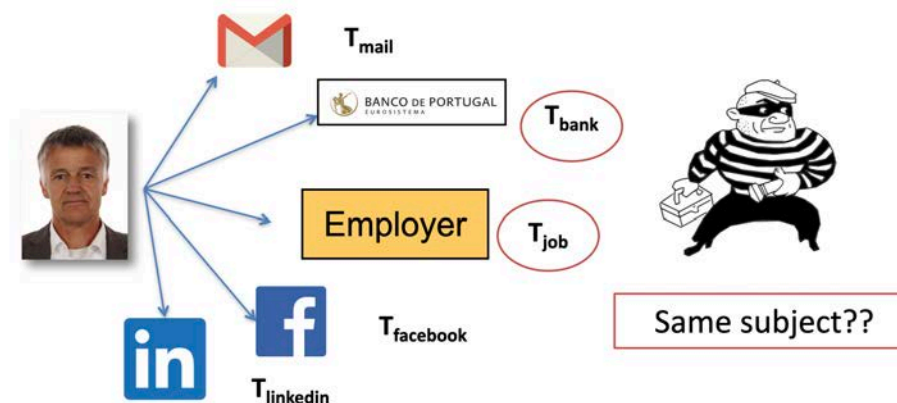
- Pose
- Illumination
- Expression and Ageing
- Presentation Attacks
- Face Image Quality
- Morphing Attack Detection



Challenges

Critical factors for Face Recognition Systems (FRS):

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



Challenges

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

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



Challenges

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

Biometric Standards

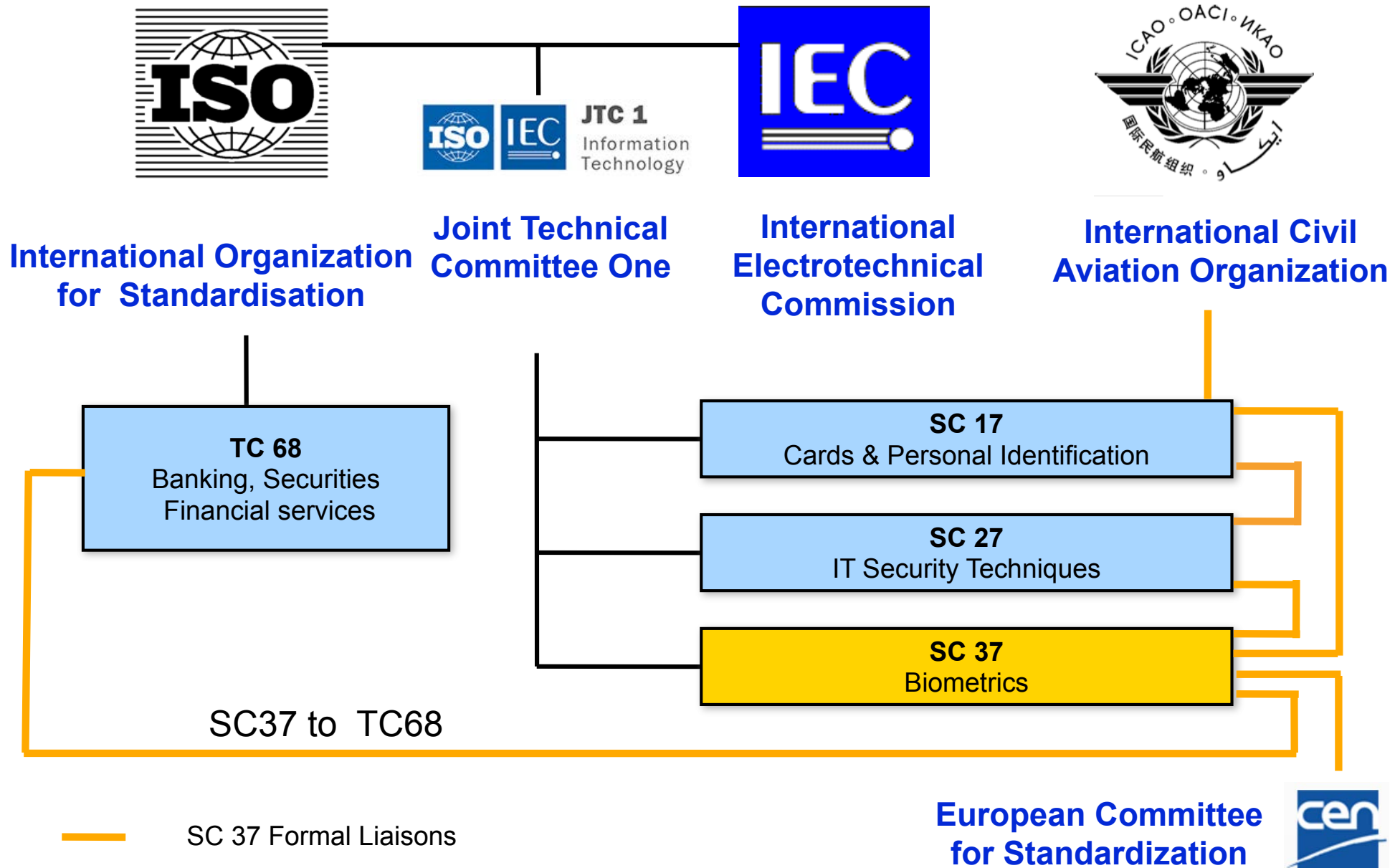


Why Standardisation?

Increase the level of **interoperability** of

- Devices and systems (provider vs. operator)
- Documents (author vs. reader)

Biometric Standardisation



ISO/IEC SC37 Biometrics

Established by JTC 1 in June 2002 to ensure

- a high-priority, focused and comprehensive approach worldwide for the rapid development of formal generic biometric standards

Scope of SC37

- “Standardization of *generic biometric* technologies pertaining to *human* beings to support *interoperability* and data interchange among applications and systems. Generic human biometric standards include: common file frameworks; biometric application programming *interfaces*; biometric data interchange *formats*; related biometric *profiles*; application of *evaluation criteria* to biometric technologies; methodologies for *performance testing* and reporting and cross jurisdictional and *societal aspects*”
- <http://www.jtc1.org>

Next meeting: July, 2026

Expressions in International Standards

In order to make clear what the user must do, the following verbal forms are used in standards:

- **Requirements** – **shall**, shall not
- **Recommendations** – **should**, should not
- Permission – may, need not
- Possibility and capability – can, cannot

Relevant Standards

Biometric Vocabulary



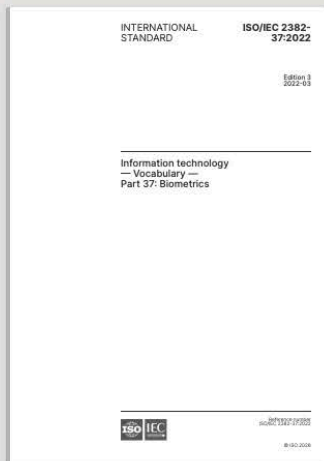
Standards

Sectors

About ISO

Insights & news

Taking part



Read sample

← TC ← ISO/IEC JTC 1/SC 37

ISO/IEC 2382-37:2022

Information technology — Vocabulary
Part 37: Biometrics

Published (Edition 3, 2022)

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

Why Standardisation?

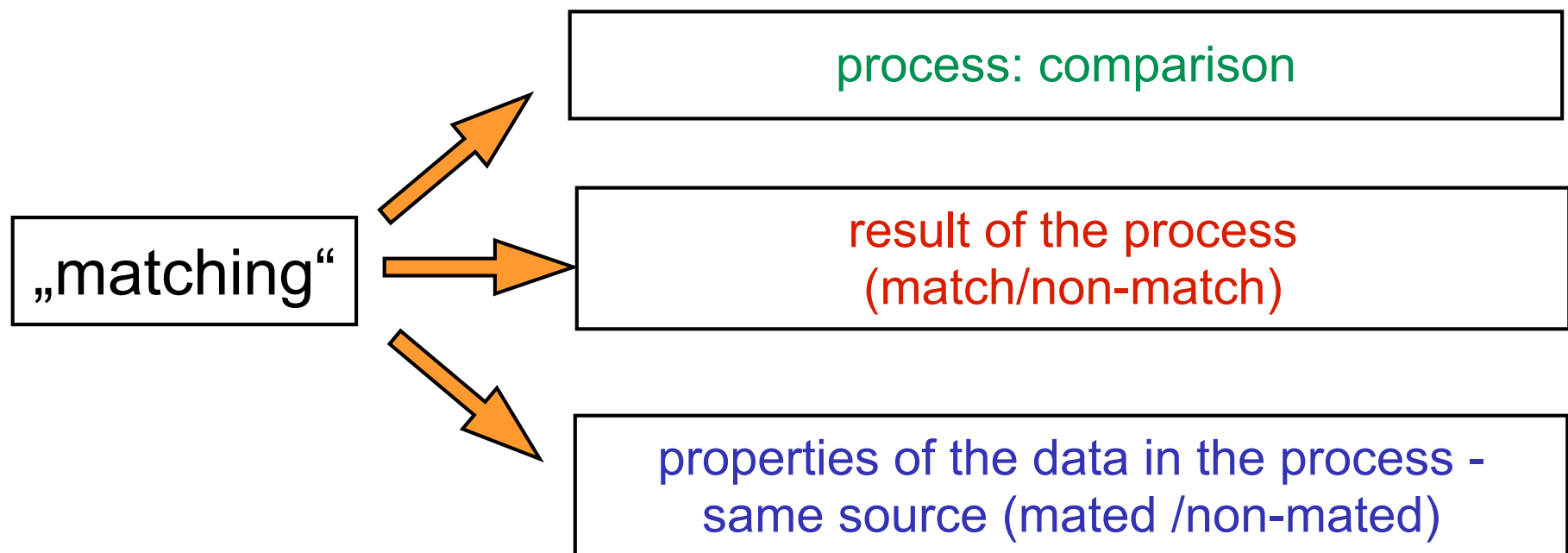
Reduce the level of **misunderstanding**

- Example statement from the literature:
 - ▶ *A false non-match occurs if two matched samples are matched and found not to match*

Why Standardisation?

Reduce the level of misunderstanding

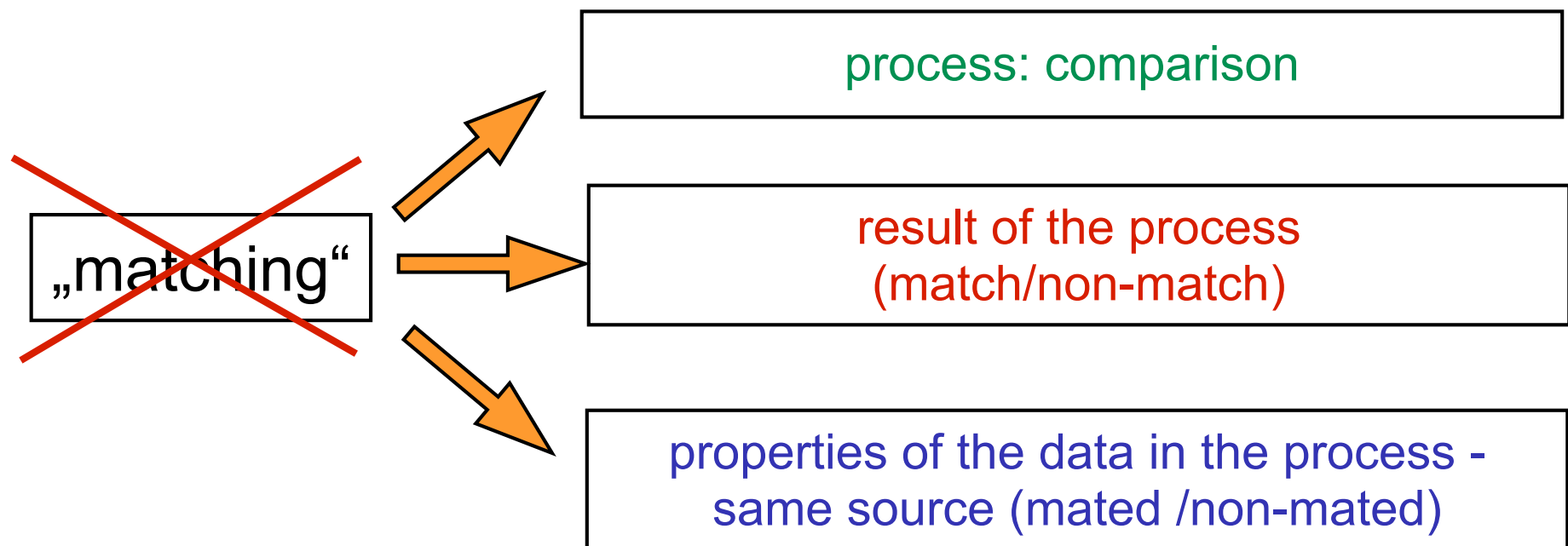
- Example:
 - ▶ A false *non-match* occurs if two *matched* samples are *matched* and found *not to match*
- Is the principle “one term = one concept” followed here?



Why Standardisation?

Reduce the level of misunderstanding

- Example:
 - ▶ A false *non-match* occurs if two *matched* samples are *matched* and found *not to match*
- Is the principle “one term = one concept” followed here?



Why Standardisation?

