Latest Developments in Face Image Quality

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

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European Association for Biometrics eab Human Identity in Europe

iMARS image manipulation attack resolving solutions

NTNU

Agenda and Disclaimer

Agenda

- Motivation for Biometric Sample Quality in iMARS
- Biometric quality standards developed in SC37
- ISO/IEC 29794-5
- Open source face image quality (OFIQ)
  - Neutral expression

Disclaimer

- This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 883356
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Motivation for Quality Assessment

Motivation for Face Image Quality Assessment (FIQA)

- Quality matters, especially in large-scale databases and with diverse application scenarios.
  - The European Entry Exit System will start soon
- Standardization and harmonization is essential for (semantic) interoperability.

Objectives of iMARS research on FIQA

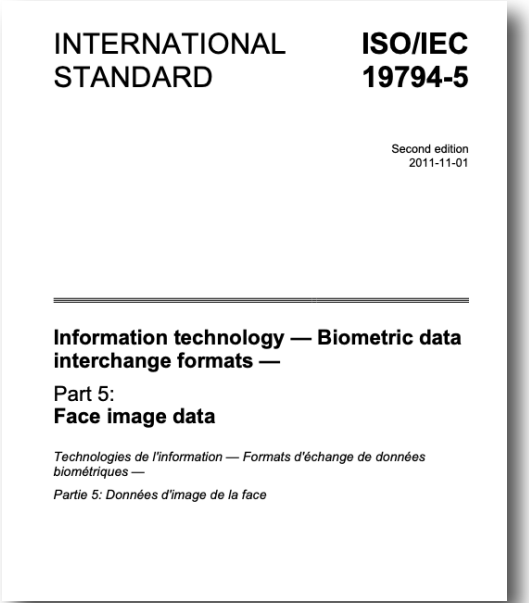
- Research: "*Benchmark the impact of face image quality on biometric recognition performance and morphing attack detection and propose appropriate metrics to assess the quality of facial images*"
- iMARS Work package 11

Face Image Quality in the EES

The objective in the EES implementing decision 2019/329

- *„The quality of the facial images, … and with the image requirements of ISO/IEC 19794-5:2011 Frontal image type*

What does that mean?


INTERNATIONAL STANDARD

ISO/IEC 19794-5

Second edition
2011-11-01

Information technology — Biometric data interchange formats —

Part 5:
Face image data

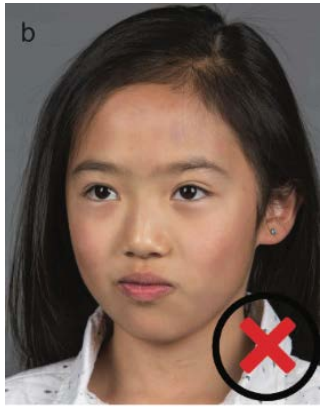
Technologies de l'information — Formats d'échange de données biométriques —

Partie 5: Données d'image de la face

Data subjects need actionable feedback

- If quality is poor, then what went wrong?

