Face Image Quality Standardization

Patrick Grother
National Institute of Standards and Technology
U. S. Department of Commerce
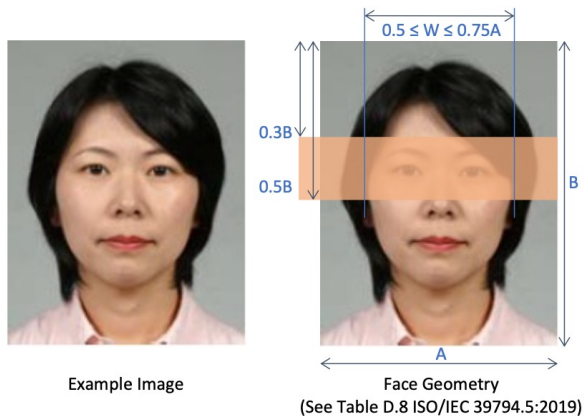
International Face Performance Conference
November 15, 2022

A tale of two face standards

Example Image

Face Geometry
(See Table D.8 ISO/IEC 39794.5:2019)

0.5 ≤ W ≤ 0.75A

0.3B

0.5B

B

A

ISO/IEC 19794-5   **ISO/IEC 39794-5**

REQUIREMENTS ON DATA ENCODING **AND APPEARANCE** OF THE FACE

ISO/IEC 29794-5 Face Image Quality
- Has requirements on QA software applied in three use-cases
- Includes definitive image-processing steps for some quality checks

NO STANDARDIZED CONFORMANCE CHECKS!
- RELIANCE ON PHOTOGRAPHER
- TRAINED REVIEWER
- COTS QUALITY CHECKING SOFTWARE

ISO/IEC 29794-5 Face Image Quality

1. Capture-device related quality checks
- 6.3.2 Background uniformity
- 6.3.3 Illumination uniformity
- 6.3.4 Moments of the luminance distribution
- 6.3.5 Under-exposure
- 6.3.6 Over-exposure
- 6.3.7 Dynamic range
- 6.3.8 De-focus
- 6.3.10 Compression ratio
- 6.3.11 Unnatural colour

2. Subject-behavior related quality checks
- 6.3.9 Motion blur
- 6.4.2 Single face present
- 6.4.3 Eyes visible
- 6.4.4 Eyes open
- 6.4.5 Mouth occlusion
- 6.4.6 Mouth closed
- 6.4.8 Inter-eye distance
- 6.4.9 Horizontal position of the face
- 6.4.10 Vertical position of the face
- 6.4.11 Pose
- 6.4.13 Expression neutrality

3. Cannot be measured from an image
- 6.5.1 Shoulder presentation
- 6.5.2 Camera to subject distance
- 6.5.3 Radial distortion
- 6.5.4 Pixel aspect ratio

6. August 2022 public draft freely available here:

https://isotc.iso.org/livelink/livelink?func=ll&objId=22304355&objAction=Open&viewType=1

4. October 2022 comments from:
- Christoph Busch (H. Darmstadt)
- Pierre Gacon (Idemia)
- Olaf Henniger (Fraunhofer)
- Markku Metsamaki (FI Border)
- Benjamin Tams (secunet)
- Jim Wayman (DHS)
- Andreas Wolf (BDR)

5. Progression
1. 2022-11 Proposed disposition of comments
2. 2023-01 Discuss comments, produce WD 6
3. 2023-04 CD 1
4. 2023-07 DIS 1
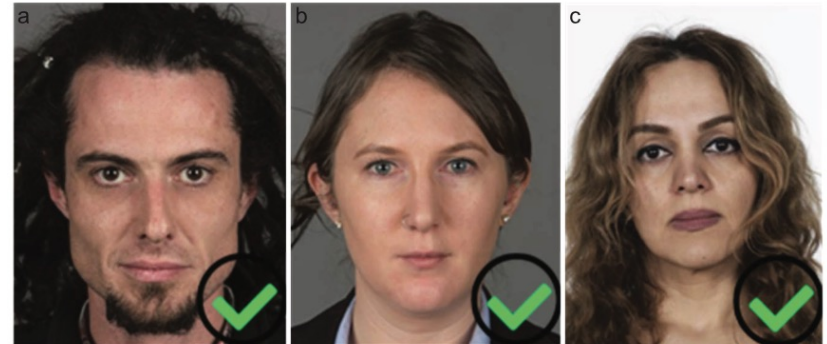5. 2023-12-23 DIS 2 to ISO for publication

Example of quality component considered intractable

Distortion occurs in all conventional photos
- How much is too much?