Reduce the level of misunderstanding

- Example:
 - ▶ A false *non-match* occurs if two *matched* samples are *matched* and found *not to match*
- Sanitised solution:
 - ▶ A false *non-match* occurs if two *mated* samples (i.e. *from the same source*) are *compared* and found *not to match*

37.05.07

comparison

DEPRECATED match

DEPRECATED matching

estimation, calculation or measurement of similarity or dissimilarity between a *biometric probe(s)* (37.03.14) and a *biometric reference(s)* (37.03.16)

<https://www.iso.org/obp/ui/en/#iso:std:iso-iec:2382:-37:ed-3:v1:en:term:37.05.07>

Relevant Standards

Biometric Performance



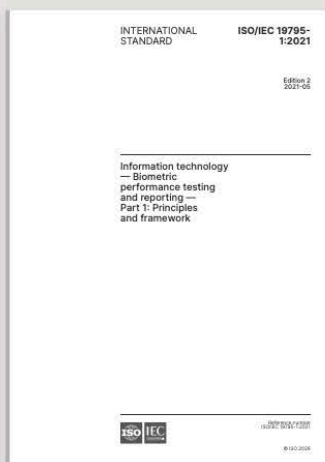
Standards

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Insights & news

Taking part



Read sample

← TC ← ISO/IEC JTC 1/SC 37

ISO/IEC 19795-1:2021

Information technology — Biometric performance testing and reporting
Part 1: Principles and framework

Published (Edition 2, 2021)

<https://www.iso.org/standard/73515.html>

Performance Metrics - Security

Probability density Distribution Function (PDF)

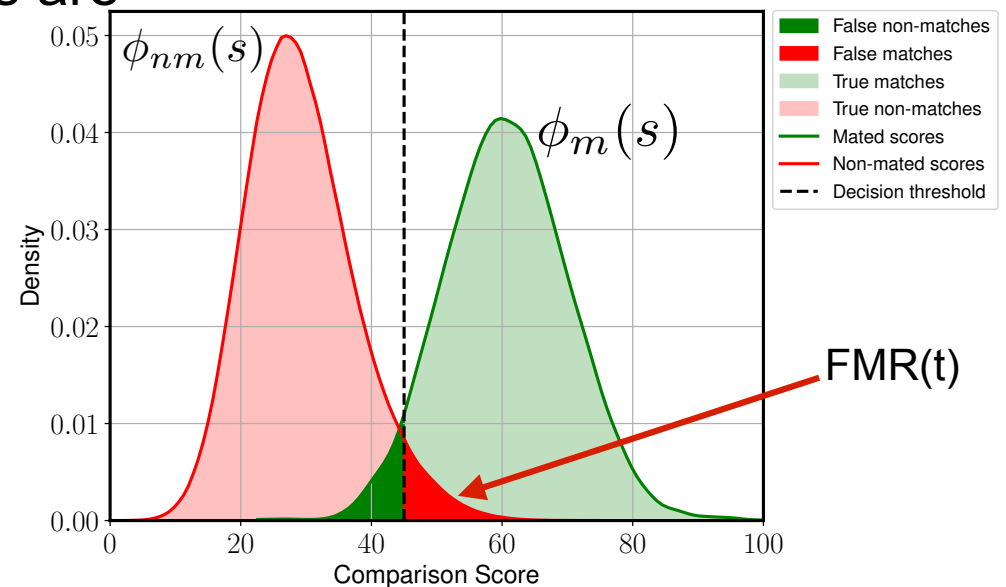
$\phi_m(s)$: PDF of mated similarity score $s(Q, R)$

$\phi_{nm}(s)$: PDF of **non-mated similarity** score $s(Q, R)$

False-Match-Rate (FMR)

- **ISO-Definition:** *proportion of the completed biometric **non-mated comparison trials** that result in a **false match***
- Note: non-mated comparison trials are also referred to as **impostor** trials
- False positive decision

$$FMR(t) = \int_t^1 \phi_{nm}(s) ds$$



Performance Metrics - Convenience

Probability density Distribution Function (PDF)

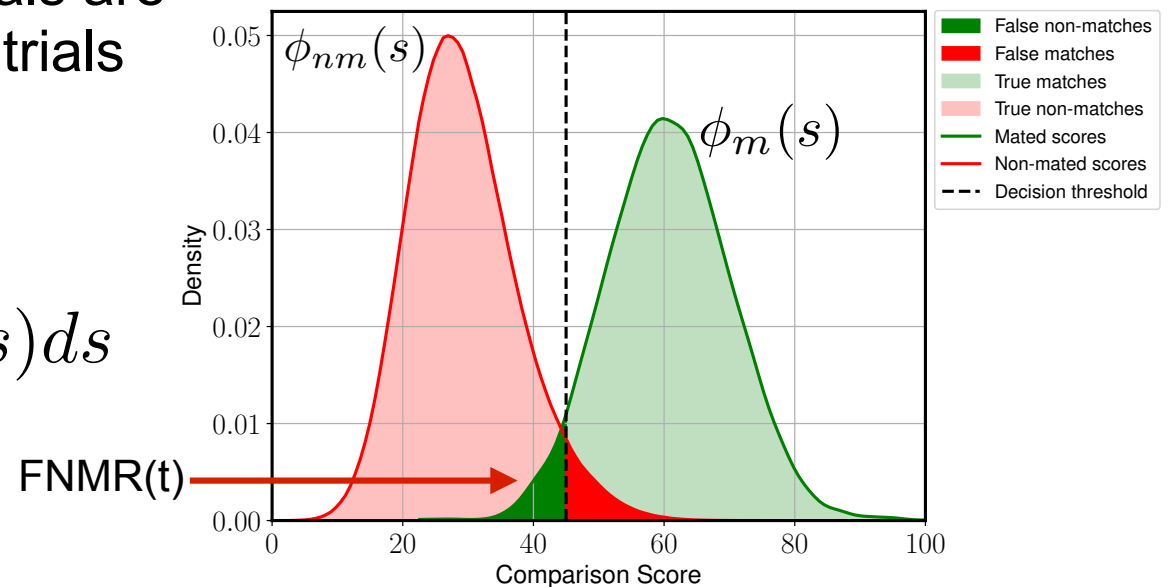
$\phi_m(s)$: PDF of **mated** similarity score $s(Q, R)$

$\phi_{nm}(s)$: PDF of non-mated similarity score $s(Q, R)$

False-Non-Match-Rate (FNMR)

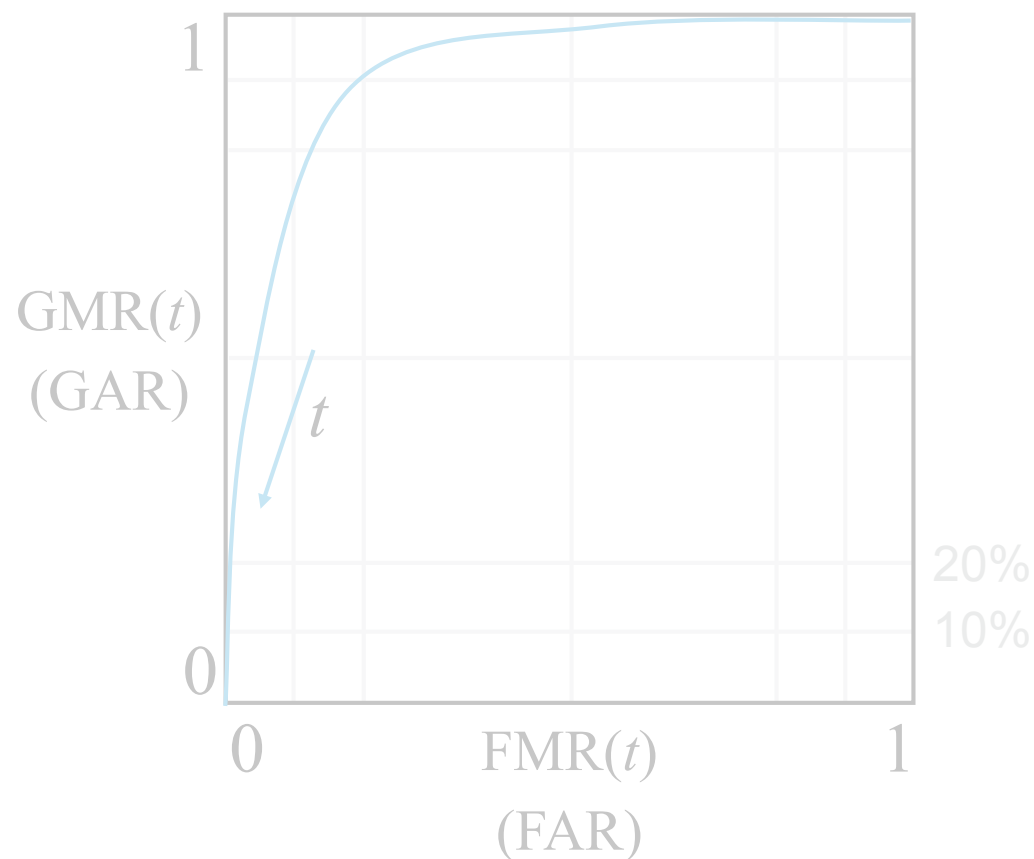
- **ISO-Definition:** *proportion of the completed biometric **mated comparison trials** that result in a **false non-match***
- Note: mated comparison trials are also referred to as **genuine** trials
- False negative decision

$$FNMR(t) = \int_0^t \phi_m(s) ds$$

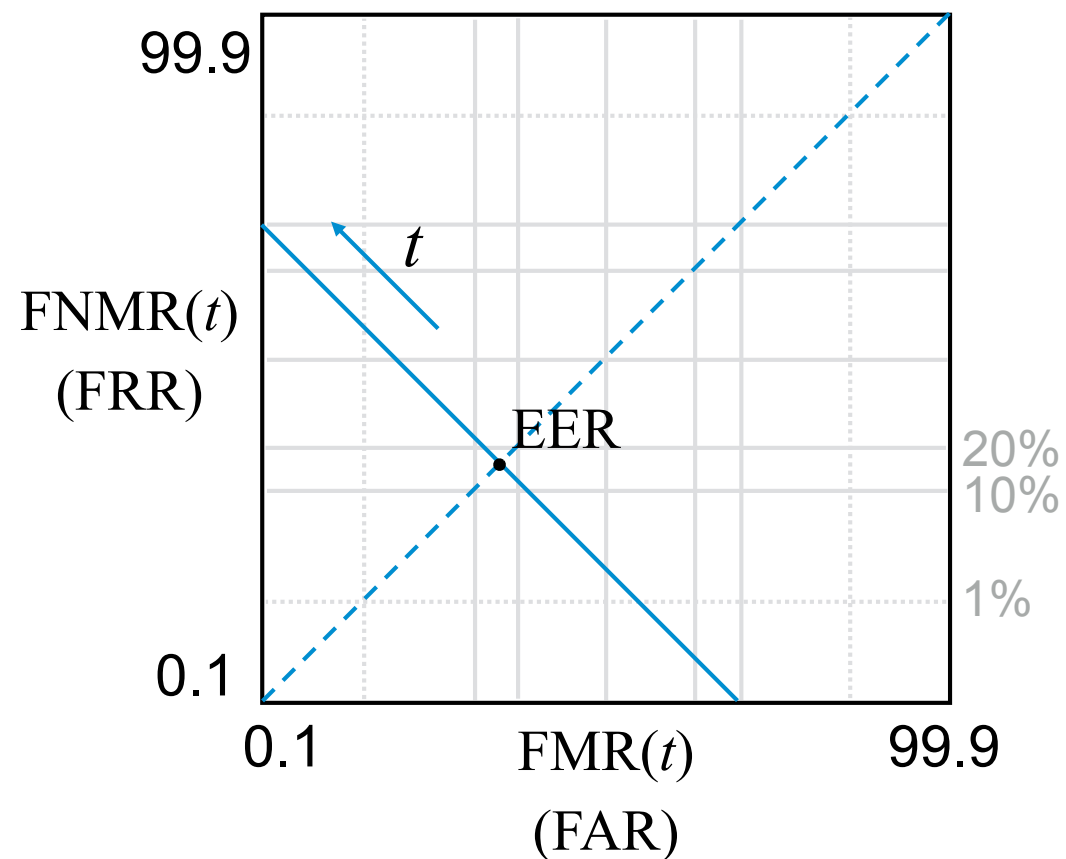


Graphical Presentation

Receiver Operating Characteristic (ROC)



