Face Image Quality Assessment - *NIST Interagency Report 8485 Specific Image Defect Detection*

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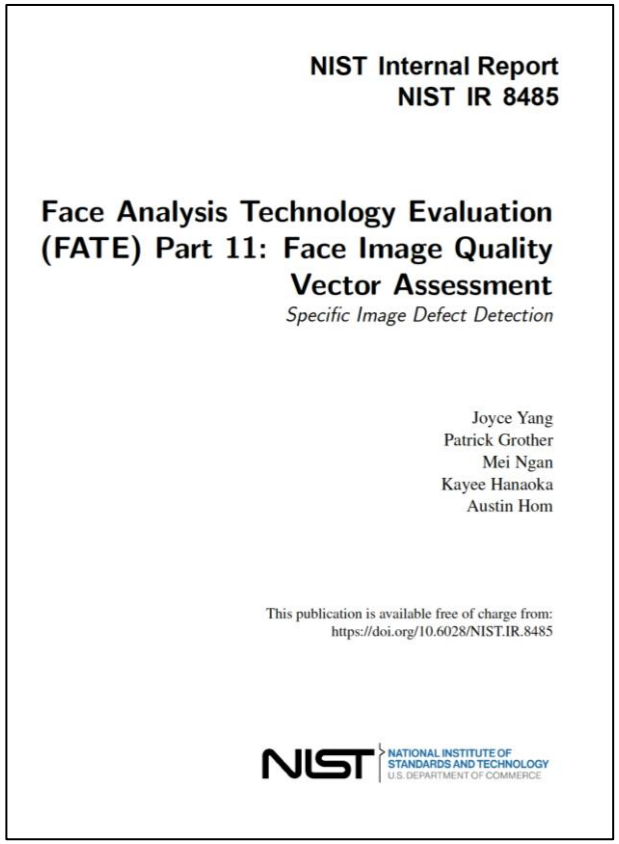
EAB/NIST Quality Workshop

November 9, 2023



NIST Internal Report
NIST IR 8485

Face Analysis Technology Evaluation (FATE) Part 11: Face Image Quality Vector Assessment

Specific Image Defect Detection

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This publication is available free of charge from:
https://doi.org/10.6028/NIST.IR.8485

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FRTE/FATE Activities

FRTE

Face Recognition Technology Evaluation

1:1 Verification	• Same person or not?
1:N Search	• Who is that?
1:N Face + Iris	• Vendor-defined fusion
Twins Disambiguation	• Is it possible to avoid false positives in twins?

