

# A Skin Tone Annotated Face Image Dataset for Studying Demographic Variability

**Christoph Busch**, Paul Kibler, Fabian Stockhardt, Christian Rathgeb

da/sec @ Hochschule Darmstadt

<https://christoph-busch.de>

<http://www.dasec.h-da.de>

2026-04-23



**da/sec**  
BIOMETRICS & SECURITY  
RESEARCH GROUP

**h\_da**  
hochschule  
darmstadt



# Fairness in Biometrics

## 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
- no single, universal notion or definition of fairness in practice
- however, everyone wants to be treated “fairly”

Reaching out towards **group fairness**



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

# Demographic Factors in Biometrics

## 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
- ▶ skin tone
- ▶ glasses



Fitzpatrick Skin Types Image Source: HSBRS, (2016)

# Demographic Factors in Biometrics

## Reach fairness

- Measure bias
- Develop **bias mitigation** techniques

## Biometric algorithms

- Recognition
- Presentation attack detection
- Morphing attack detection
- **Sample quality**

## Approach

- Semi-synthetic face images
- **Create dataset with real face images**  
with strong skin tone variation

# ISO/IEC 29794-5: Face Image Quality

## Standardize and develop quality measures

- <https://www.iso.org/standard/81005.html>
- <https://github.com/BSI-OFIQ/OFIQ-Project>
- <https://christoph-busch.de/projects-ofiq.html>

## Open Source Face Image Quality (OFIQ)

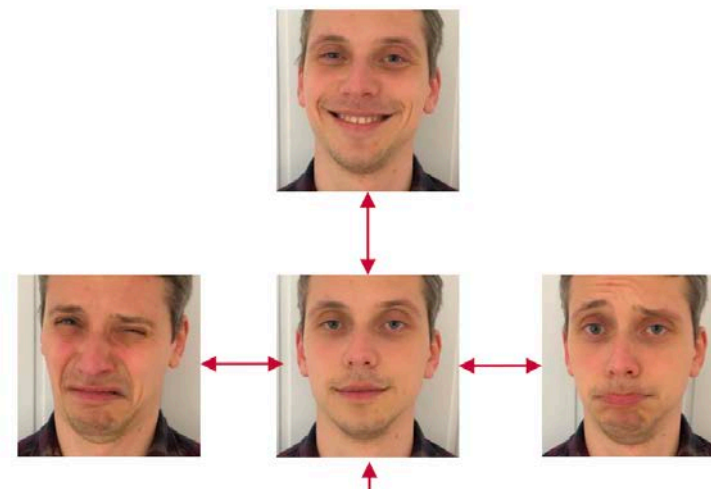
- **Unified** quality **score** (UQS)
- **Capture-related** quality measures
- **Subject-related** quality measures
  - ▶ Quantify **expression** neutrality