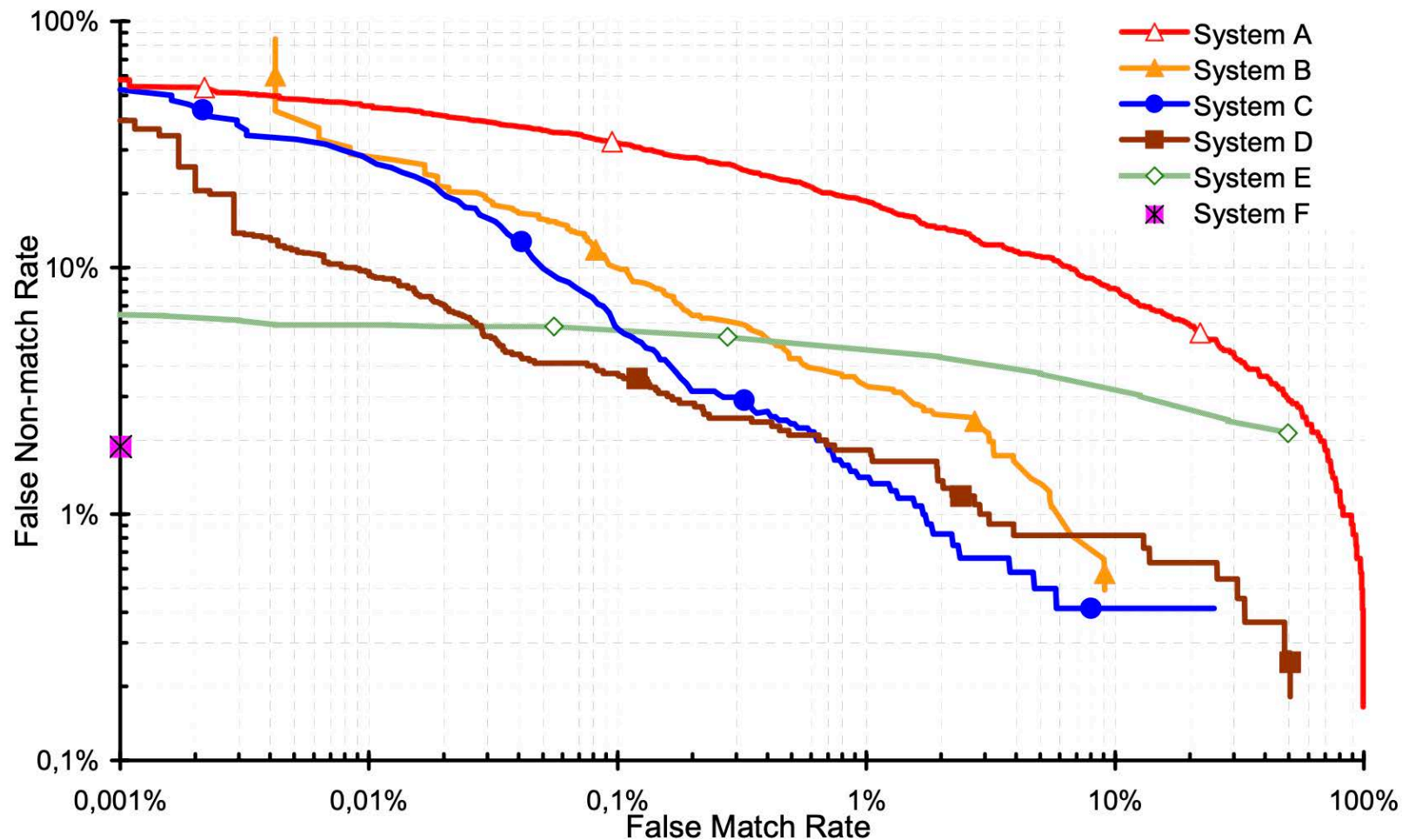
Detection Error Trade-off (DET) curve



Graphical Presentation

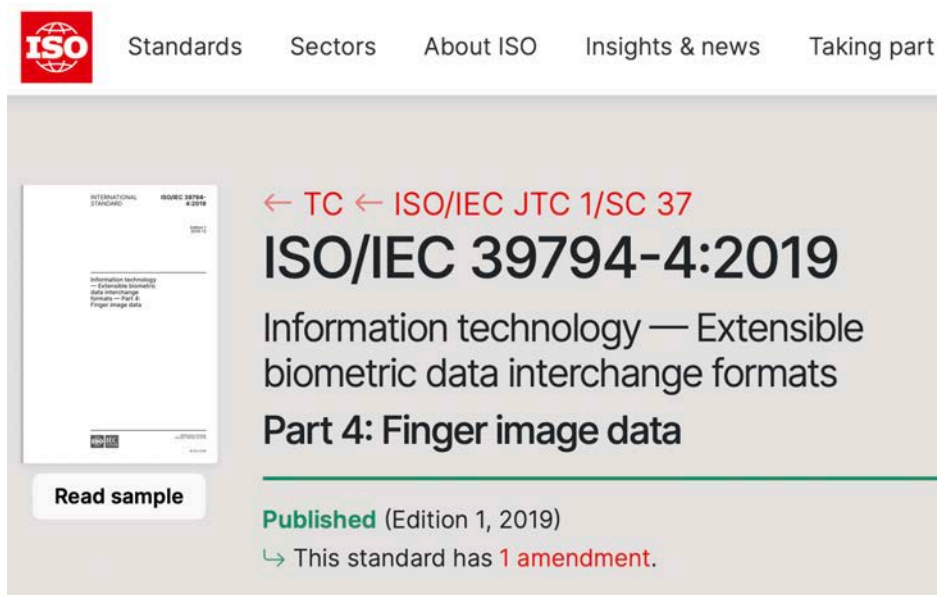
DET curve (detection error trade-off curve)

- Plots show error rates on both axes
 - ▶ **false positives** on the x-axis



Relevant Standards

Data Interchange Formats (for ICAO 9303 Passports)



ISO Standards Sectors About ISO Insights & news Taking part

← TC ← ISO/IEC JTC 1/SC 37


ISO/IEC 39794-4:2019

Information technology — Extensible biometric data interchange formats — Part 4: Finger image data

[Read sample](#)

Published (Edition 1, 2019)

↳ This standard has **1 amendment**.



ISO Standards Sectors About ISO Insights & news Taking part

← TC ← ISO/IEC JTC 1/SC 37

ISO/IEC 39794-5:2019

Information technology — Extensible biometric data interchange formats — Part 5: Face image data

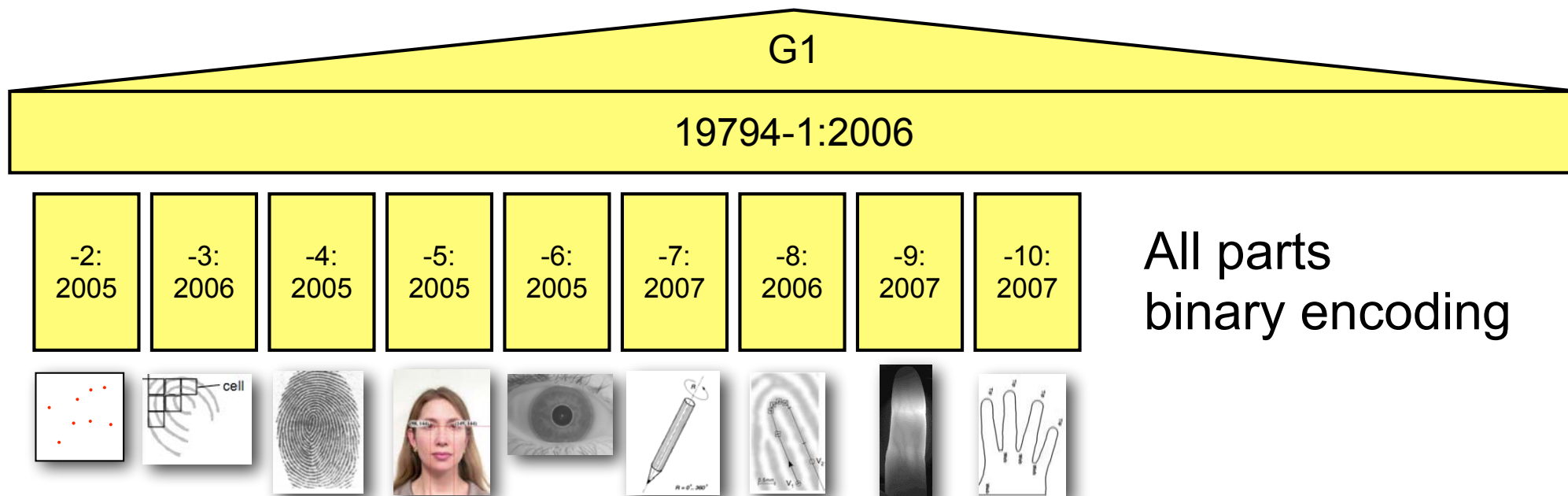
[Read sample](#)

Published (Edition 1, 2019)

<https://www.iso.org/standard/72155.html>

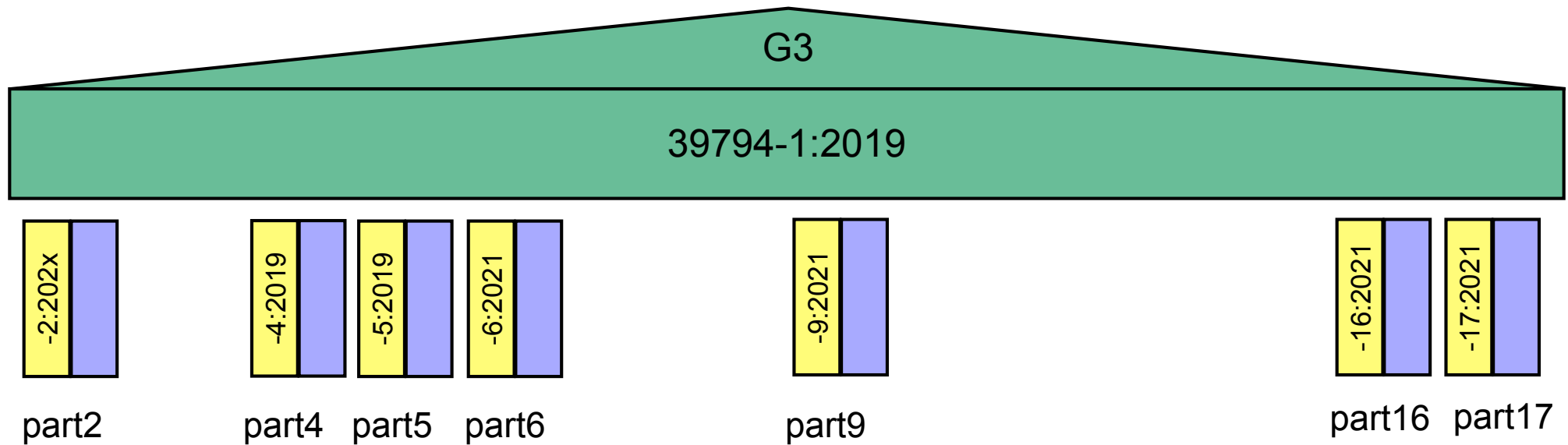
<https://www.iso.org/standard/72156.htm>

First Generation Format Standards



The 19794-Family: Biometric data interchange formats

Third Generation Format Standards




Generation 3:


- Common semantics amongst all part
- All parts contain ASN.1 module and XSD schema
- Common document structure
- XSD to ASN.1 conversion tool exists

Relevant Standards

Presentation Attack Detection (PAD)




Standards Sectors About ISO Insights & news Taking part




← TC ← ISO/IEC JTC 1/SC 37
ISO/IEC 30107-1:2023
Information technology — Biometric presentation attack detection
Part 1: Framework

[Read sample](#)

Published (Edition 2, 2023)



Standards Sectors About ISO Insights & news Taking part



← TC ← ISO/IEC JTC 1/SC 37
ISO/IEC 30107-3:2023
Information technology — Biometric presentation attack detection
Part 3: Testing and reporting

[Read sample](#)

Published (Edition 2, 2023)

<https://www.iso.org/standard/83828.html>

<https://www.iso.org/standard/79520.html>

Presentation Attacks

Impostor

- **Impersonation** attack
 - ▶ Positive access 1:1 (two factor application)
 - ▶ Positive access 1:N (single factor application)
- Finding a look-a-like
- Making appearance similar to the reference
- 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 - Testing

Definition of detection capabilities metrics

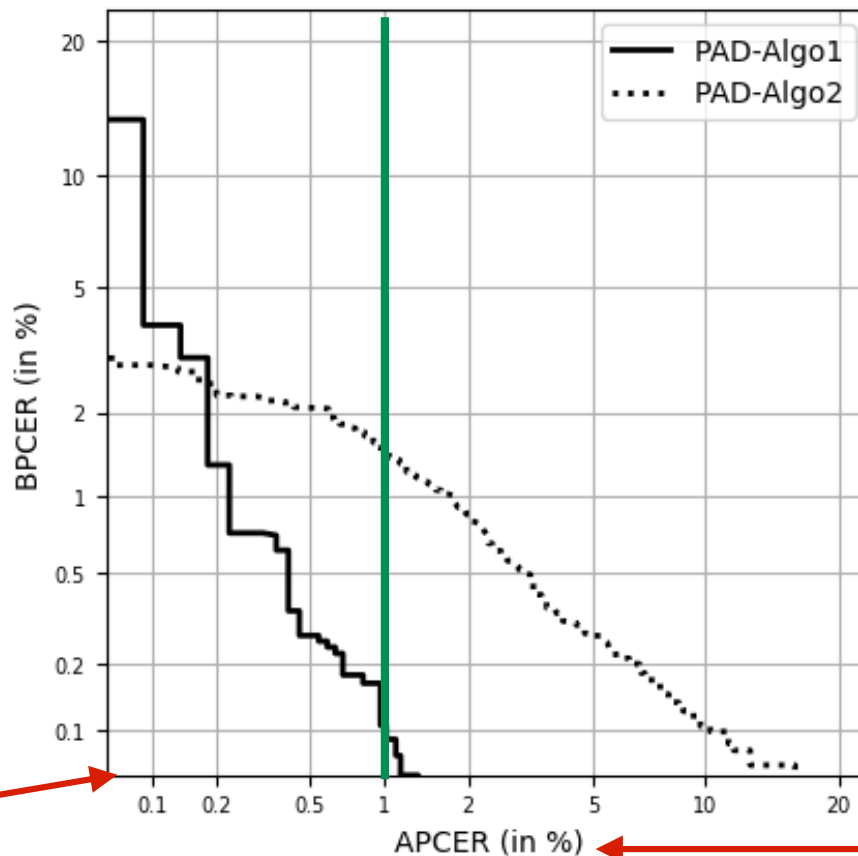
- Testing the **PAD subsystem** with false-negative and false-positive errors:
- **Attack presentation classification error rate (APCER)**
*proportion of **attack presentations** using the same PAI species incorrectly **classified as bona fide presentations** in a specific scenario*
- **Bona fide presentation classification error rate (BPCER)**
proportion of bona fide presentations incorrectly classified as attack presentations in a specific scenario

Source: ISO/IEC 30107-3

Presentation Attack Detection - Testing

Definition of PAD metrics in ISO/IEC 30107-3

- DET curve reports operating points for various thresholds showing **security** measures versus **convenience** measures
- Example:



**convenience
measure**

**Ideal:
APCER - low
BPCER - low**

**security measure
(strength of function)**

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**.