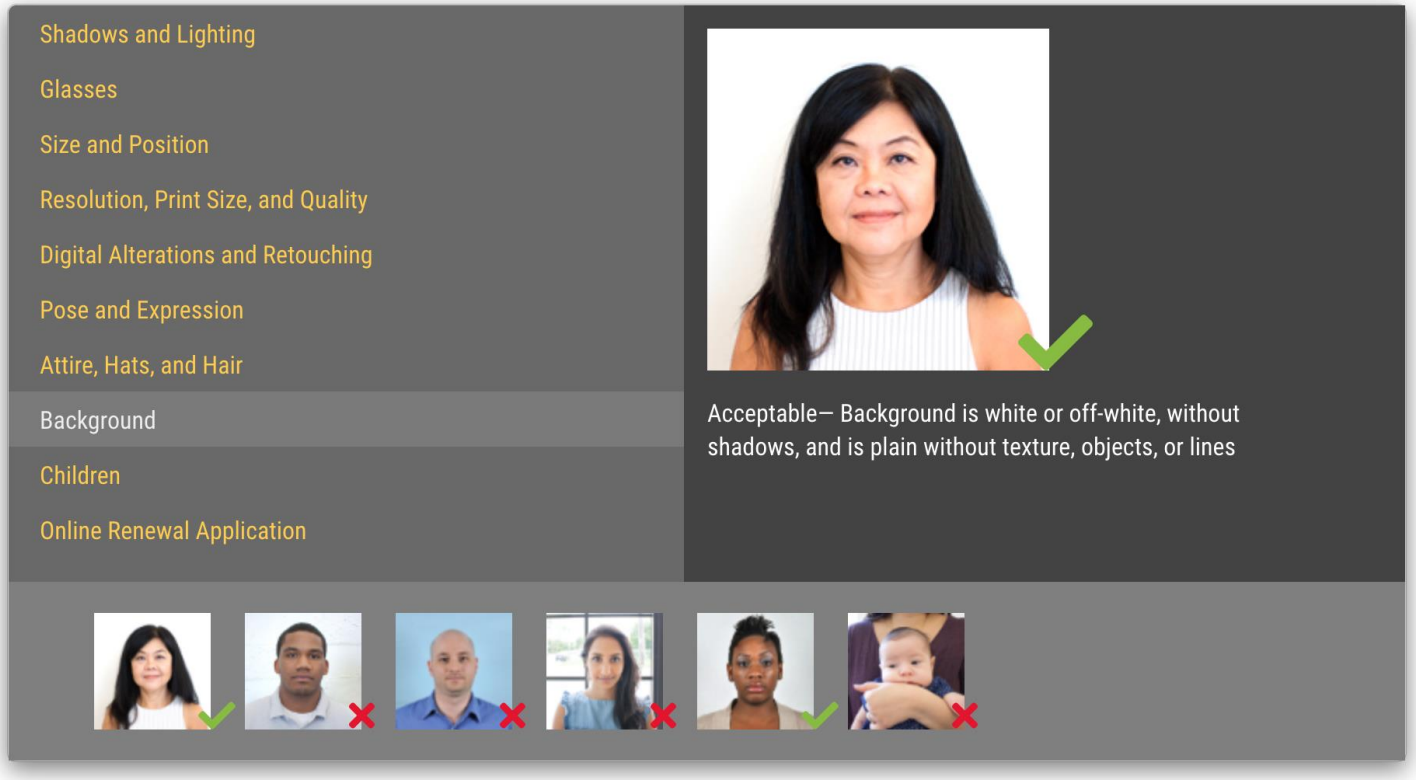
FATE

Face Analysis Technology Evaluation

Morph Detection	• Two faces in one passport!
Quality Summarization	• **Predict future recognition failure?**
Quality Defect Detection	• **What exactly is wrong with a face image?**
Presentation Attack Detection	• Is this image intended to subvert the system?
Age Estimation	• How old? Old enough?

Why Specific Image Defect Detection?

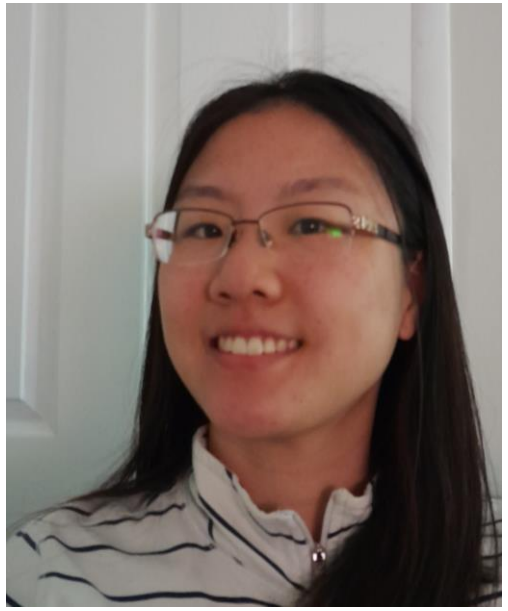
- Automated face recognition is sensitive to quality problems in images
- Standards set requirements on images
  - For MRTD, ISO/IEC:39794-5
  - For law enforcement, ANSI/NIST standard
- SIDD gives users a set of tools to check those requirements



US Passport Photo Guidelines from
https://travel.state.gov/content/travel/en/passports/how-apply/photos.html

FATE Quality Specific Image Defect Detection Assessment

- FATE SIDD extends the Quality Assessment evaluation of algorithms that answer the question “How good is this image?”
  - This is the face equivalent of NFIQ
- We test specific image defect detectors- algorithms that answer the question “What specifically is wrong with this image, and to what extent?”
- The two main goals of the SIDD evaluation are to support quality algorithm development and to support ISO/IEC 29794-5.