Compliant image



Pose

Eyes open

Mouth open

Inhomogenous background

Source: ISO/IEC 39794-5

Quality Measures for Facial Images

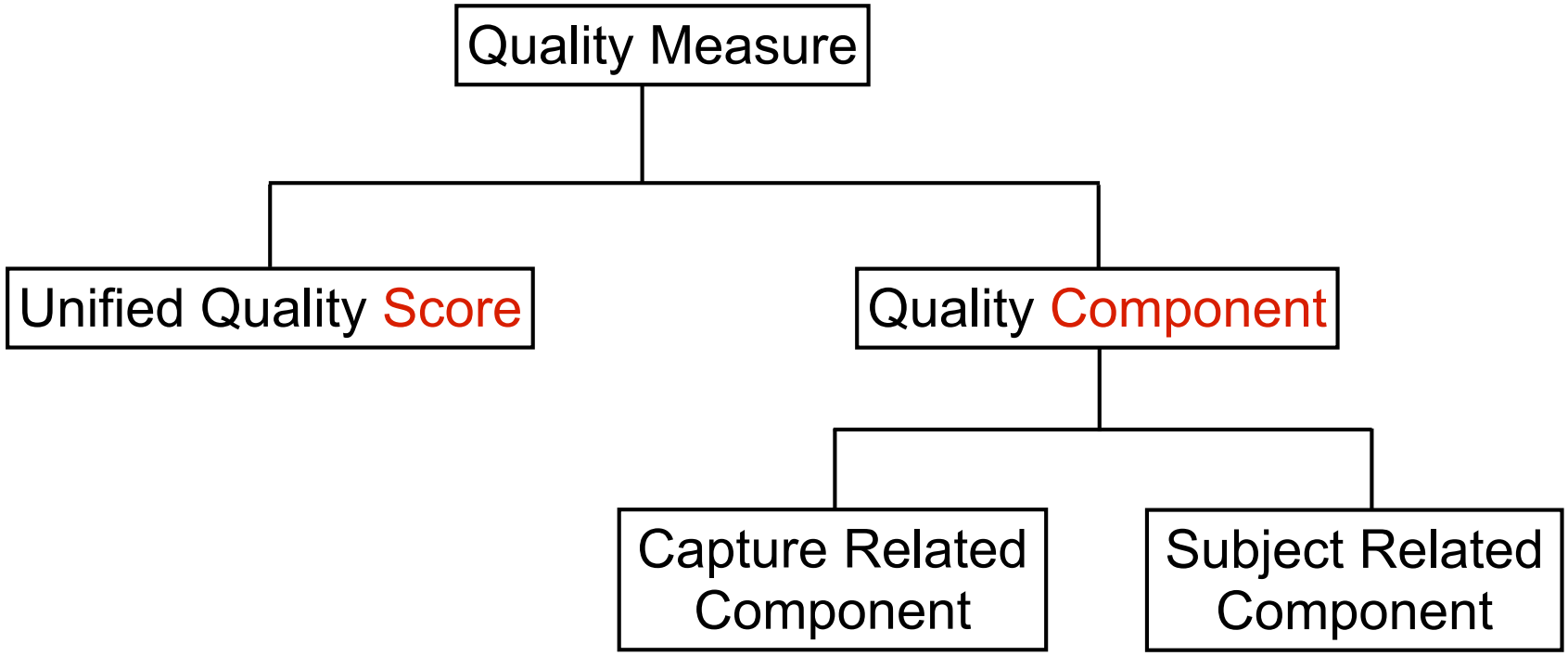
How to develop face quality measures? - Standardisation

- 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
- Final Draft International Standard (FDIS)
- 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



- Higher quality scores imply higher biometric utility

ISO/IEC 29794-5: Face Image Quality

ISO/IEC FDIS 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

Capture device related

a) Compliant image b) Low contrast

Image Source: ISO/IEC 39794-5

Explainable Quality Assessment

Subject related

Image Source: ISO/IEC 39794-5

Image Source:ISO/IEC FDIS 29794-5

Open Source Face Image Quality (OFIQ)

Approach

- Library with quality assessment algorithms
- Open source
  - enables commercial use
- Support for major OS platforms (including mobile OS)
  - C/C++
- Aligned with ISO/IEC 29794-5
  - serves as reference implementation
  - providing target values for conformance tests
- Selection criteria for integrated algorithms
  - accuracy (NIST FATE SIDD evaluation)
  - low computational complexity
  - liberal license (MIT or alike)

Quality Measures for Facial Images

How to find the best face quality measures?

- 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	Face count
	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	-

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

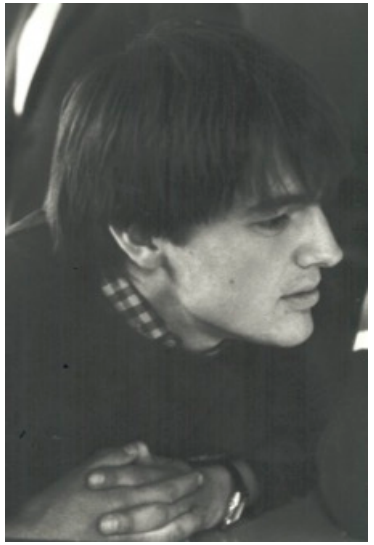
General, holistic unified quality score (OFIQ-UQS)

- Not limited to certain quality criteria / defects
- CNN MagFace (iResNet 50 model)
- Shows good prediction of face recognition scores