a) Compliant image

b) Low contrast

source: ISO/IEC 39794-5:2019, Annex D



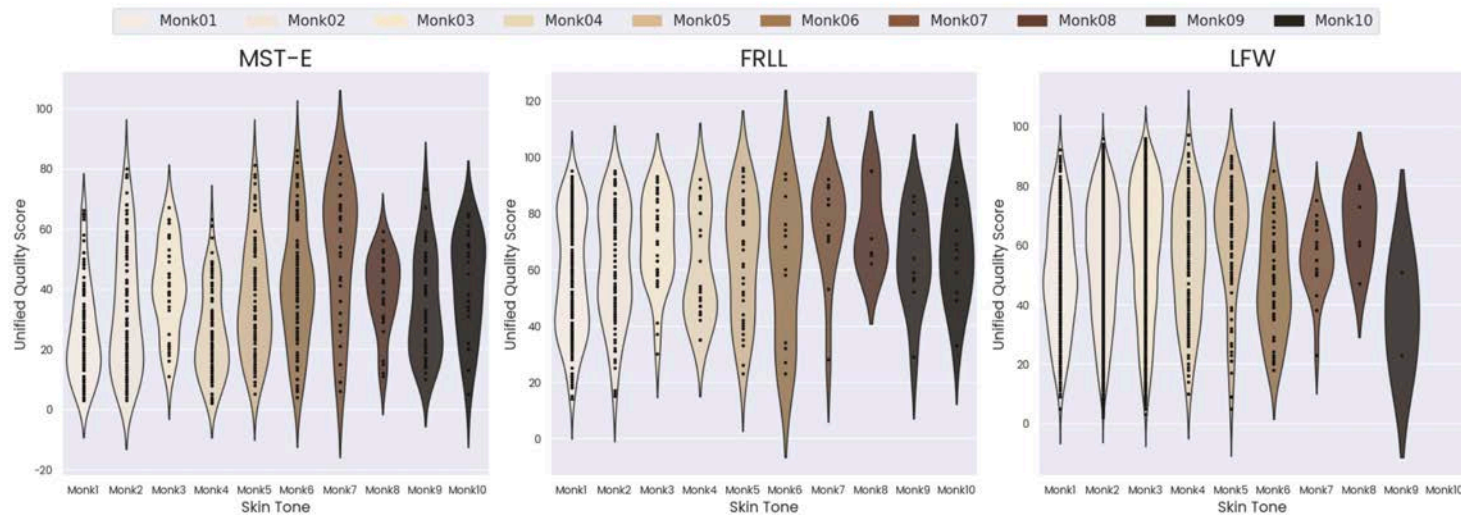
[GRVB2023] M. Grimmer, C. Rathgeb, R. Veldhuis, C. Busch: "NeutrEx: A 3D Quality Component Measure on Facial Expression Neutrality", in Proceedings of International Joint Conference on Biometrics (IJCB), (2023)

[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)

# Face Image Quality

## Investigate demographic variability (DV)

- Unified quality score distributions across skin tone scales
  - ▶ Fitzpatrick Skin Types (FST)
  - ▶ Monk Skin Tone Scale (MST)
  - ▶ Colorimetric Skin Tone Scale (CST)



- Drawback: Skin tone class labels estimated

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

[Utcke2026] S. Utcke, S. Kramp, S. Engelhardt, W. Kabbani, C. Rathgeb, T. Schlett, J. Merkle, B. Tams, J. Dehen, C. Busch: "Demographic Variability of Face Image Quality Measures in Operational Data", in IEEE Access, (2026)

# Face Image Quality

## Investigate **demographic variability (DV)**

- ISO/IEC technical report on  
Demographic variability of face image quality measures  
[https://www.iso.org/committee/313770.html?t=pbkdp2EjRvj8aKJD\\_DJuyD-UVGVhaafFTG1SHYW1UKrmbchG6jLf6jqoqARosEWf&view=documents#section-isodocuments-top](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 1859

ISO/IEC JTC 1/SC 37/WG 3 "Biometric data interchange formats"  
Convenorship: DIN  
Convenor: **Busch Christoph Mr Prof. Dr.**



### 3rd WD TR 25722 Demographic variability of face image quality measures

Document type	Related content	Document date	Expected action
Project / Other	Project: <a href="#">ISO/IEC AWI TR 25722</a>	2026-03-04	<b>COMMENT/REPLY</b> by 2026-05-24

# DArmstadt Skin Tone Dataset (DAST)

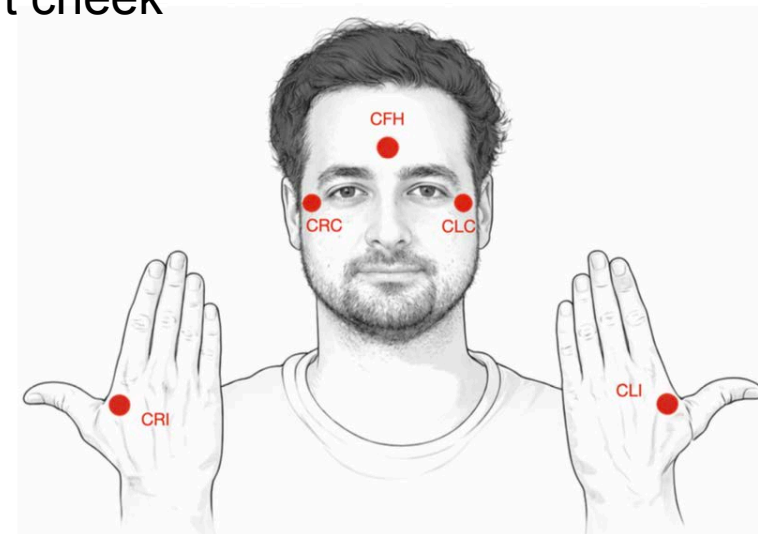
## Ground truth skin tone **measurement**