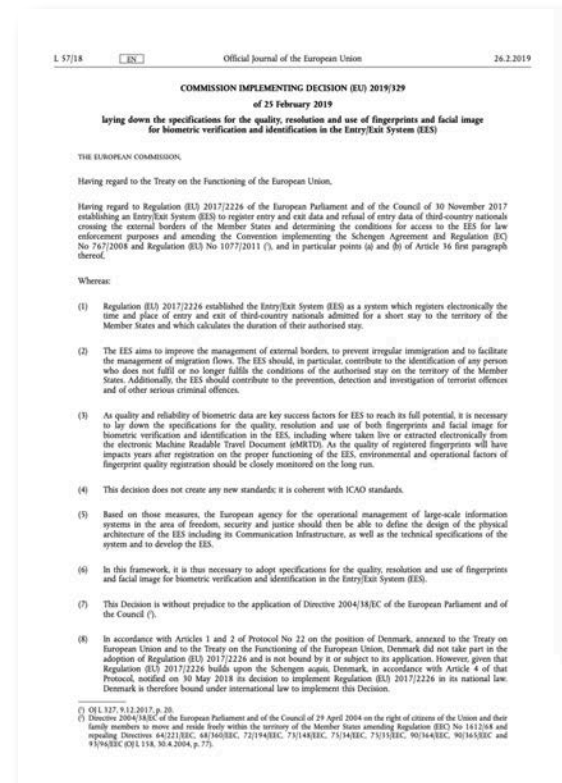
Image Source: eu-LISA



Quality Measures for Fingerprint Images

NFIQ2.0

- The Entry Exit System implementing decision 2019/329 defines the mandatory use:
- *„At the moment of enrolment, the version 2.0 (or newer version) of the Fingerprint Image Quality (NFIQ) metric shall be used for verifying that the quality of the captured fingerprint data respects the thresholds ...“*



Quality Requirements for Facial Images

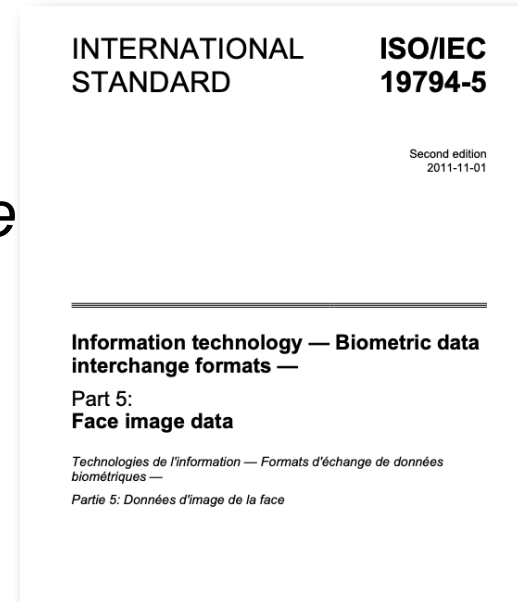
The requirement in EES implementing decision 2019/329

- „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**

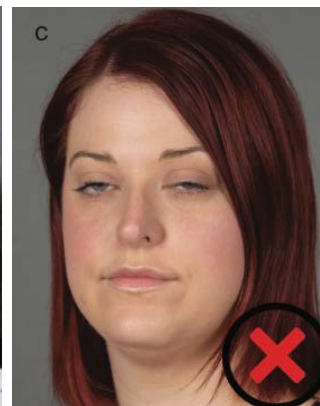
- If quality is poor, then what went wrong?



Compliant image



Pose



Eyes open



Mouth open



Inhomogenous background

Source: ISO/IEC 39794-5

Quality Measures for Facial Images

How to develop face image quality measures?

- Strong confusion in the industry regarding what means „**ICAO compliance**“ ?
- As for fingerprint (i.e. NFIQ2.3) - let a **standardised methodology** decide
 - ▶ **what is** an **ICAO compliant** image
 - ▶ and what is **NOT** an ICAO compliant image

Quality Measures for Facial Images

How to develop face image quality measures?

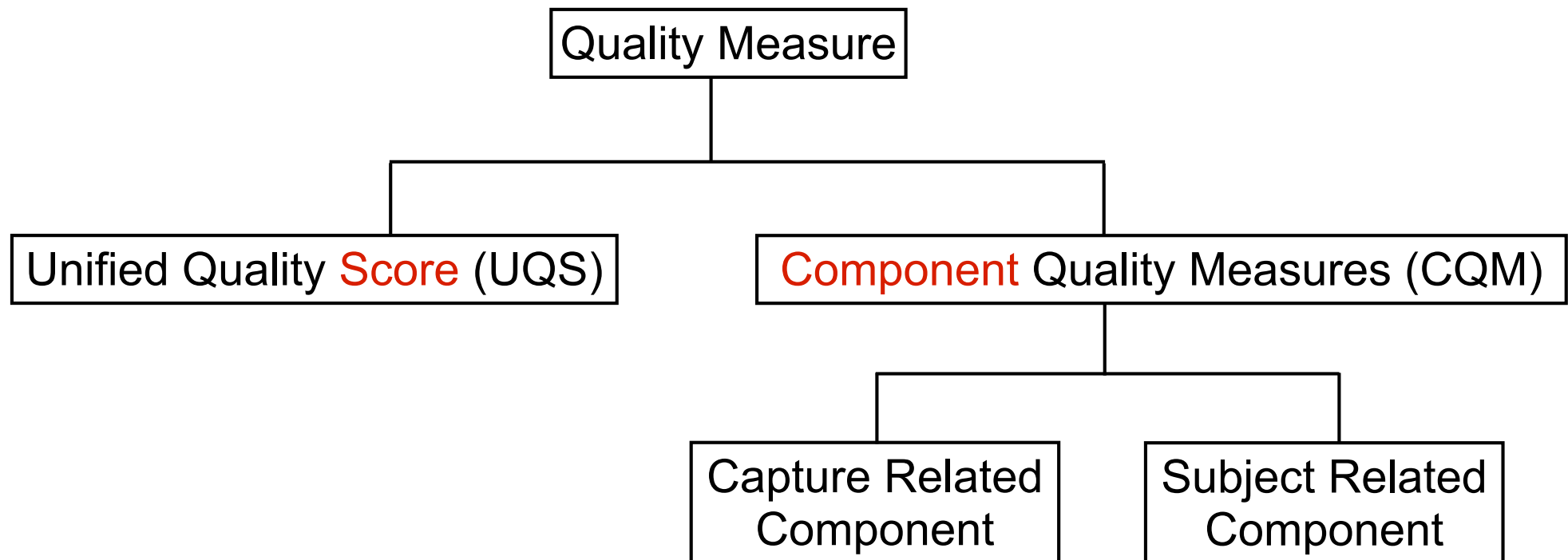
- International Organization for Standardization, ISO/IEC 29794-5, Information technology - Biometric sample quality - Part 5: Face image data,
<https://www.iso.org/standard/81005.html>
 - ▶ Providing measures for requirements from ISO/IEC 19794-5:2011 and ISO/IEC 39794-5:2019
 - Use-1: **Reference image 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)

Reference implementation of ISO/IEC 29794-5

- **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++
- **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)
 - ▶ Limited demographic variability

Quality Measures for Facial Images



How to find the best face quality measures?

- **Accuracy** testing



Patrick Grother
Mei Ngan
Joyce Yang

Category	ISO/IEC 29794-5 Quality Check	SIDD Quality Component
Capture device-related	6.3.2 Background uniformity	Background uniformity
	6.3.3 Illumination uniformity	-
	6.3.4 Moments of the luminance distribution	-
	6.3.5 Under-exposure	Under-exposure
	6.3.6 Over-exposure	Over-exposure
	6.3.7 Dynamic range	-
	6.3.8 De-focus	Resolution
	6.3.9 Motion blur	Motion blur
	6.3.10 Compression ratio	Compression artifacts
	6.3.11 Unnatural color	-
	6.3.12 Radial distortion	-
	6.3.13 Pixel aspect ratio	-
	6.3.14 Camera to subject distance	-
	Subject-related	6.4.2 Single face present
6.4.3 Eyes visible		Sunglasses + eyeglasses
6.4.4 Eyes open		Eyes open
6.4.5 Mouth occlusion		Face occlusion
6.4.6 Mouth closed		Mouth open
6.4.7 Nose occlusion		Face occlusion
6.4.8 Inter-eye distance		Spatial sampling rate
6.4.9 Horizontal position of the face		Face cropping and margin
6.4.10 Vertical position of the face		Face cropping and margin
6.4.11 Pose		Pose
6.4.12 Shoulder presentation		-
6.4.13 Expression neutrality		-



ISO/IEC 29794-5
Patrick Grother
Benjamin Tams
Johannes Merkle
Christoph Busch

- FATE Quality - Specific Image Defect Detection (SIDD)

https://pages.nist.gov/frvt/reports/quality_sidd/frvt_quality_sidd_report.pdf



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?

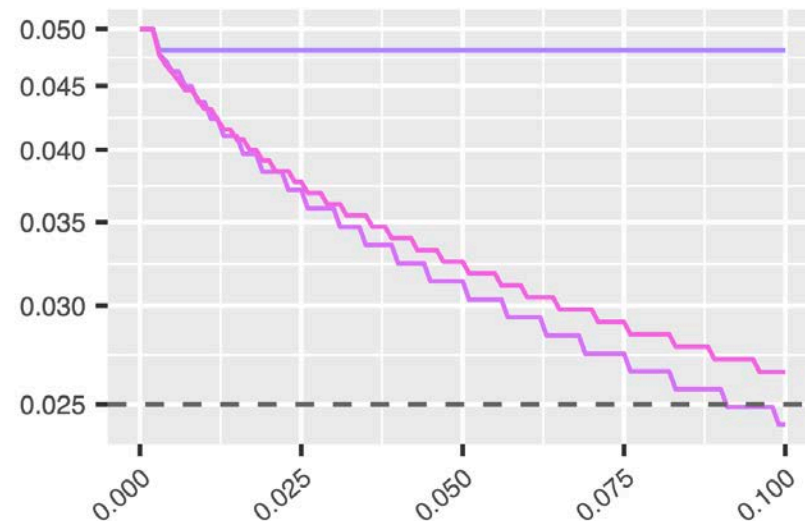
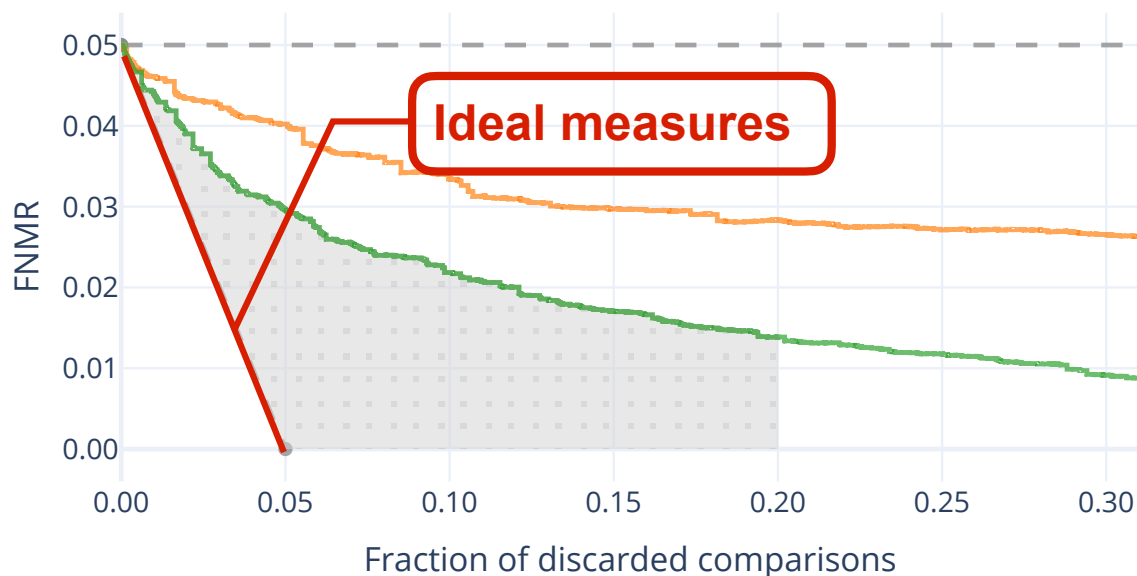


Image Source: NIST FATE SIDD report

[Schlett2023] T. Schlett, C. Rathgeb, J. Tapia, C. Busch: "Considerations on the Evaluation of Biometric Quality Assessment Algorithms", in IEEE Transactions on Biometrics, Behavior, and Identity Science (TBIOM), (2023)

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)

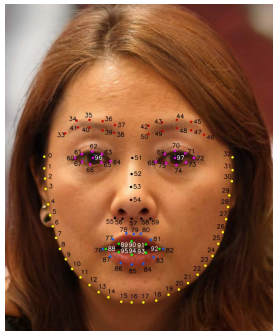
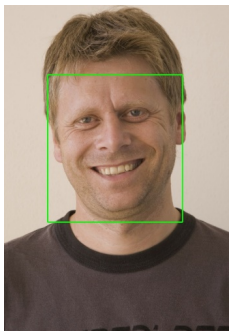
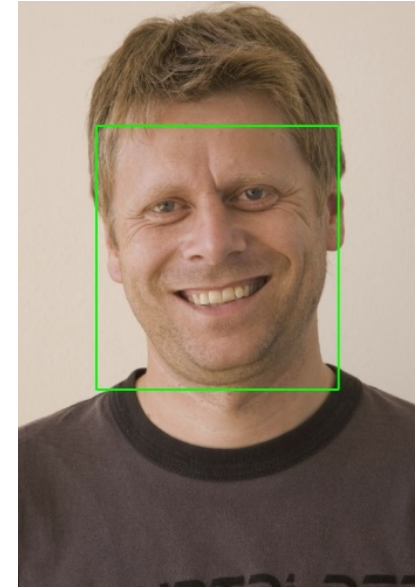


Image Source: OFIQ public report and ISO/IEC FDIS 29794-5

Open Source Face Image Quality (OFIQ)