OFIQ-UQS=84

OFIQ-UQS=61

OFIQ-UQS=26

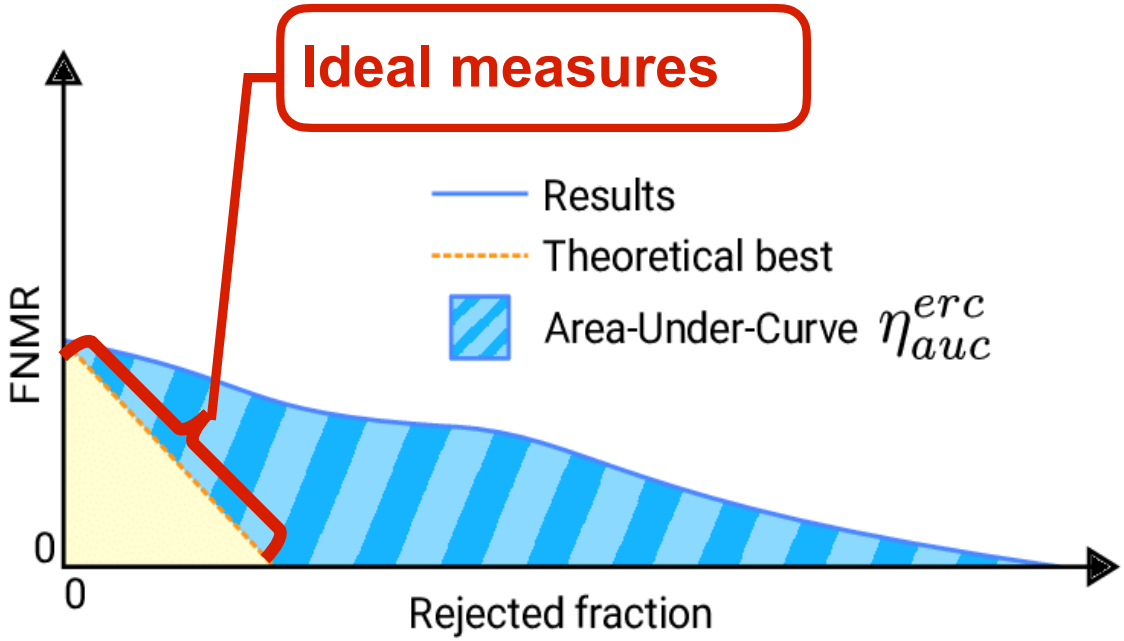


OFIQ-UQS=7

OFIQ - Unified Quality Score

Prediction of low face recognition scores

- OFIQ is the best performing algorithm in Error versus Discard Characteristic (EDC) curve
  - How much is the FNMR reduced, when poor images are discarded/rejected?
  - Answer to our question: "*Benchmark the impact of face image quality on biometric recognition performance* …"



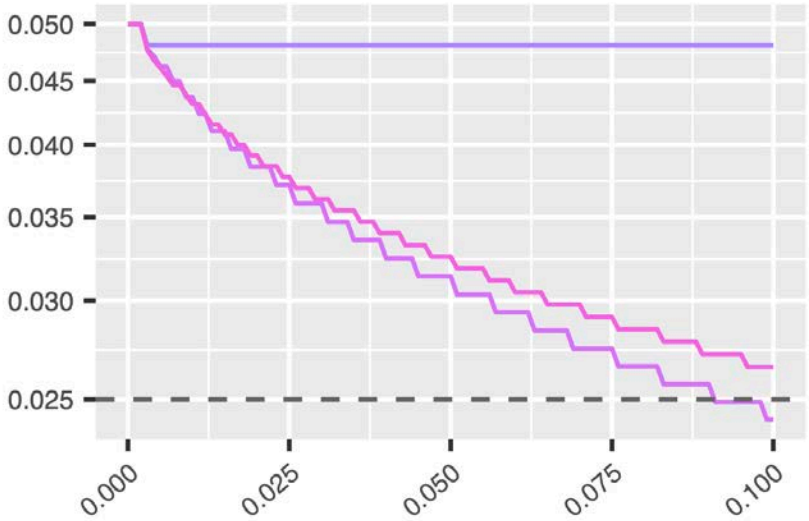


Image Source:NIST FATE SIDD report

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)