SubjectPoseYaw = 20°

MouthOpen = 0.08

BackgroundUniformity = 0.8

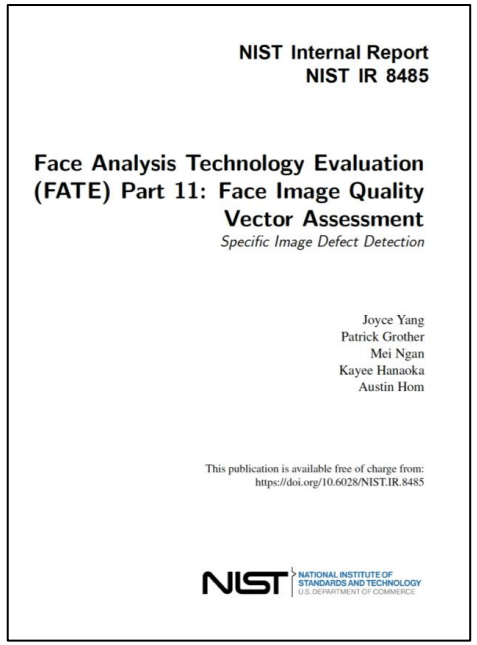
EyeGlassesPresent = 1

FATE SIDD Support of ISO/IEC 29794-5

Category	ISO/IEC 29794-5 Quality Check	SIDD Quality Component
Capture device-related	7.3.2 Background uniformity	Background uniformity
	7.3.3 Illumination uniformity	-
	7.3.4 Moments of the luminance distribution	-
	7.3.5 Under-exposure prevention	Under-exposure
	7.3.6 Over-exposure prevention	Over-exposure
	7.3.7 Dynamic range	-
	7.3.8 Sharpness	Resolution
	7.3.9 Motion blur prevention	Motion blur
	7.3.10 Compression ratio	Compression artifacts
	7.3.11 Natural color	-
Subject-related	7.4.2 Single face present	Face count
	7.4.3 Eyes open	Eyes open
	7.4.4 Mouth closed	Mouth open
	7.4.5 Eyes visible	Sunglasses + eyeglasses
	7.4.6 Mouth occlusion prevention	Face occlusion
	7.4.7 Face occlusion prevention	Face occlusion
	7.4.8 Inter-eye distance	Inter-eye distance
	7.4.9 Head size	Distance from eyes to edges
	7.4.10 Crop of the face Image	Distance from eyes to edges
	7.4.11 Pose	Pose
	7.4.12 Expression neutrality	-
	7.4.13 No head covering	-

The FATE SIDD evaluation quantifies how well algorithms perform the checks detailed in ISO/IEC 29794-5.

The NIST IR 8485 SIDD Report at a Glance



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Algorithm	TotalFacesPresent	SubjectPosePitch	SubjectPoseYaw	SubjectPoseRoll	EyesOpen	InterEyeDistance	MouthOpen	BackgroundUniformity	Resolution	Underexposure	Overexposure	PixelsFromEyeToLeftEdge	PixelsFromEyeToRightEdge	PixelsFromEyesToTop	PixelsFromEyesToBottom	EyeGlassesPresent	SunGlassesPresent	CompressionArtifacts	FaceOcclusion	MotionBlur	UnifiedQualityScore
dermalog-002	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y				Y
digidata-001	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y										Y
igd-001	Y	Y	Y	Y		Y			Y	Y	Y	Y	Y	Y	Y						
frpkauai-000	Y	Y	Y	Y	Y	Y		Y	Y												
idemia-002	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
neurotechnology-002	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
neurotechnology-003	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
rankone-005	Y	Y	Y	Y	Y	Y	Y		Y			Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
seamfix-001	Y	Y	Y	Y			Y	Y	Y	Y	Y					Y	Y				
secunet-001	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y										
secunet-002	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y										Y