Face Detection

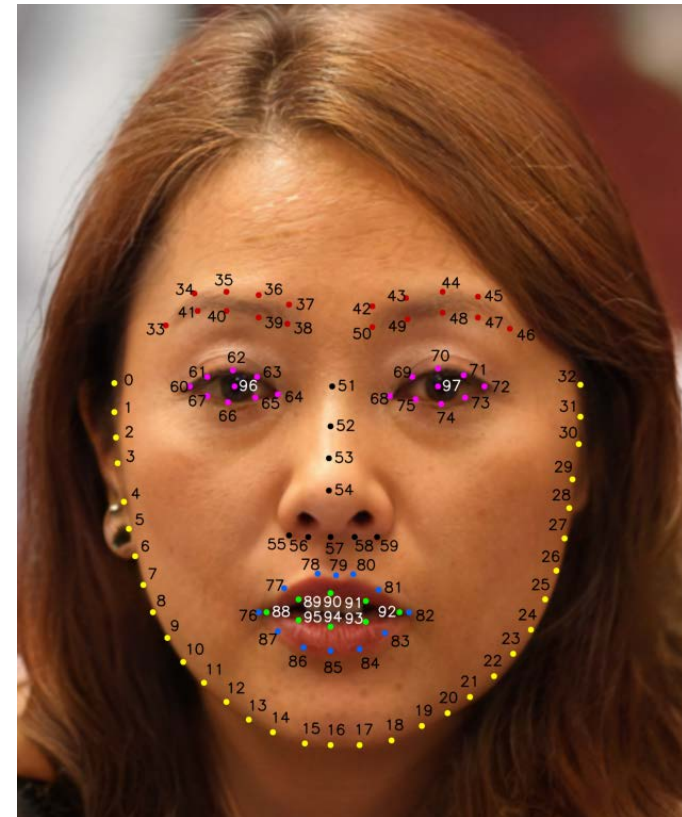
- Bounding box of all detected faces
- SSD face detection CNN
<https://github.com/sr6033/face-detection-with-OpenCV-and-DNN>
- Largest face is assessed further



Open Source Face Image Quality (OFIQ)

Face Landmark Estimation

- Localization of **key points** of facial traits
- CNN from repository ADNet
<https://github.com/huangyangyu/ADNet>
 - ▶ **98 Landmarks**
- Most time consuming algorithm



Open Source Face Image Quality (OFIQ)

Alignment

- Unified positioning of face within image
 - ▶ Eyes on same height
- Based on landmarks of eyes, nose & mouth



Open Source Face Image Quality (OFIQ)

Face Occlusion Segmentation

- Identify **un-occluded region** of face (incl. forehead)
- Occlusions:
 - ▶ Hair (not facial hair)
 - ▶ Objects (e.g. face masks, sunglasses)
 - ▶ Body parts (hand, tongue) except face
 - ▶ Frames of and reflections on eyeglasses
- CNN from repository FaceExtraction

<https://github.com/face3d0725/FaceExtraction>



Open Source Face Image Quality (OFIQ)

Face Parsing

- **Identify** different **regions** of the subject in image
 - ▶ Face parts (eyes, eye brows, nose, lips, skin)
 - ▶ Neck, ears, hair
 - ▶ Glasses, clothes, hats, earrings, necklaces
 - ▶ Background
- CNN from repository `face-parsing.PyTorch`

<https://github.com/VisionSystemsInc/face-parsing.PyTorch>

Index	Feature	Index	Feature
0	background	10	nose
1	face skin	11	mouth
2	left eye brow	12	upper lip
3	right eye brow	13	lower lip
4	left eye	14	neck
5	right eye	15	necklace
6	eyeglasses	16	clothing
7	left ear	17	hair
8	right ear	18	head covering
9	earring		



OFIQ - Quality Components

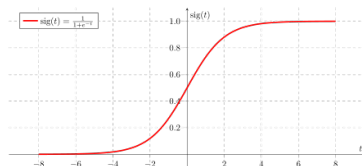
Example algorithm: Mouth Closed

- 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

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



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

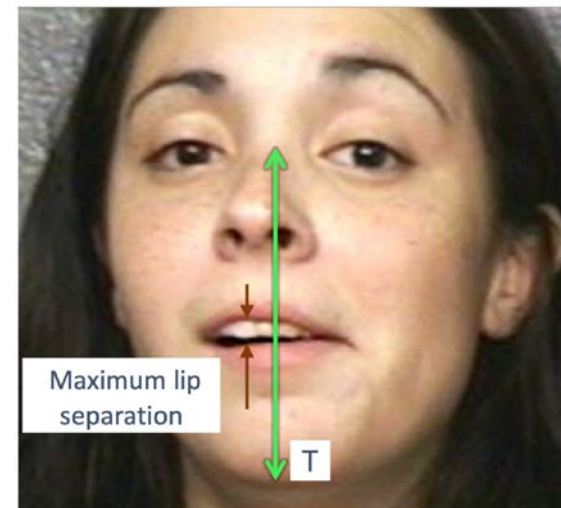


Image Source: NIST FATE SIDD report

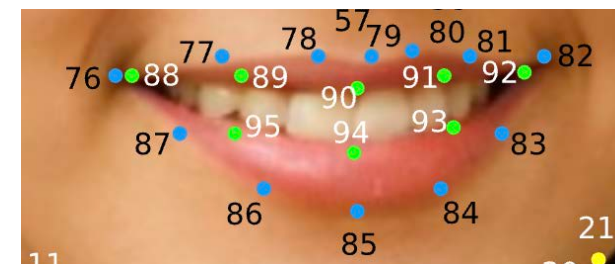


Image Source: ISO/IEC 29794-5

OFIQ - Quality Components

Example algorithm: Face occlusion prevention

- What is **occlusion**? For instance:
 - ▶ **Hair** on the forehead hanging over the eyes
 - ▶ Frames of eyeglasses / **specular reflections** if they occlude either eye
 - ▶ Any objects (for example, hands or protective faces **masks**)
- What is not an occlusion?
 - ▶ Transparent lenses of spectacles
 - ▶ Beards and moustaches
 - ▶ Eyebrows
- Face occlusion segmentation
- Compute ratio of un-occluded landmarked regions



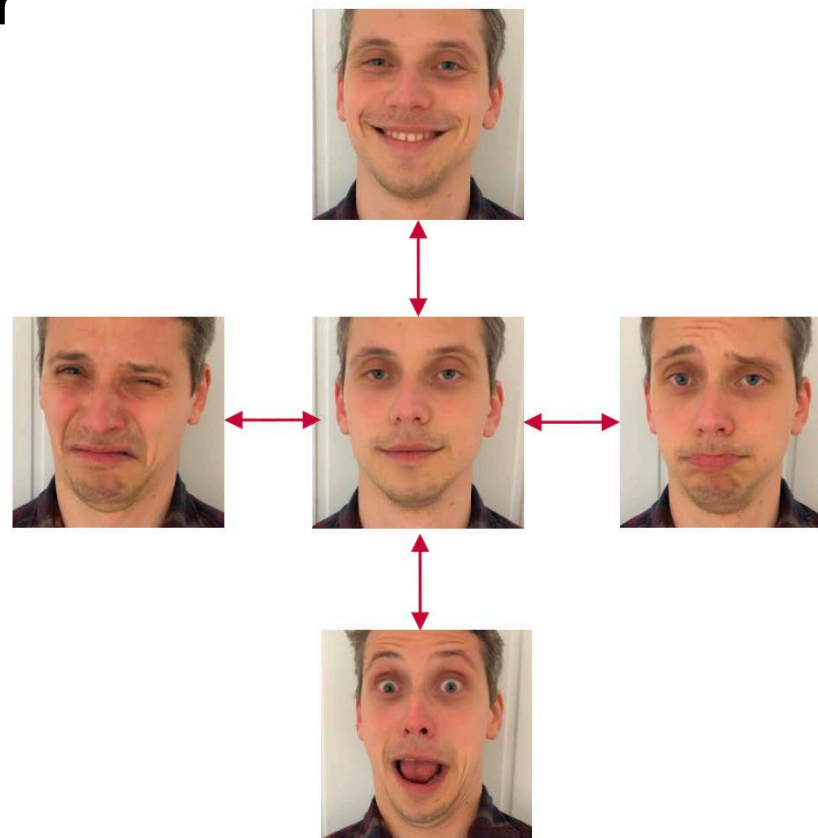
$$\alpha = |G \cap R| / |G|$$

$$Q = \text{ROUND}(100(1 - \alpha))$$

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



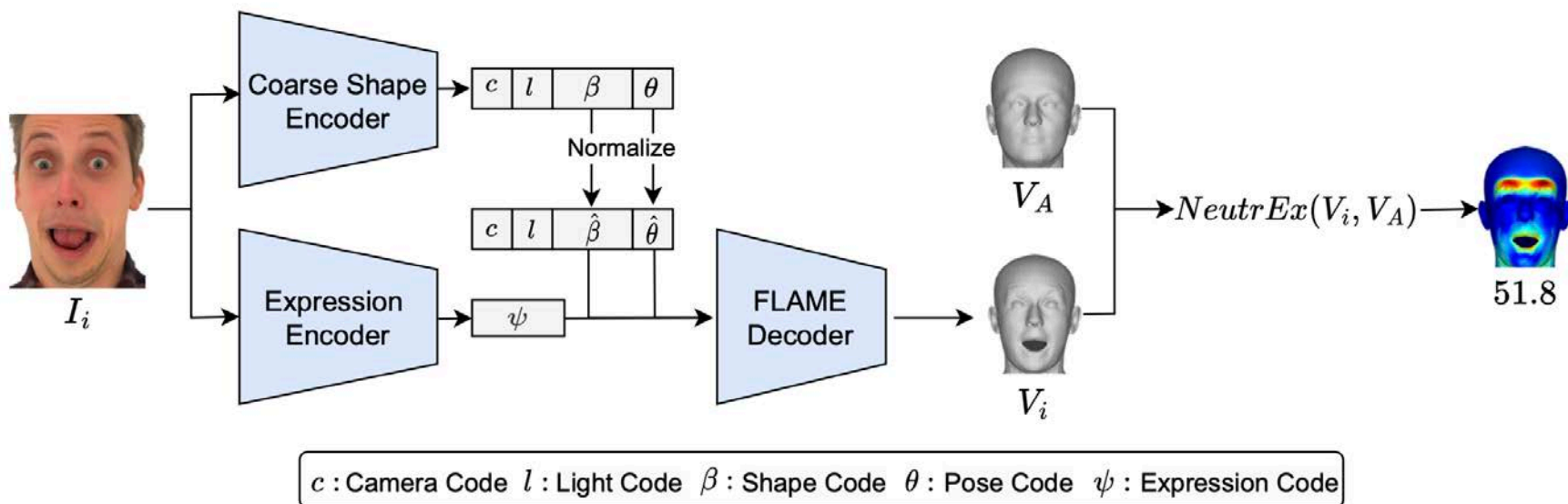
[GRVB2023] M. Grimmer, C. Rathgeb, R. Veldhuis, C. Busch: "NeutrEx: A 3D Quality Component Measure on Facial Expression Neutrality", in Proceedings of International Joint Conference on Biometrics (IJCB), (2023)

[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)

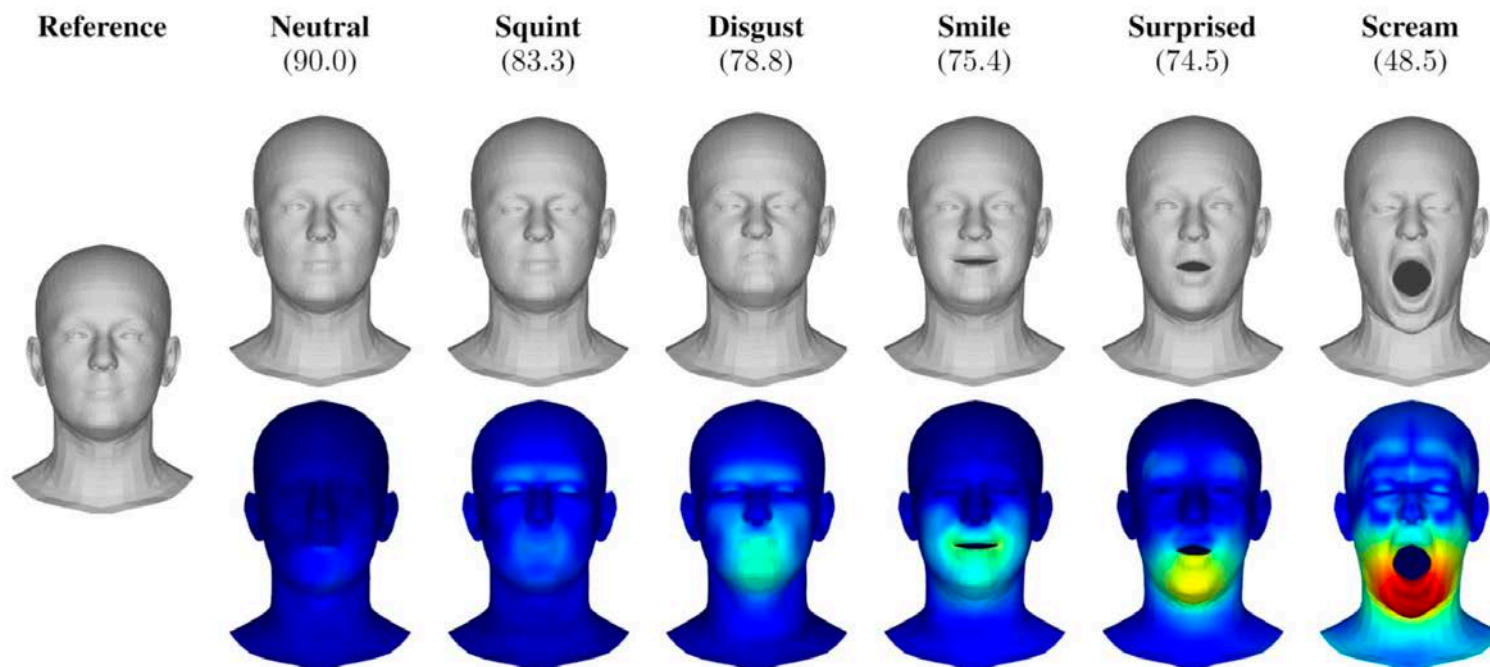


[GRVB2023] M. Grimmer, C. Rathgeb, R. Veldhuis, C. Busch: "NeutrEx: A 3D Quality Component Measure on Facial Expression Neutrality", in Proceedings of International Joint Conference on Biometrics (IJCB), (2023)