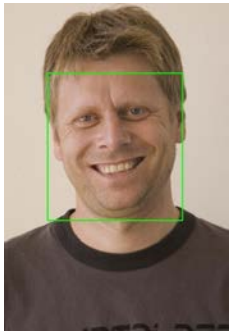
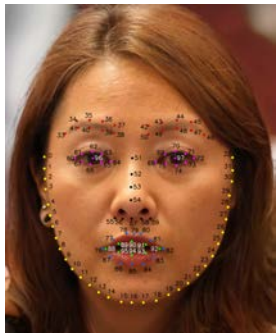
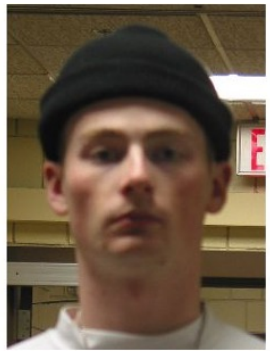




Image Source: OFIQ public report and ISO/IEC FDIS 29794-5

OFIQ - Quality Components

Example algorithm: Sharpness

- Is the capture device in focus on the capture subject?



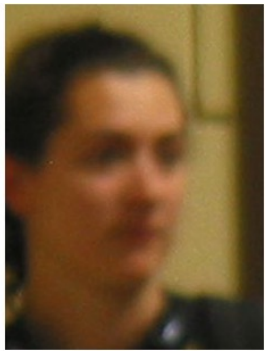


Image Source: FRGCv2 database

- Restricted to landmarked region
- Several filters were combined:
  - Sobel-Filter
  - Laplace filter
  - Difference of image from mean-filtered image
- Random Forest classifier
- Trained on synthetic and real blur

Image Source: OFIQ public report

OFIQ - Quality Components

Example algorithm: Mouth Closed

- Algorithms based on landmarks
- Maximum distance between lips

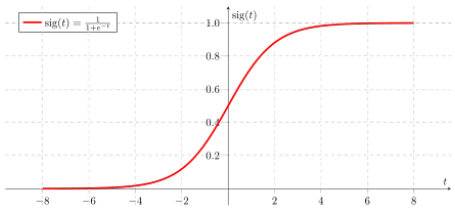
$$D_L = \max\left(\|L_{89} - L_{95}\|_2, \|L_{90} - L_{94}\|_2, \|L_{91} - L_{93}\|_2\right)$$