By analyzing JUST the image, error rates > 0 because
- some faces will naturally look distorted
- Some distorted faces will look natural

a) Good appearance   b) Good appearance   c) Good appearance
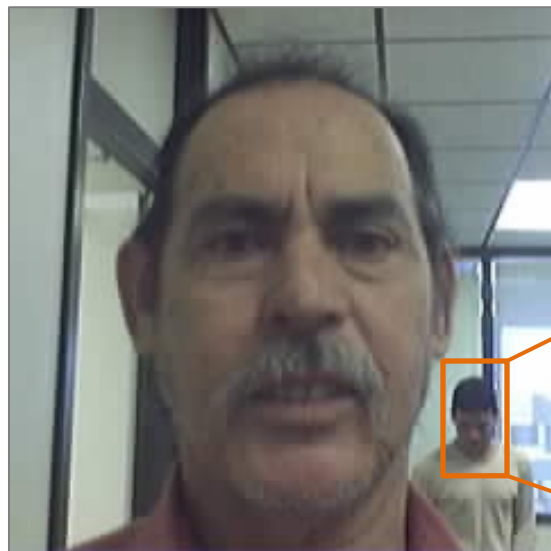
Source: ISO/IEC 39794-5:2019

d) Too strong magnification distortion   e) Too strong magnification distortion   f) Too strong magnification distortion
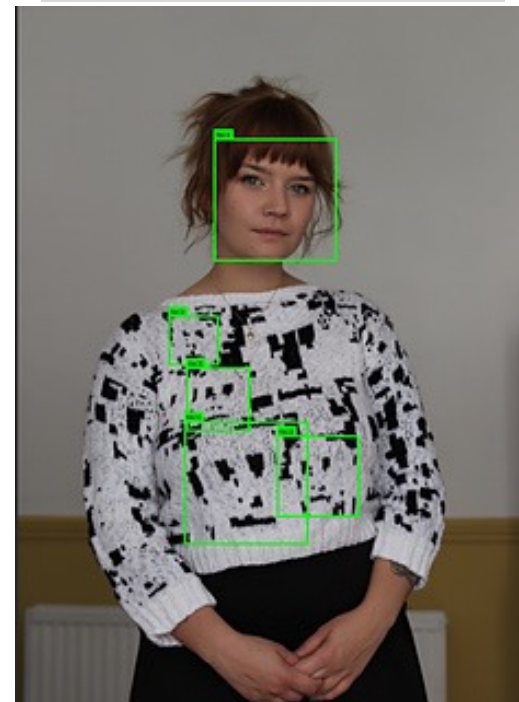
Example component: Number of faces
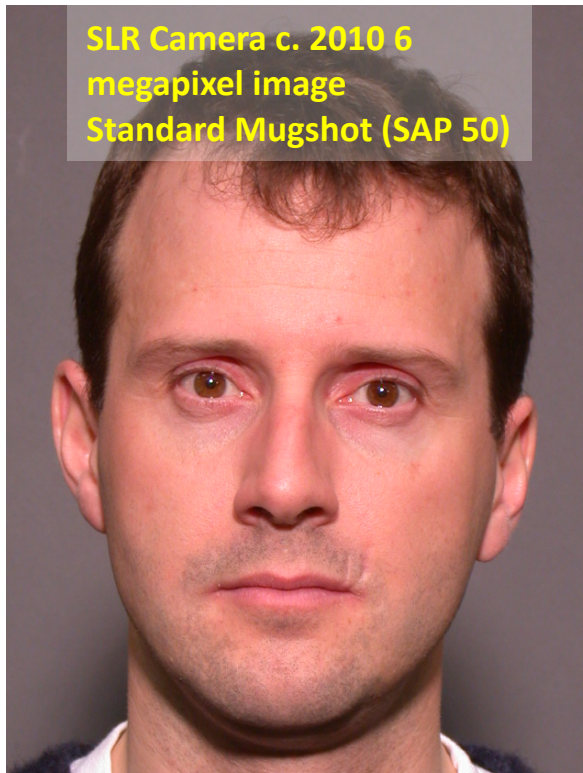
240 pix

240 pix

Source: MEDS, NIST Special Database 32

Very high non-mate scores from many algorithms

Source: https://www.ravelry.com/patterns/library/anti-surveillance-jumper

NIST

SLR Camera c. 2010 6 megapixel image Standard Mugshot (SAP 50)

3000 x 2000

e-Passport 2004…2016 0.3 megapixels
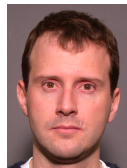
640 x 480