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**

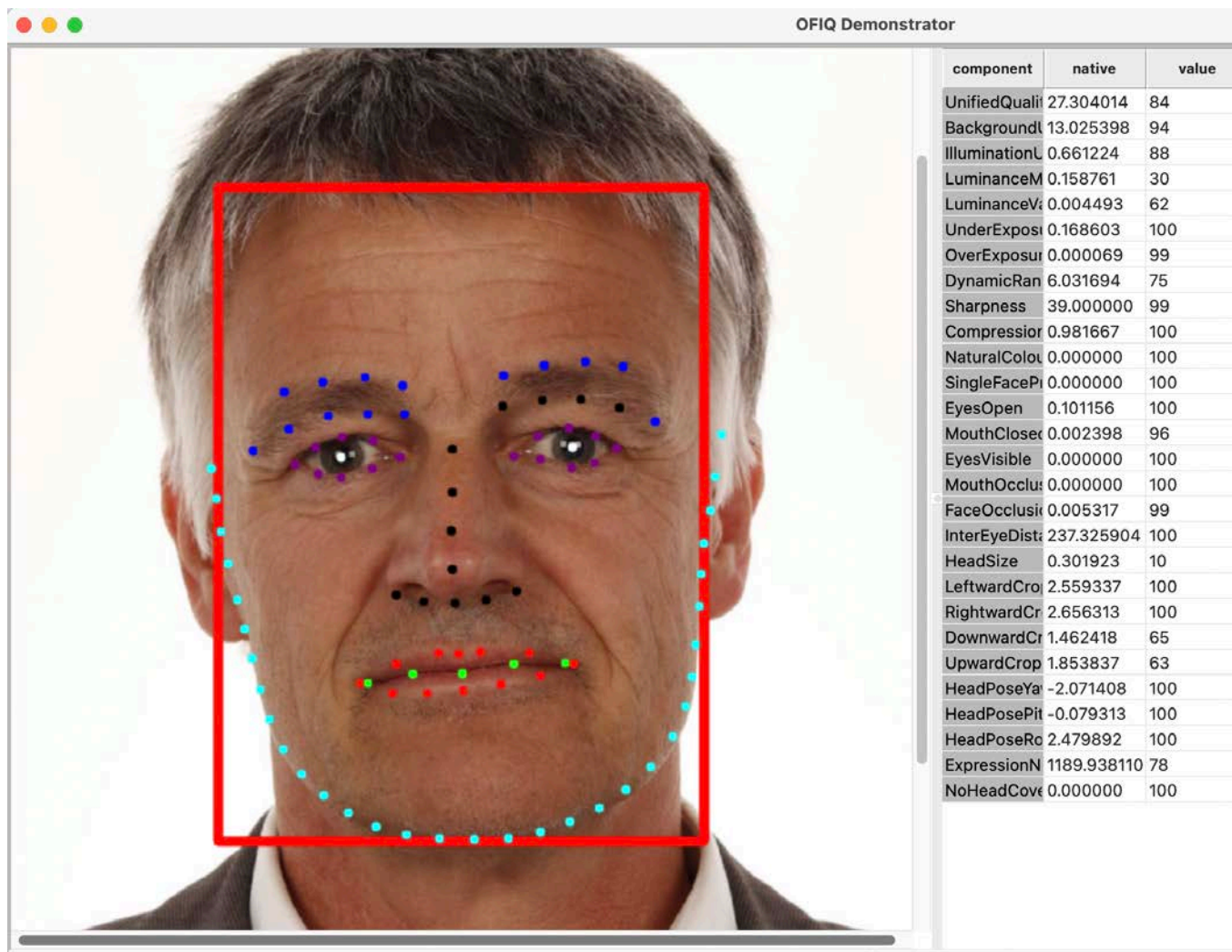


[GRVB2023] M. Grimmer, C. Rathgeb, R. Veldhuis, C. Busch: "NeutrEx: A 3D Quality Component Measure on Facial Expression Neutrality", in Proceedings of International Joint Conference on Biometrics (IJCB), (2023)

OFIQ - Demonstrator

Demonstrator to understand the processing

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



The screenshot displays the OFIQ Demonstrator interface. On the left, a portrait of a man's face is shown with a red bounding box and various colored dots representing facial landmarks. On the right, a table lists quality components, their native values, and their corresponding OFIQ values.

component	native	value
UnifiedQuali	27.304014	84
BackgroundI	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
HeadPosePit	-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 - 2026-07-21:
<https://eab.org/events/program/401>

Fairness of Algorithms



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

Fairness of Biometric Algorithms

What is fairness?

- Dictionary:
*“the quality of **treating** people **equally** or in a way that is right or reasonable”*

An inherently ethical and social concept

- Influenced by cultural, historical, legal, religious, personal, and other factors
- Everyone wants to be treated “fairly”

Reaching out towards **group fairness**

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



Movie Coded Bias - Image Source: Netflix

Fairness of Biometric Algorithms

Possible Consequences of unfair algorithmic (and human) decision systems

- **Differential treatment**
 - ▶ **Definition:** *different set of actions for a biometric enrollee or biometric capture subject based on their demographic group*
<https://www.iso.org/obp/ui/en/#iso:std:iso-iec:19795:-10:ed-1:v1:en>
- Unintentional **discrimination**
- Individual and collective social **harms**
 - ▶ social stigmatisation (e.g. Uigur people in China)



Demographic Factors in Biometrics

Measure and report

- **Demographic differentials**

- ▶ **Definition:** *extent of difference in outcome of a biometric system across socially recognized sectors of the population*

<https://www.iso.org/obp/ui/en/#iso:std:iso-iec:2382:-37:ed-3:v1:en:term:37.09.28>

- **Demographic variables**

- ▶ gender
- ▶ age
- ▶ glasses
- ▶ skin tone



Fitzpatrick Skin Types Image Source: HSBRS, (2016)

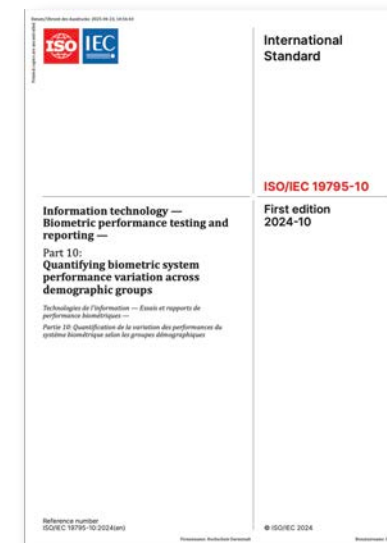
Demographic Effects

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>

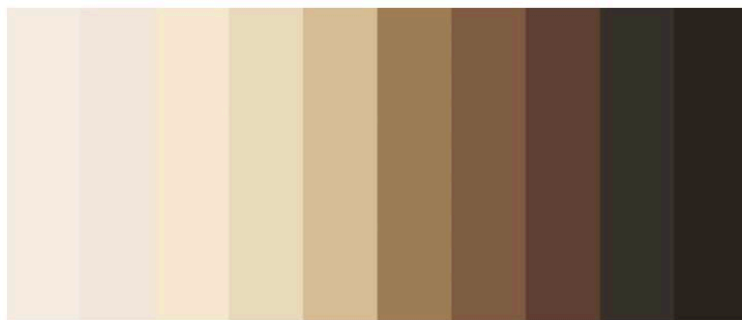


[Droz2020] P. Drozdowski, C. Ratgeb, A. Dantcheva, N. Damer, C. Busch: "Demographic Bias in Biometrics: A Survey on an Emerging Challenge", in IEEE Transactions on Technology and Society (TTS), (2020)

Face Image Quality - Demographic Variability

Research tasks

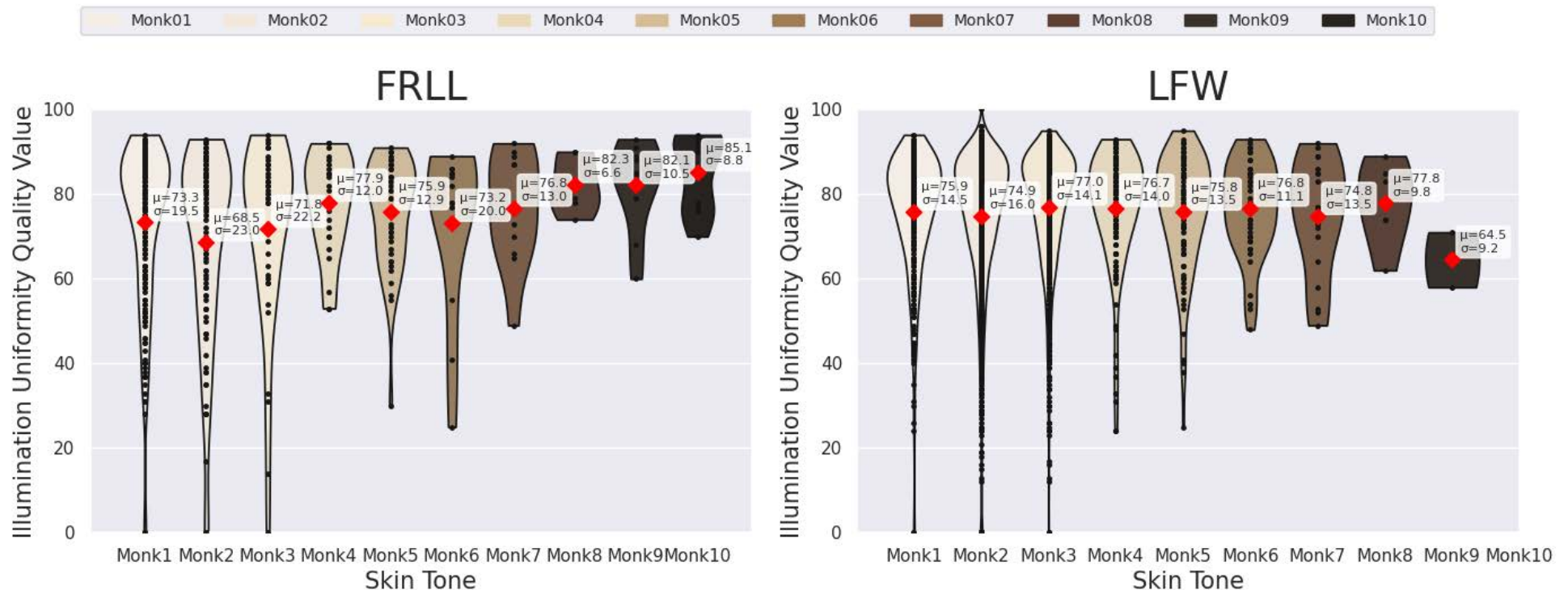
- Investigate **demographic variability** (DV) of quality measures
- Skin tone variation is a **continuous** demographic **variable**
- **Transformation** to **discrete** categories
 - ▶ Monk skin tone scale (MST) vs.
 - ▶ Colorimetric skin ton (CST) vs.
 - ▶ PANTONE Skin Tone (PST)



Face Image Quality - Demographic Variability

Research tasks

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



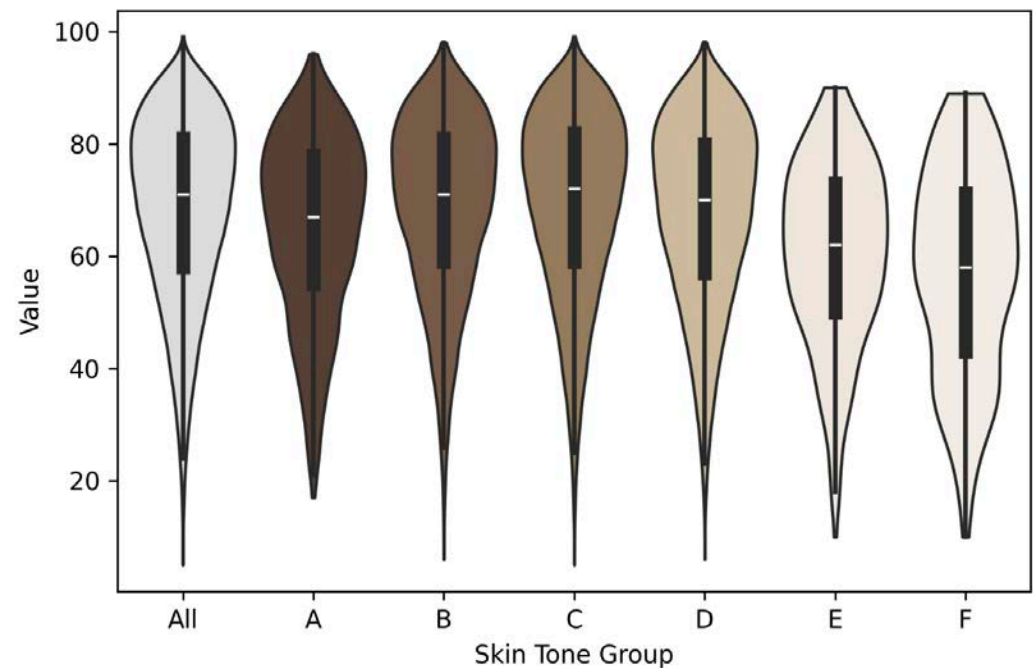
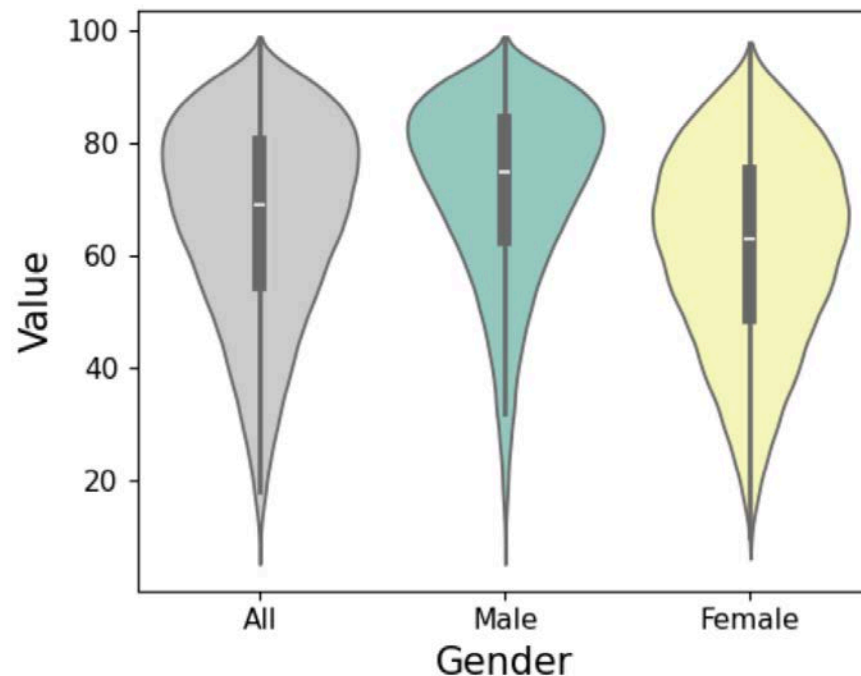
[KRRB2024] W. Kabbani, K. Raja, R. Raghavendra, C. Busch: "Demographic Differentials in Face Image Quality Measures", in Proceedings of the IEEE 23rd International Conference of the Biometrics Special Interest Group (BIOSIG), Darmstadt, September 25-27, (2024)