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

$$T = \left\| \frac{L_{60} + L_{64} + L_{68} + L_{72}}{4} - L_{16} \right\|_2$$

- Mouth openness aspect $\omega = \frac{D_L}{T}$

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



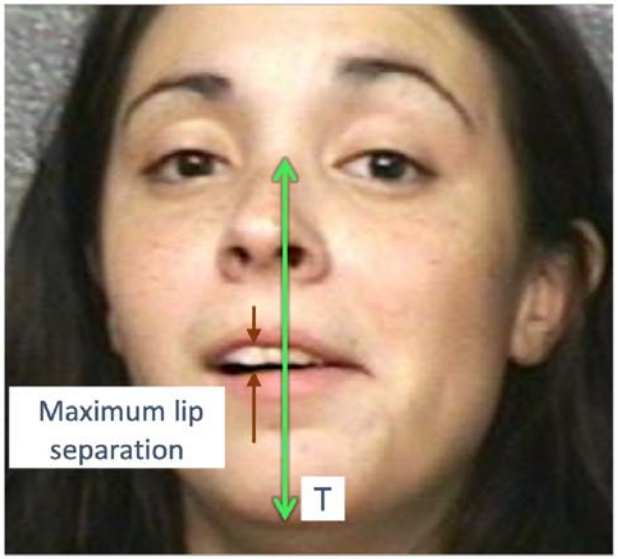


Image Source:NIST FATE SIDD report

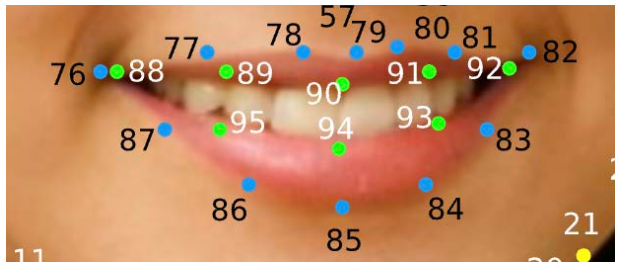
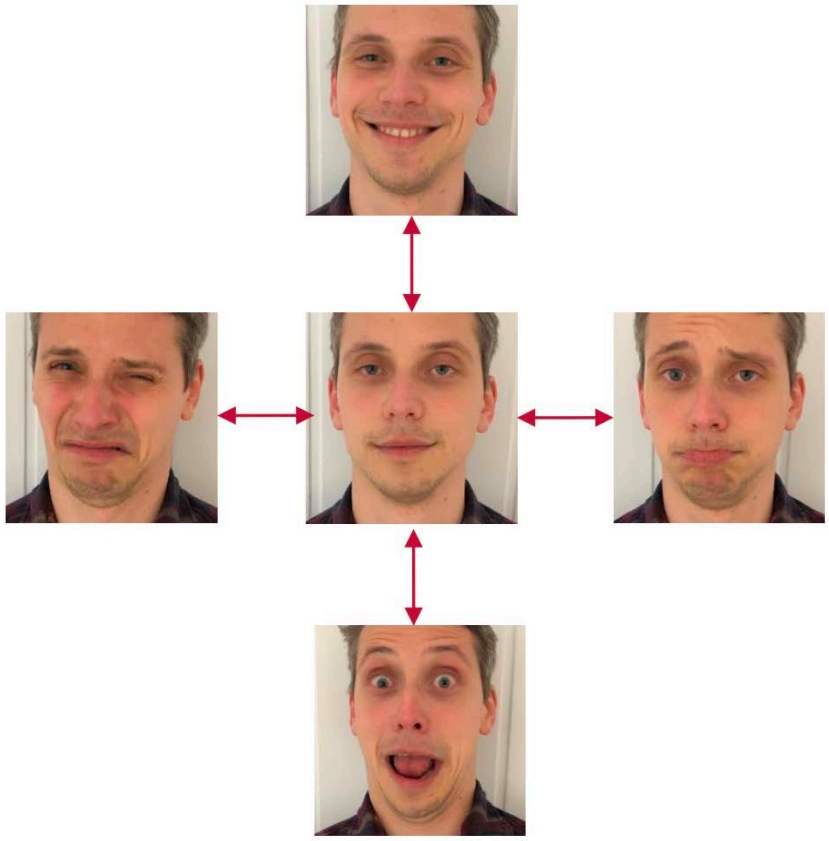


Image Source:ISO/IEC FDIS 29794-5

OFIQ - Quality Components

Example algorithm: Expression Neutrality

- Reduced biometric performance for extreme facial expressions
- Known fact:
  - best-possible utility through neutral expressions
- Goal:
  - quantify expression neutrality