Input layer for typical leading DNN c. 2022

112x112

32 x 24

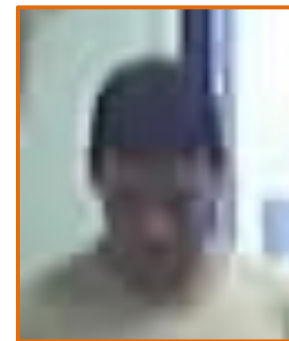**Background face from prior slide**

32 x 24
NOT TO SCALE

⚠️ Up-sampled image fed into a typical CNN gives high non-mate scores

6

NIST
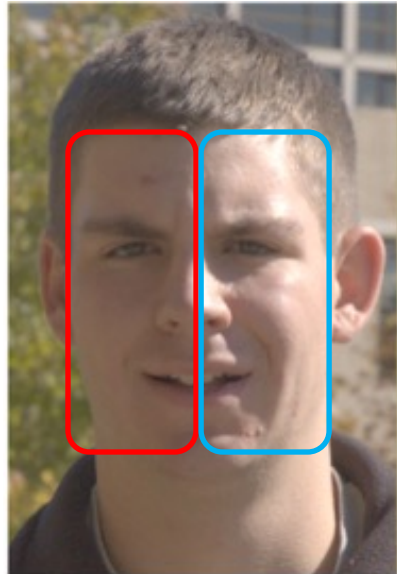
Proportion of pixels with greylevel i on left side

Proportion of pixels with greylevel i on right side

$$D = \sum_{i=0}^{M} min(p_i, q_i)$$

$D \longrightarrow 1$ implies symmetric lighting

Quality value encoded in an interchange record
QS = round(100 D)

Example component: Dynamic Range
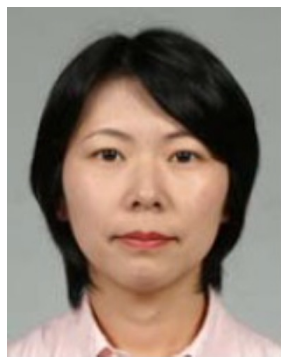
- Find face region
- Compute luminance
- Compute greylevel histogram
- Compute entropy

$$H = -\sum_{i=0}^{M} h_i \ \log_2 h_i$$

H

COMPUTE QUALITY SCORE: EITHER LINEAR TO [0,100]

Quality increases linearly with entropy

QS = 12.5 H

OR SOMETHING NON LINEAR

Quality is very low if H below ~ 5 bits

$QS = \dfrac{100}{1+e^{-(H-5)}}$

- ISO/IEC 29794-5 is draft.
- Exact mapping here yet to be confirmed.
- Decision should be based on false non-match rates.

Quality component: Underexposure

1. Dark skin is difficult to image
   1. Low diffuse reflection
   2. High specular reflection

2. Sufficient underexposure will lead to detection or false negative recognition error

3. Hot spots may give false positives

4. Are DNNs tolerant?

Hot spots aka specular reflections

Better photo of same person

Underexposure

Source: NIST Special Database 32 aka "MEDS", subject S171

Google's Real Tone
(in Pixel 6+ phones)

Image equity: Making image tools more fair for everyone

Oct 19, 2021   As part of Google's Product Inclusion efforts, our teams are building more equitable camera and imaging products
3 min read   for people of color.

Florian Koenigsberger
Google Image Equity Lead

Share

https://store.google.com/intl/en/ideas/real-tone/

Pictures are a big part of how we see each other and the world around us, and historically racial bias in camera technology has overlooked and excluded people of color. That same bias can carry through in our modern imaging tools if they aren't tested with a diverse

- For aesthetic purposes

- Not specifically for biometrics, though it may have benefits

- Ask phone camera developers to include an API dedicated to *biometric* face capture leveraging e.g. high bit-depth sensors, computational photography.
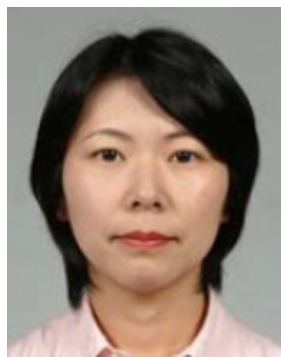
- https://blog.google/products/pixel/image-equity-real-tone-pixel-6-photos/
- https://blog.google/inside-google/company-announcements/super-bowl-ad-2022/   10

Example component: Dynamic Range

$$H = -\sum_{i=0}^{M} h_i \, \log_2 h_i$$

- Find face region
- Compute luminance
- Compute greylevel histogram
- Compute entropy

H

EITHER

Quality increases linearly with entropy

QS = 12.5 H

OR

Quality is very low if H below ~ 5 bits

$QS = \dfrac{100}{1+e^{-(H-5)}}$

THREE USE CASES

Mandatory	**UC1:** Creation of reference samples Seek rules like accept if QS > 75 say
Optional	**UC2:** Probe for instantaneous recognition
Optional	**UC3:** System enrolment, current or later creation of a reference, delayed recognition.