Face Image Quality - Demographic Variability

Research tasks

- Investigate **variability** across demographic **groups**
 - ▶ **Distribution** of unified quality score (UQS)
 - ▶ Based on operational data 100.000+ images for UC1

Demographic groups		UC1	UC3
Gender	Female	57,133	90,199
	Male	52,391	81,884
Age Group	0-20	5,169	7,534
	20-30:	24,576	37,802
	30-40:	27,878	46,140
	40-50:	18,710	29,702
	50+:	33,191	50,905
Skin Tone	A	1,308	1,410
	B	15,994	16,519
	C	51,954	55,126
	D	38,894	47,104
	E	384	419
	F	240	291
Origin	Africa	39	485
	America	4,616	7,360
	Asia	56,052	99,934
	Europe	45,050	58,435
	Oceania	3,765	5,866

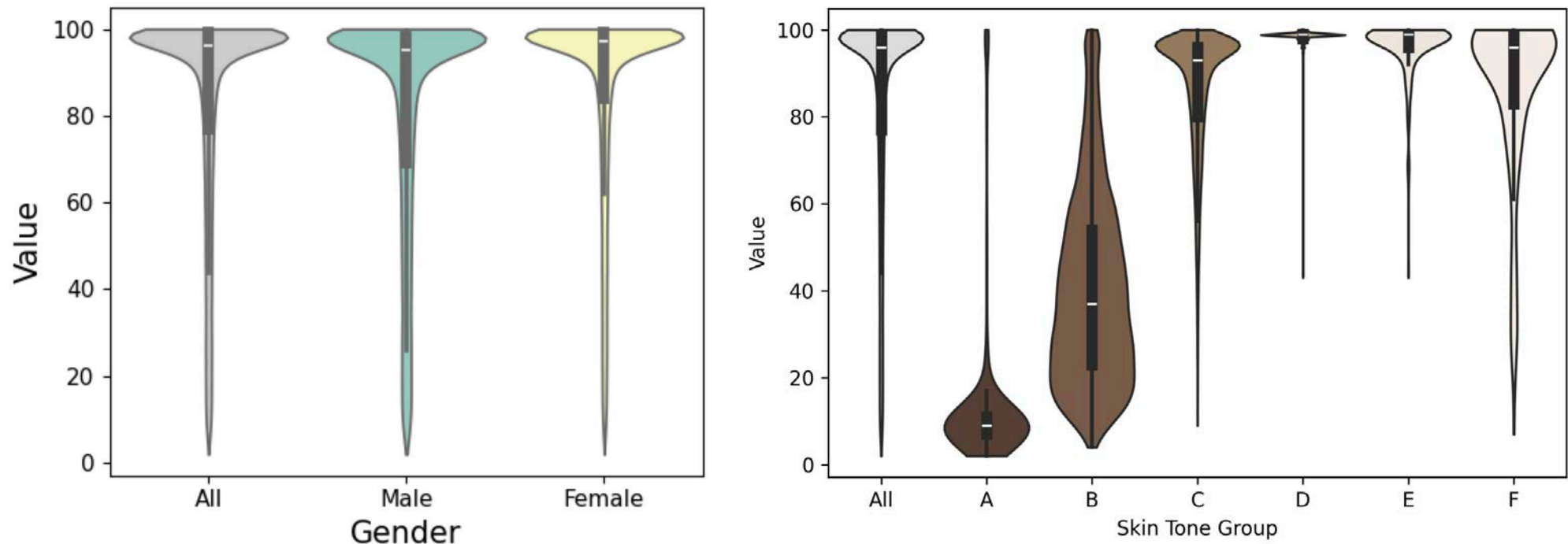


[Utcke2026] S. Utcke et al.: "Demographic Variability of Face Image Quality Measures in Operational Data", in IEEE Access, (2026), <https://ieeexplore.ieee.org/document/11411711>

Face Image Quality - Demographic Variability

Research tasks

- Investigate **variability** across demographic **groups**
 - ▶ **Distribution** of component quality measures (CQM)
Luminance Mean quality component values
 - ▶ Based on operational data 100.000+ images for UC1



[Utcke2026] S. Utcke et al.: "Demographic Variability of Face Image Quality Measures in Operational Data", in IEEE Access, (2026), <https://ieeexplore.ieee.org/document/11411711>

Face Image Quality - Demographic Variability

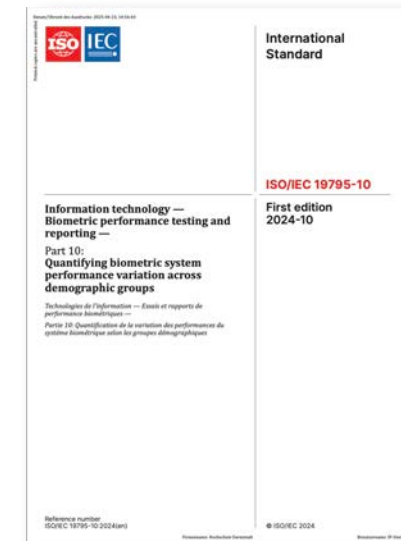
International Standard

- ISO/IEC 19795-10

<https://www.iso.org/standard/81223.html>

- Clause 5.2.1

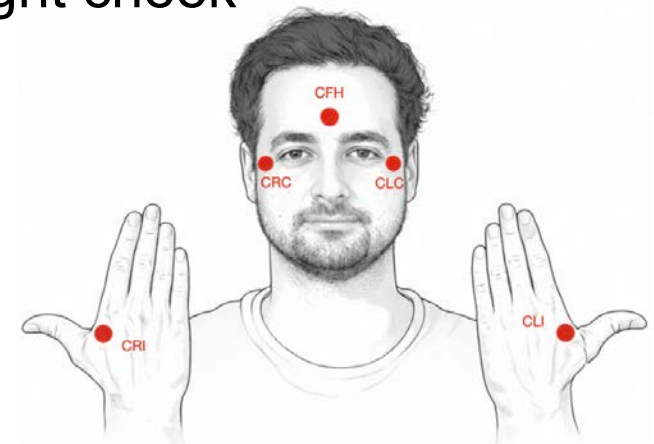
“Demographic group membership should not be inferred directly from biometric samples. An example of this is assigning the value of ethnicity or the value of gender from a face sample”



DArmstadt Skin Tone Dataset (DAST)

Ground truth skin tone **measurement**

- Handheld DSM-4 **colorimeter**
 - ▶ measures a skin area of approximately 50 mm² under standardised D65 illumination generated by four light-emitting diodes.
 - ▶ Skin color is quantified using diffuse reflectance spectroscopy
- **Locations** of colorimeter measurements
 - ▶ CFH: Colorimeter measure forehead of the face
 - ▶ CLC: Colorimeter measure forehead of the left cheek
 - ▶ CRC: Colorimeter measure forehead of the right cheek
 - ▶ CLI: Colorimeter measure left hand
 - ▶ CRI: Colorimeter measure right hand



[Busch2026] C. Busch et al.: A Skin Tone Annotated Face Image Dataset for Studying Demographic Variability", in Proceedings of 14th International Workshop on Biometrics and Forensics (IWBF), (2026)
<https://christoph-busch.de/files/Busch-DAST-IWBF-2026.pdf>

DArmstadt Skin Tone Dataset (DAST)

Ensure **homogeneous illumination**

- Compliant with ISO/IEC 39794-5:2019, Annex E
- Nanlite SBPR90Q and Sirui Quick Release softboxes

Capture devices

- Canon EOS 50D (3,168×4,752 px) equipped with a Canon EF-S 18–200 mm f/3.5–5.6 IS lens
- Sony ILCE-7M2 (4,000×6,000 px) equipped with a FE 90 mm F2.8 Macro G OSS lens.



DArmstadt Skin Tone Dataset (DAST)

Exposure Levels

- **Examples of** 12 face images per subject in different illumination conditions
 - ▶ 2 cameras
 - ▶ 5 exposure levels

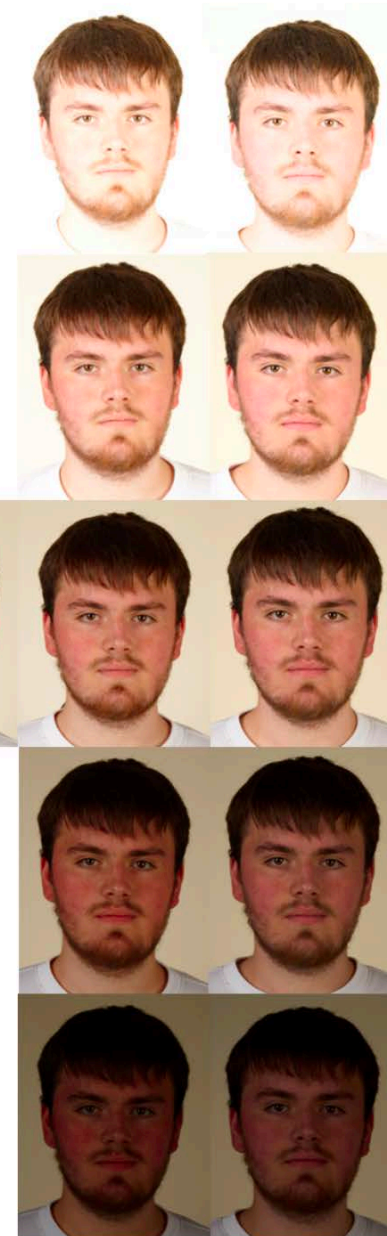


TABLE II: Number of subjects per gender and skin tone class

Gender	CST classes									
	1	2	3	4	5	6	7	8	9	10
Male	0	4	8	9	9	8	6	9	8	0
Female	2	6	2	1	1	2	4	1	0	0

TABLE I: Settings for face image acquisition.

EL	Flash settings	Camera settings
EL1	small SB 1/8 +0.3 large SB 1/8 BG 1/64	SS 1/100 iso 100 F16
EL2	small SB 1/8 +0.3 large SB 1/8 BG 1/64	SS 1/100 iso 100 F22
EL3	small SB 1/8 +0.3 large SB 1/8 BG 1/64	SS 1/100 iso 100 F11
EL4	small SB 1/4 +0.3 large SB 1/4 BG 1/32	SS 1/125 iso 100 F11
EL5	small SB 1/2 +0.3 large SB 1/2 BG 1/16	SS 1/160 iso 100 F11

SB: Softbox, BG: Background, SS: Shutter speed

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

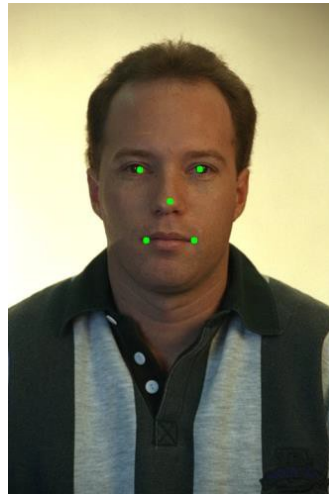
(Pre-) processing

- Face detection, landmarks, cropping and blurring

Original - RGB



Detect landmarks



Crop and change to 112x113 px



Monochrome



Blur -
outside ROI



Compress

- Compression



JPEG



2000



XL



AI



HEIF

webp

Compact Face Image Encoding

Encoding options:

- ISO/IEC 10918 JPEG
- ISO/IEC 15444 JPEG 2000
- ISO/IEC 18181 JPEG-XL
- ISO/IEC 6048-1 JPEG AI
- ISO/IEC 23008-12 HEIC
- ISO/IEC 23000-22 AVIF
- WEBP Image Format IETF RFC 9649 2024-11-12

Impact of encoding?