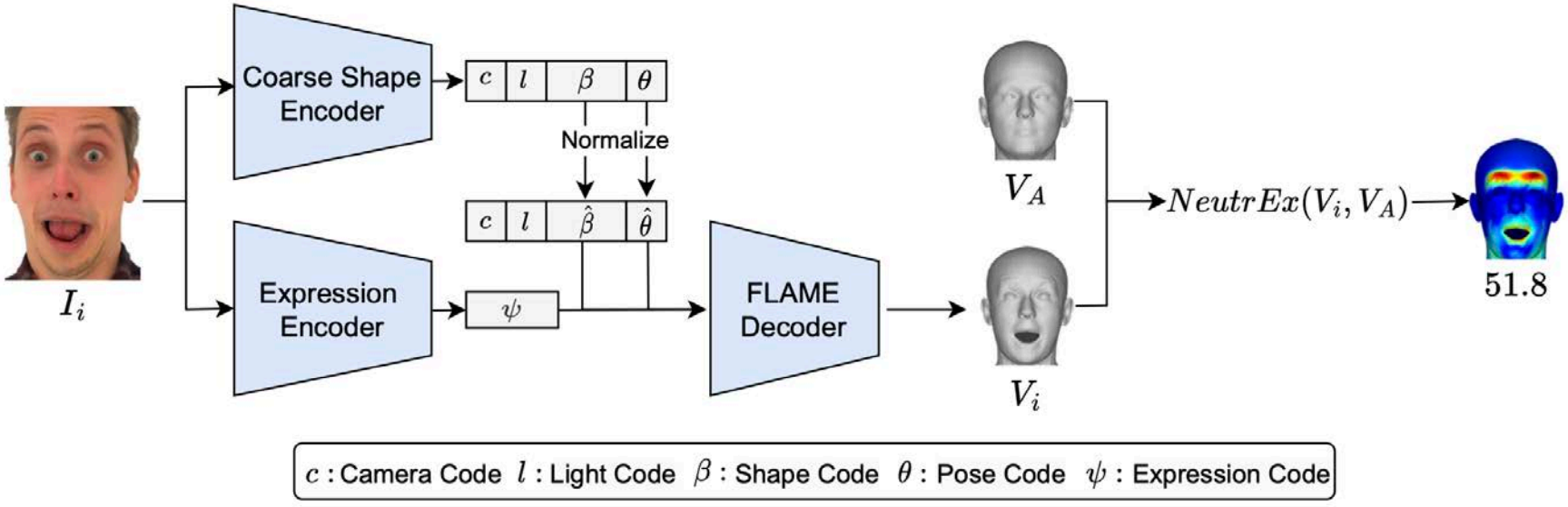
[GRVB2023] M. Grimmer, C. Rathgeb, R. Veldhuis, C. Busch: "NeutrEx: A 3D Quality Component Measure on Facial Expression Neutrality", in Proceedings of International Joint Conference on Biometrics (IJCB), (2023)

[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)



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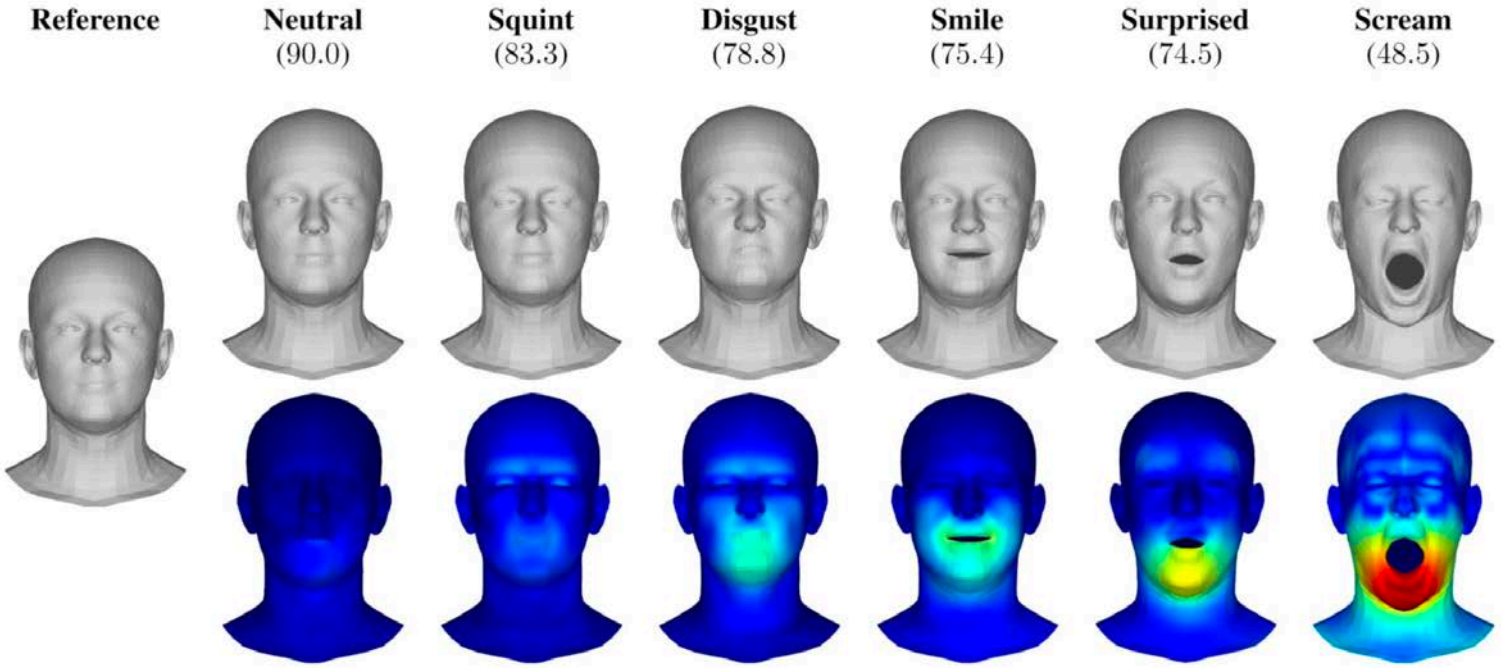
OFIQ - Quality Components