Mandatory or Optional

#	Image quality aspect	Sub-clause	Collection of reference samples for ID documents	Collection of probe for instantaneous recognition	System enrolment, current or later creation of a reference, delayed recognition
1.	Unified quality score	6.2	M	M	M
2.	Background uniformity	6.3.2	M	O	O
3.	Illumination uniformity	6.3.3	M	O	O
4.	Illumination mean	6.3.4.2	M	O	O
5.	Illumination variance	6.3.4.3	M	O	O
6.	Illumination skewness	6.3.4.4	M	O	O
7.	Illumination kurtosis	6.3.4.5	M	O	O
8.	Under-exposure	6.3.5	M	O	O
9.	Over-exposure	6.3.6	M	O	O
10.	Dynamic range	6.3.7	M	O	O
11.	De-focus	6.3.8	M	O	O
12.	Image sharpness	6.3.9	M	O	O
13.	Motion blur	6.3.10	M	O	O
14.	Edge density	6.3.11	M	O	O
15.	Compression ratio	6.3.12	O	O	O
16.	Unnatural colour and colour balance	6.3.13	M	O	O
New	Polarization filter		M	O	O
New	Radial distortion		O	O	O
New	Pixel aspect ratio		O	O	O
17.	Camera lens focal length	6.3.14	O	O	O
18.	Camera subject distance	6.3.15	O	O	O
new	Single subject		M	M	M
new	Shoulders squared on		O	O	O
19.	Eyes visible	6.4.2	M	O	M
20.	Mouth occlusion	6.4.3	M	O	M
21.	Nose occlusion	6.4.4	M	O	M
22.	Inter-eye distance	6.4.5	M	M	M
23.	Horizontal position of the face	6.4.6	M	M	M
24.	Vertical position of the face	6.4.7	M	M	M
new	No head coverings	New	M	O	M
new	Pose angle yaw frontal alignment	6.4.8.1	M	O	M
new	Pose angle pitch frontal alignment	6.4.8.2	M	O	M
new	Pose angle roll frontal alignment	6.4.8.3	M	O	M
26.	Expression neutrality	6.4.9	M	O	O
27.	Mouth closed	6.4.10	M	O	M
28.	Eyes open	6.4.11	M	O	O

- Snapshot from 2022 draft of ISO/IEC 29794-5

- Requirements on what software library must support?

- Requirements on what must be done in each use-case?

Presentation Attack: Impersonation

by maximizing similarity score

A: Instruments
- Replay
- Cosmetics
- Masks

Presentation Attack: Evasion

by minimizing similarity score

B: Instruments
- Replay
- Masks
- Cosmetics
- Image manipulation

C: Behaviours
- Adverse Pitch | Yaw
- Pronounced expression
- Occlusion
- Motion Blur

Common Image Quality Problems

D: Imaging problems
- Blur
- Illumination
- Exposure
- …

Incorrect Arrests in Michigan and New Jersey
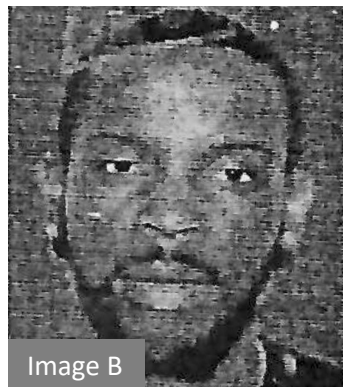
NIST

PROBE

INCORRECT PERSON
ROBERT WILLIAMS

Image A

https://www.cbsnews.com/news/facial-recognition-60-minutes-2021-05-16/

INCORRECT PERSON
NIJEER PARKS

PROBE

GALLERY
RETRIEVED

NEWS
PHOTO

Image B

Image C

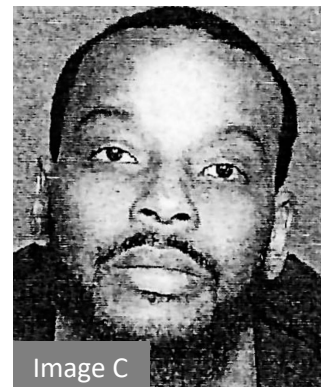https://www.cnn.com/2021/04/29/tech/nijeer-parks-facial-recognition-police-arrest/index.html

https://www.nytimes.com/2020/12/29/technology/facial-recognition-misidentify-jail.html