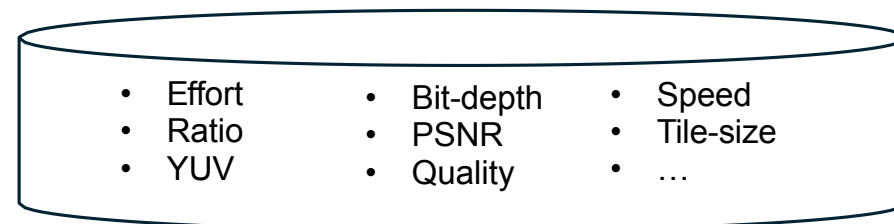
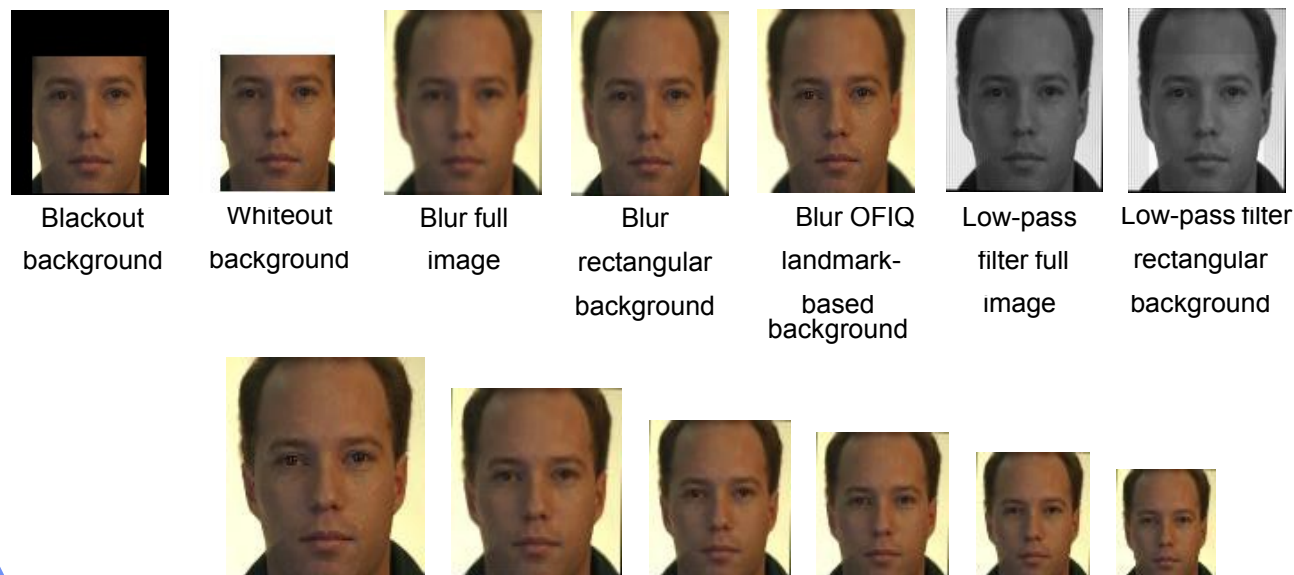
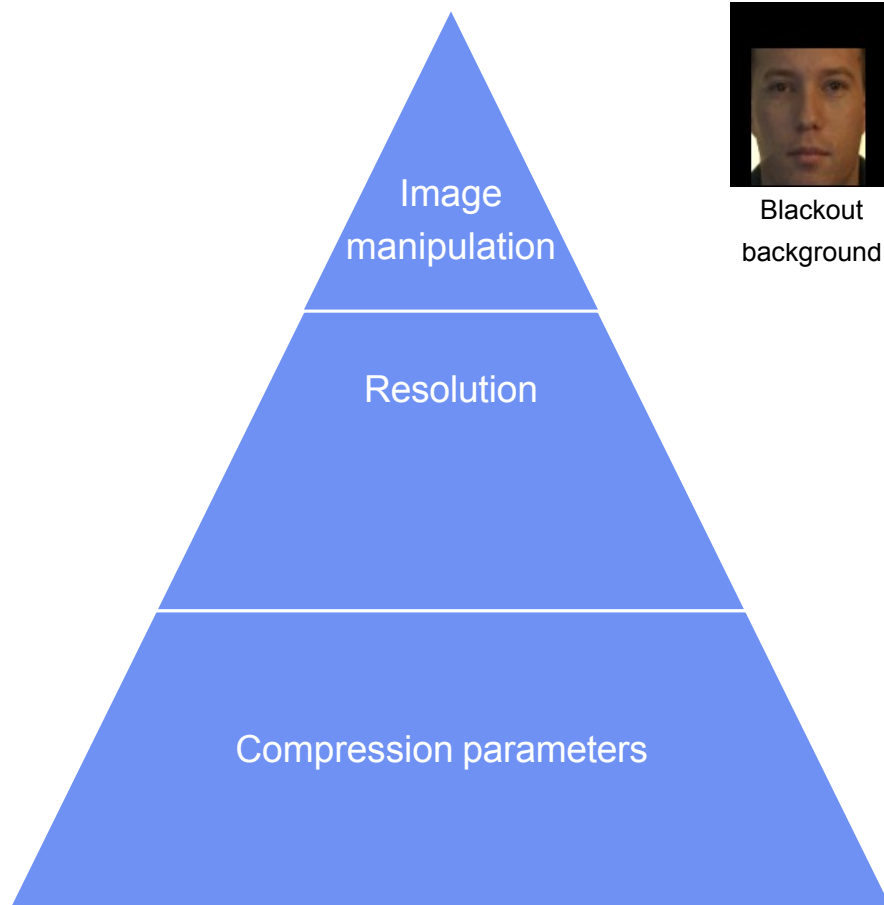


[Schlett2023] T. Schlett, S. Schachner, C. Rathgeb, J. Tapia, C. Busch: "Effect of Lossy Compression Algorithms on Face Image Quality and Recognition", in Proceedings of the International Conference on Acoustics, Speech and Signal Processing (ICASSP), Rhodes Island, GR, June 4-10, (2023)

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

Compact Face Image Encoding

Optimisation

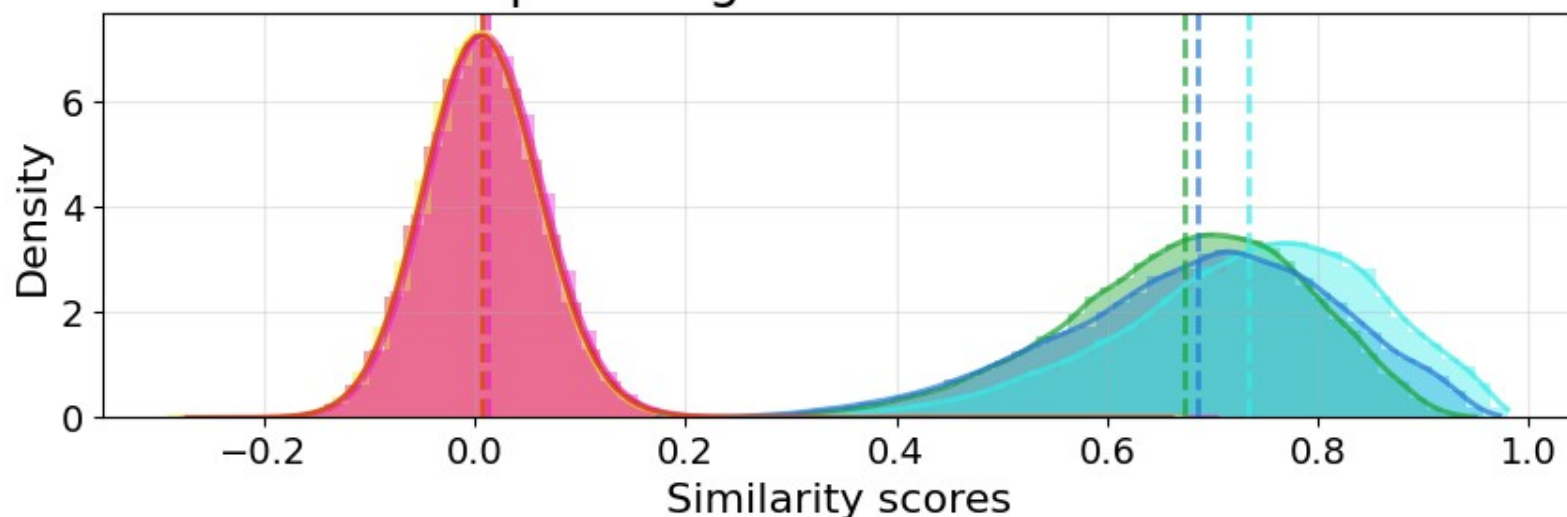


[Busch2026] P. Andreas, T. Schlett, C. Busch: "Optimizing Lossy Image Compression for Face Recognition within 1024 Bytes", in Proceedings of 14th International Workshop on Biometrics and Forensics (IWBF), (2026)
<https://christoph-busch.de/files/Andreas-FRwith1kB-IWBF-2026.pdf>

Compact Face Image Encoding

Results - score distributions

Development of the similarity score distributions of JPEG AI compared against the full dataset



- Mated similarity scores of original color images ($\mu=0.7343$, $\sigma=0.1214$)
- Mated similarity scores of compressed color images ($\mu=0.6726$, $\sigma=0.1149$)
- Mated similarity scores of compressed grayscale images ($\mu=0.6858$, $\sigma=0.1300$)
- Non-mated similarity scores of original color images ($\mu=0.0112$, $\sigma=0.0556$)
- Non-mated similarity scores of compressed color images ($\mu=0.0061$, $\sigma=0.0552$)
- Non-mated similarity scores of compressed grayscale images ($\mu=0.0074$, $\sigma=0.0557$)

Compact Face Image Encoding

Results on the FERET dataset

Compression algorithm	Settings used	FNMR in % at FMR = 0.01%	False non-matches in total
No compression (baseline)	Color, resolution = 112	0.0100	4
AVIF	YUV format=420, speed=1, color, resolution = 56, rectangle blur	0.0151	6
WebP	Method = 6, SNS = 40, color, resolution = 64, rectangle blur	0.0176	7
JPEG AI	Color, resolution = 180, OFIQ blur	0.0201	8
JPEG XL	Quality, effort = 10, color, resolution = 64, rectangle blur	0.0251	10
JPEG 2000	Ratio, number of resolutions = 3, color, resolution = 56, rectangle blur	0.0251	10
HEIF	Chroma downsampling = average, color, resolution = 96, rectangle blur	0.0276	11
JPEG	Gray, arithmetic, smooth = 50, grayscale, resolution = 96, rectangle blur	0.0878	35

- 39,857 mated similarity scores
- 29,301,902 non-mated similarity scores

Compact Face Image Encoding

Impact of Lossy Image Compression

- Perceptual quality



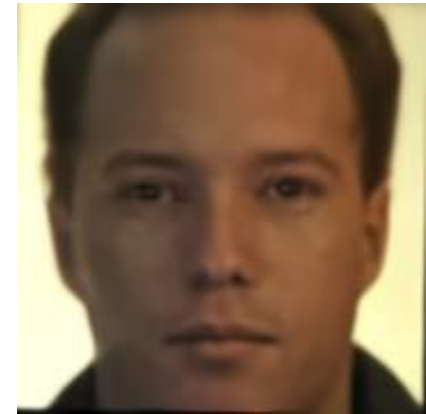
original



AVIF



WebP



JPEG AI

Compact Face Image Encoding

Get involved in the standardisation process



ISO/IEC JTC 1/SC 37/WG 3 N 1858

ISO/IEC JTC 1/SC 37/WG 3 "Biometric data interchange formats"

Convenorship: DIN

Convenor: Busch Christoph Mr Prof. Dr.



1st WD 59794-5 Information technology — Compact biometric samples for 2D barcodes — Part 5: Face image data

Document type	Related content	Document date	Expected action
Project / Draft	Project: ISO/IEC AWI 59794-5	2026-03-03	COMMENT/REPLY by 2026-05-24

- Contact details

- ▶ <https://www.iso.org/about/members>

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

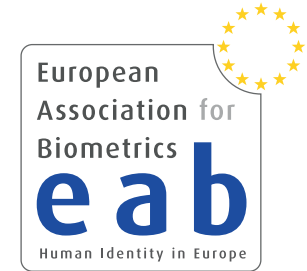


[B2024] C. Busch: "Challenges for Automated Face Recognition Systems", in Nature Reviews Electrical Engineering, (2024), <https://christoph-busch.de/files/Busch-NatureReview-ChallengesFRS-2024.pdf>

More Information on Biometrics

European Association for Biometrics (EAB)

- The EAB is a **non-profit**, nonpartisan **association**
<https://eab.org/>
- **EAB** supports all sections of the ID community across Europe, including **governments**, NGO's, **industry**, associations and special interest groups and **academia**.
- EAB role is to promote the **responsible use** and adoption of modern **digital identity systems** that enhance people's lives and drive economic growth.
- **Free membership** for master and PhD students!
https://eab.org/membership/types_of_membership.html



Questions and Answers?

Take home information:

- Face image quality website:
<https://christoph-busch.de/projects-ofiq.html>
- Fingerprint image quality website:
<https://www.christoph-busch.de/projects-nfiq2.html>
- Morphing attack detection website:
<https://christoph-busch.de/projects-mad.html>
- Standards website:
<https://www.christoph-busch.de/standards-sc37wg3.html>



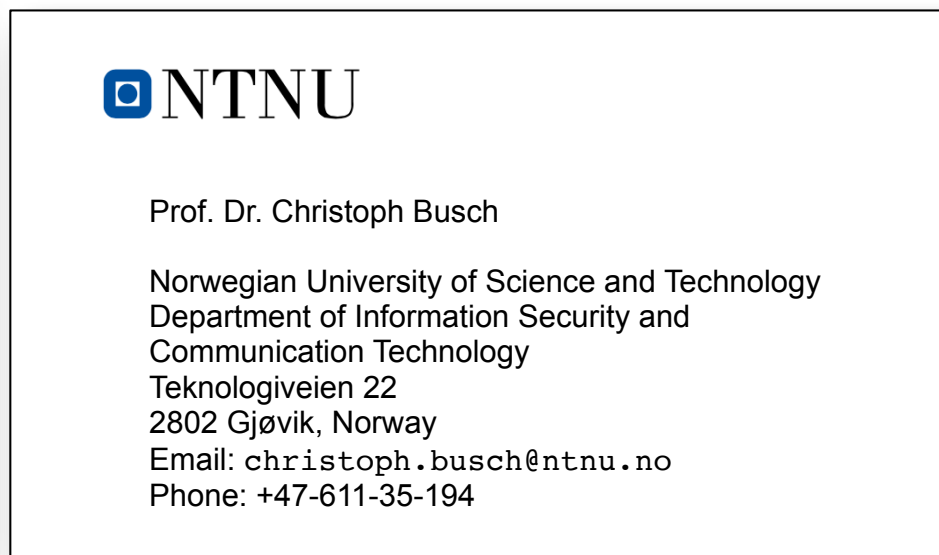
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