- Original report released Sep. 20
- Covered algorithms submitted from Sep 2022 to Sep 2023

- 20 quality measures+ Unified Quality Score
- Updated on Nov 6
  - Adds results for IDEMIA, Dermalog, SeamFix
  - Replaces median absolute error with mean absolute error
  - Adds sets for manually determined pitch and yaw

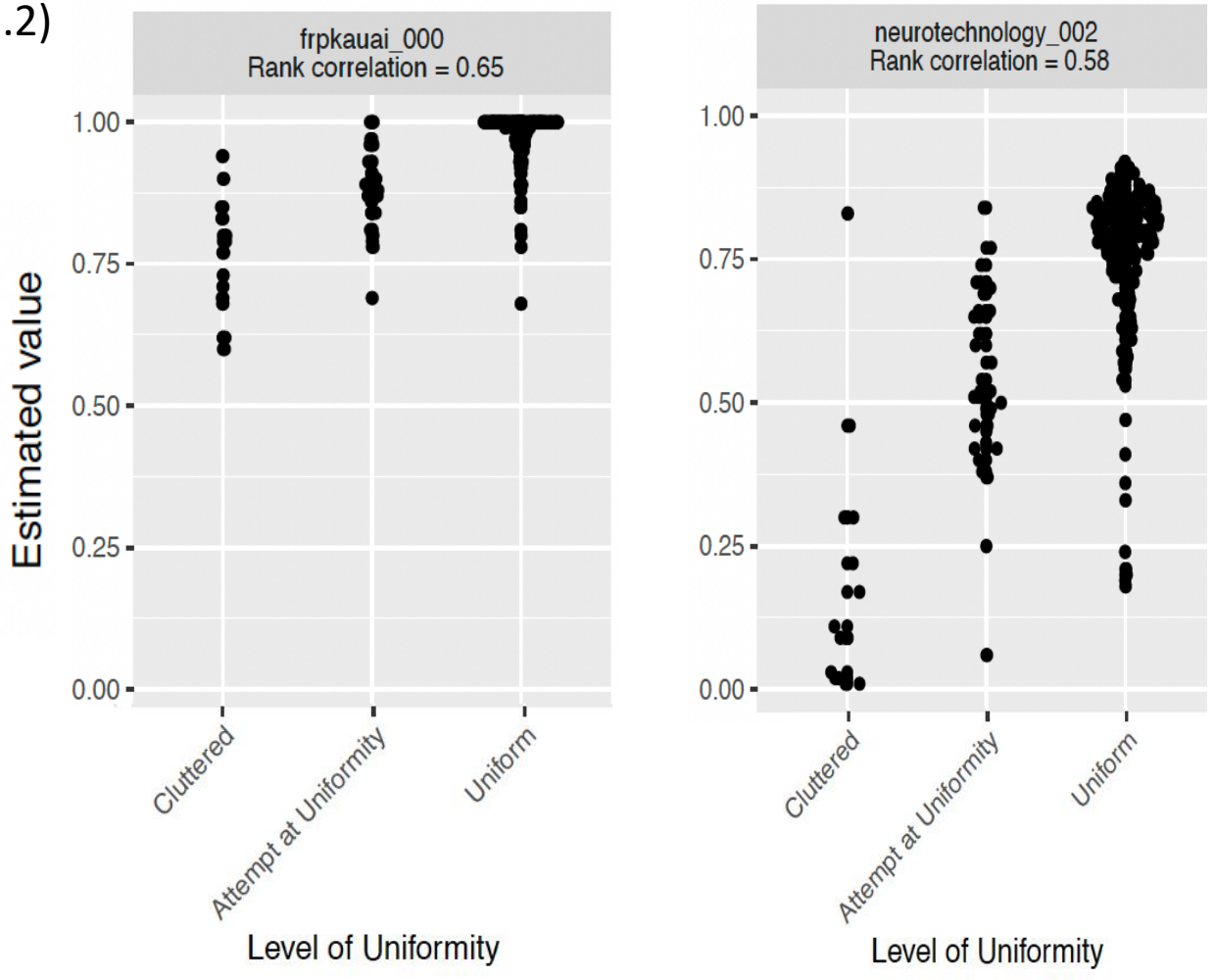
Capture-Related Measures

FATE SIDD Report – Results for Background Uniformity

ISO/IEC 29794-5 Quality Check: Background Uniformity (7.3.2)