Future roles for quality?
1. Issue caution to an investigator when signal is "low / unavailable" (Image A) or "noisy" (Image B)
2. Issue caution to someone putting a poor image (Image C) in an authoritative database

The FRVT Program

- U.S. Government
- Department of Commerce

- 2000 – 2022

- Public
- Independent
- Free
- Open worldwide

- Collaboration with USG agencies

| 1:1 | ▪2017-02 ...
 ▪Verification | Authorization | Non-repudiation |
| --- | --- |
| 1:N | ▪2018-01 ...
 ▪Investigation | Duplicate detection | Identification |
| Morph Detection | ▪2018-09 ...
 ▪Single-image | Differential two-image |
| Quality Summarization | ▪2019-02 ...
 ▪Produce a number predicting mate matching outcomes |
| Quality Defect Detection | ▪2022-08 ...
 ▪Find specific image quality problems (blur, pose, sunglasses etc) |
| Presentation Attack Detection | ▪2023-01
 ▪Is the image or video showing subversive behavior? |
| Twins Low False Match Demonstration | ▪2022-09 ...
 ▪High resolution images |

FRVT Quality Tracks

TRACK A
Quality
Summarization
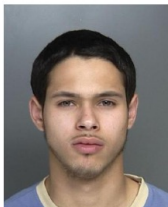
SCALAR: Q = 98

DECISION: Y, Accept

BOX 0.   QUALITY BENCHMARK
— One "visa – border" dataset
— No longer use wild
— Extend to use new "kiosk" dataset

TRACK B
Specific
Image
**Defect**
Detection

BOX 1.   QUALITY BENCHMARK
— Concept presented at the Nov Q Workshop 2021-11
— API + Concept Published 2021-07-07 for comment.
— Final specifications 2022-09
— Algorithms to NIST 2022-09
— Align with ISO/IEC 29794-5

BOX 2.   IMAGING VARIABLES THAT INFLUENCE ACCURACY
— Illumination adequacy + uniformity
— Exposure
— Focus, blur
— Resolution / Sp. Sampling Rate

BOX 3.   SUBJECT VARIABLES THAT INFLUENCE ACCURACY
— Head orientation (R, P, Y)
— Expression neutrality
— Sunglasses, face masks
— Motion blur
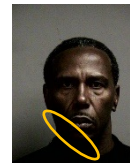— No, or additional, faces
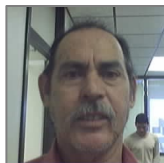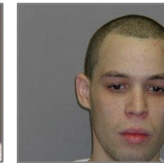
Two People | No People | Noise | Over-exposure | Under-exposure | Hot Spots | Mis-focus | Cropped | Non-frontal
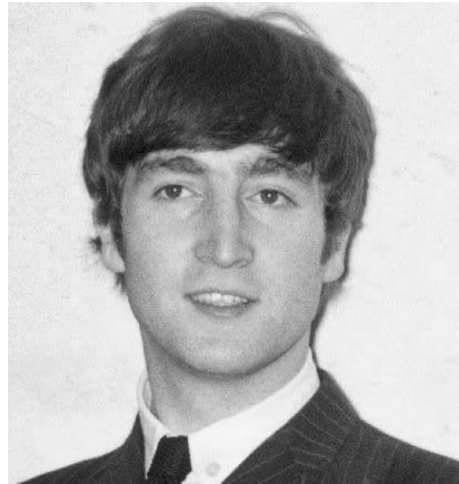
Summary

NIST

ISO/IEC 29794-5

» Defines a set of quality measurements

- Compute a raw component value
  - Some computations are explicit
  - Some computations are abstract
    e.g. "estimate pose" without saying how

- Compute an interpretable quality score [0,100]
- Actionable feedback - "focus score too low"

» Mandates subsets of those computations depending on use-case

» Conceives of three use-cases

Quality evaluation

» FRVT Specific Image Defect Detection

- Do 29794-5 quality assessment algorithms work well?
- Do 29794-5 relate to face recognition accuracy?

NIST

THANKS!

PATRICK.GROTHER@NIST.GOV

FRVT@NIST.GOV

Beatle John Lennon between the release of the Red Album and the Blue Album, ~5 years.

Year	Developer	Algorithm	Score	FMR	Outcome
2022	Cogent Thales	007	3322	< 5e-07	**Strong match**
2021	Idemia	008	7438.78	< 5e-07	**Strong match**
2022	Paravision	010	0.38308	< 5e-07	**Strong match**
2014	Cogent Thales	A20A	2521	0.48	**Failed match**
2014	NEC	E20A	0.562	0.002	**Failed match**