- Handheld DSM-4 **colorimeter**

- ▶ measures a skin area of approximately 50 mm<sup>2</sup> 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



# 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

- By combining camera and flash settings **five** distinct **exposure levels** (ELs) were realised:
  - ▶ EL1: strongly underexposed, approximately 25% of the nominal exposure
  - ▶ EL2: underexposed, approximately 50% of the nominal exposure
  - ▶ EL3: nominal exposure (reference exposure level)
  - ▶ EL4: overexposed, approximately 200% of the nominal exposure
  - ▶ EL5: strongly overexposed, approximately 400% of the nominal exposure

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

# 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

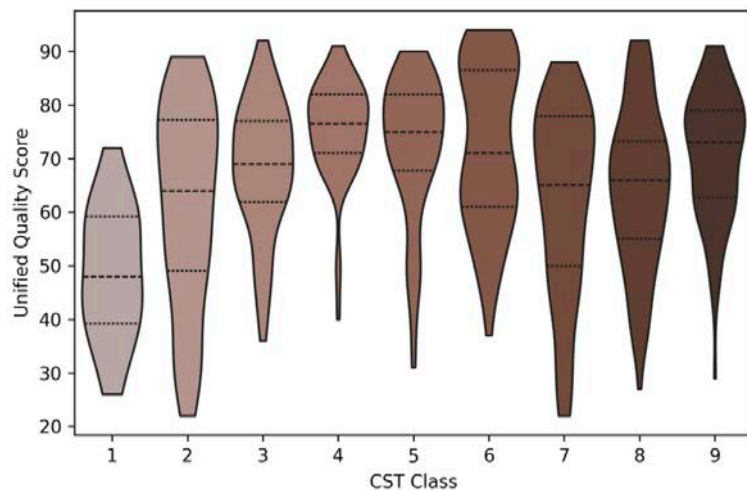
SB: Softbox, BG: Background, SS: Shutter speed

# DArmstadt Skin Tone Dataset (DAST)

## Example application(s)

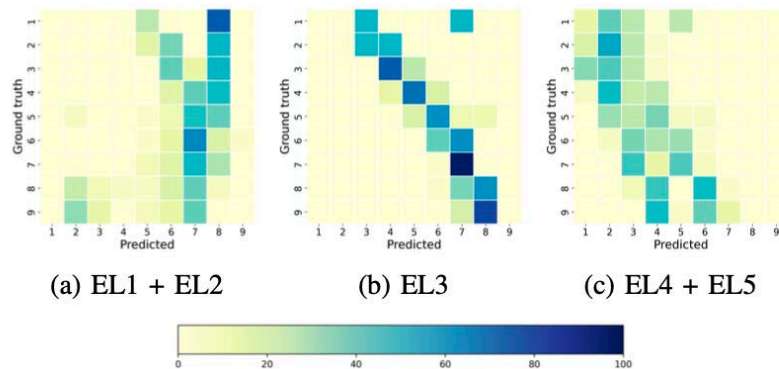
- **Demographic variability**

- ▶ Distribution of unified quality scores across CST classes in DAST



- **Skin tone estimation**

- ▶ Develop more reliable skin ton estimation algorithms



# Conclusion - Limitations

## DAST dataset

- Contains 80 data subjects
- 12 high resolution face images per subject
- CST classes 2 to 9 are covered by 10 subjects per class

## Limitations

- Images are captured in **one single session**
- **Short-term** physiological and environmental **factors** (e.g., makeup, skin temperature influenced by season, perspiration) could **affect** both **appearance** and **skin tone** measurements

## Further information and example data

<https://github.com/dasec/DAST-SkinTone-database>



# Contact



**Prof. Dr. Christoph Busch**  
Principal Investigator

Hochschule Darmstadt FBI

Schöfferstr. 3  
64295 Darmstadt, Germany  
christoph.busch@h-da.de

Telefon +49-6151-533-30090  
<https://dasec.h-da.de>  
<https://www.athene-center.de>