Category	Cluttered	Attempt at Uniformity	Uniform
Example			
	0	0.5	1

- Images fall into three categories:
  - Uniform (plain background, no shadows)
  - Attempt at uniformity
  - Cluttered



- FRP Kauai performs best based on rank correlation

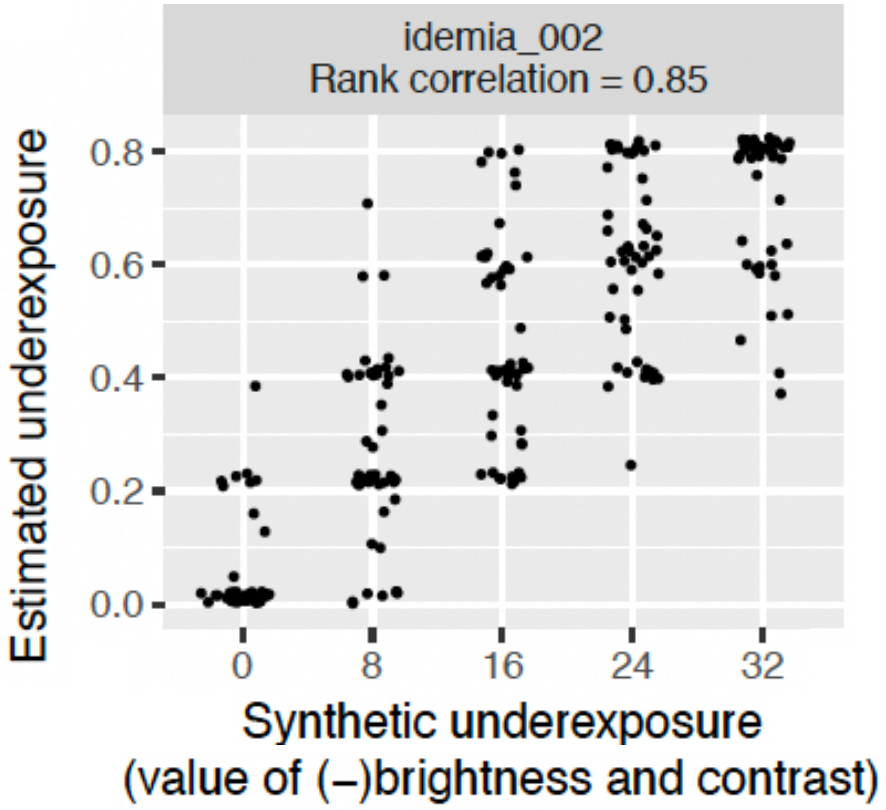
Second image from NIST Special Dataset 32, MEDS

FATE SIDD Report – Results for Underexposure

ISO/IEC 29794-5 Quality Check: Under-exposure Prevention (7.3.5)

Brightness and contrast (d_1, d_2)	(0,0)	(-16,16)	(-32,32)
Result of convert -brightness-contrast d_1xd_2			

- The images in this set are mugshots that are synthetically underexposed
- Brightness and contrast are applied with equal magnitudes and opposite sign