Example algorithm: Expression Neutrality

- Cumulative 2-Norm Distances: $D(V_i, V_A) = ||V_i - V_A||_2$
- NeutrEx Measure: $\text{NeutrEx}(V_i, V_A) = 100 \cdot (1 - \frac{D(V_i, V_A) - D_{min}}{D_{max} - D_{min}})$
- 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)

Face Image Quality Impact on MAD

Quality of gate images

- Research: "*Benchmark the impact of face image quality on … morphing attack detection …*"
- Impact measured in terms of $\Delta_{\text{D-EER}}$

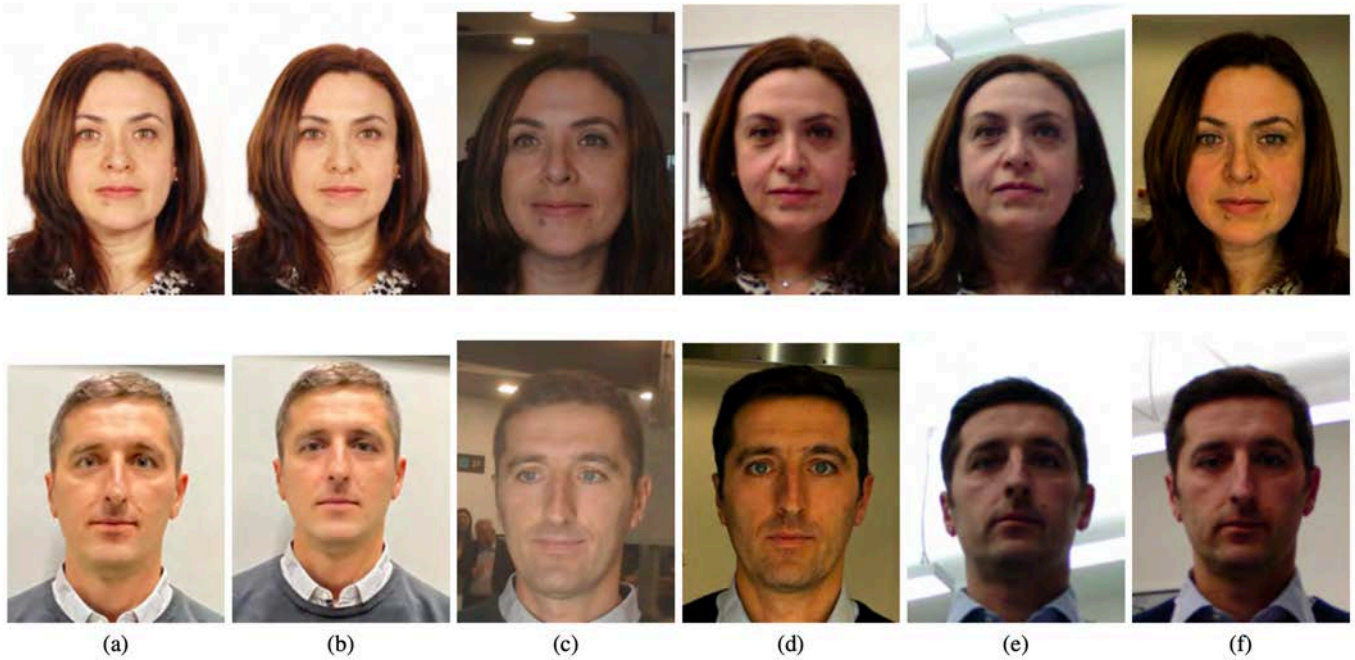


Figure 1. Example of images contained in the iMARS MQ database for two different subjects. For each row, bona fide, morphed and gate images are reported in the first (a), second (b) and last four (c-f) columns, respectively.

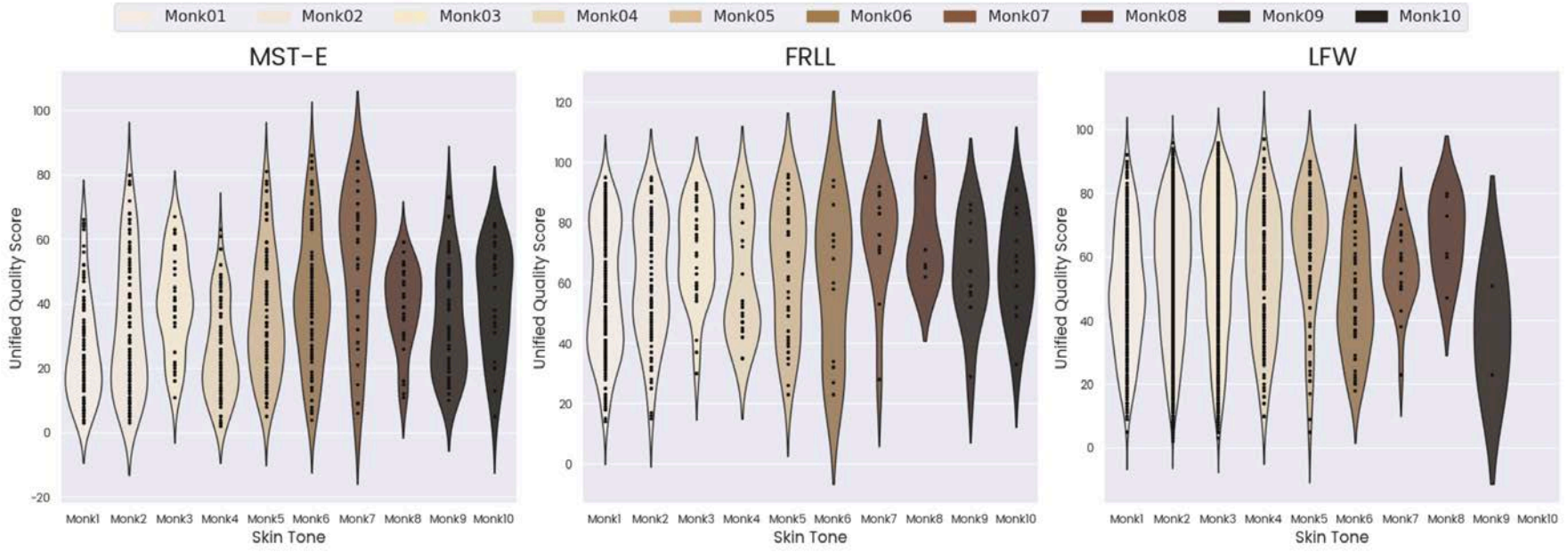
Measure	*Demorphing*
Illumination	**-12.60%**
Defocus	**-27.68%**
Pitch	**-41.11%**
Yaw	**-25.74%**
Shadows	11.13%

[FFLBM2024] A. Franco, M. Ferrara, C. Liu, C. Busch, D. Maltoni: "On the Impact of Face Image Quality on Morphing Attack Detection", in Proceedings of International Joint Conference on Biometrics (IJCB), Buffalo, US, September 15-18, (2024)

Future work

Open research tasks

- Further innovation of quality measures
- Add missing components (e.g. motion blur)
- Investigate demographic variability
  - Unified quality score distributions across MST 10 skin tone scale



[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)

Summary and Outlook

Summary

- Face image quality assessment is possible with algorithms
- Better image quality leads to better recognition performance
- Better image quality leads to better morphing detection

Status of OFIQ

- OFIQ is the reference implementation of ISO/IEC 29794-5
- Maintenance of OFIQ ⟶ eu-LISA

Perspective

- First operational use cases:
  - Entry-Exit-System (EES) enrolment at German airports
  - eu-LISA USK

Questions and Answers?

Take home information

- OFIQ open source code:
  https://github.com/BSI-OFIQ/OFIQ-Project
- Image Source: 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