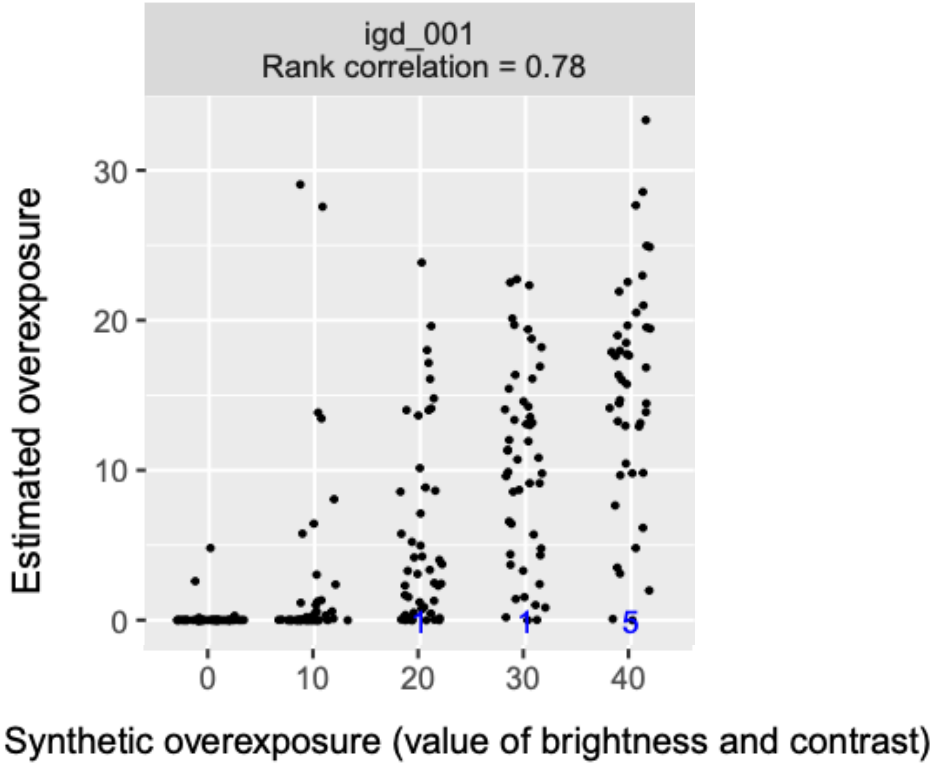


- IDEMIA performs best based on rank correlation

FATE SIDD Report– Results for Overexposure

ISO/IEC 29794-5 Quality Check: Overexposure Prevention (7.3.6)

Brightness and contrast (d_1, d_2)	(0,0)	(20,20)	(40,40)
Result of convert -brightness-contrast d_1xd_2			

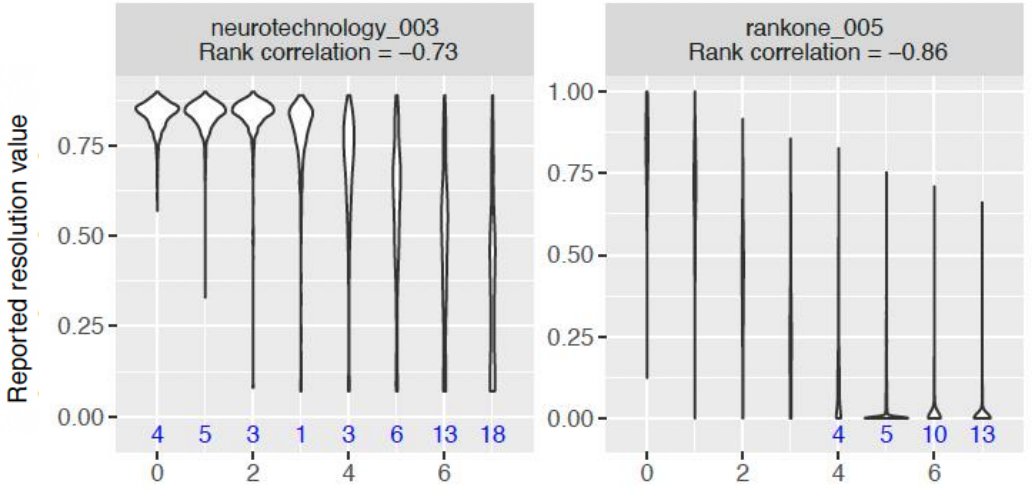


- Brightness and contrast are increased with equal magnitude and sign
- IGD and Neurotechnology perform best based on rank correlation

FATE SIDD Report – Results for Resolution

ISO/IEC 29794-5 Quality Check: Sharpness (7.3.8)

Standard deviation σ	0	2	5
Result of convert -gaussian-blur 0xσ			



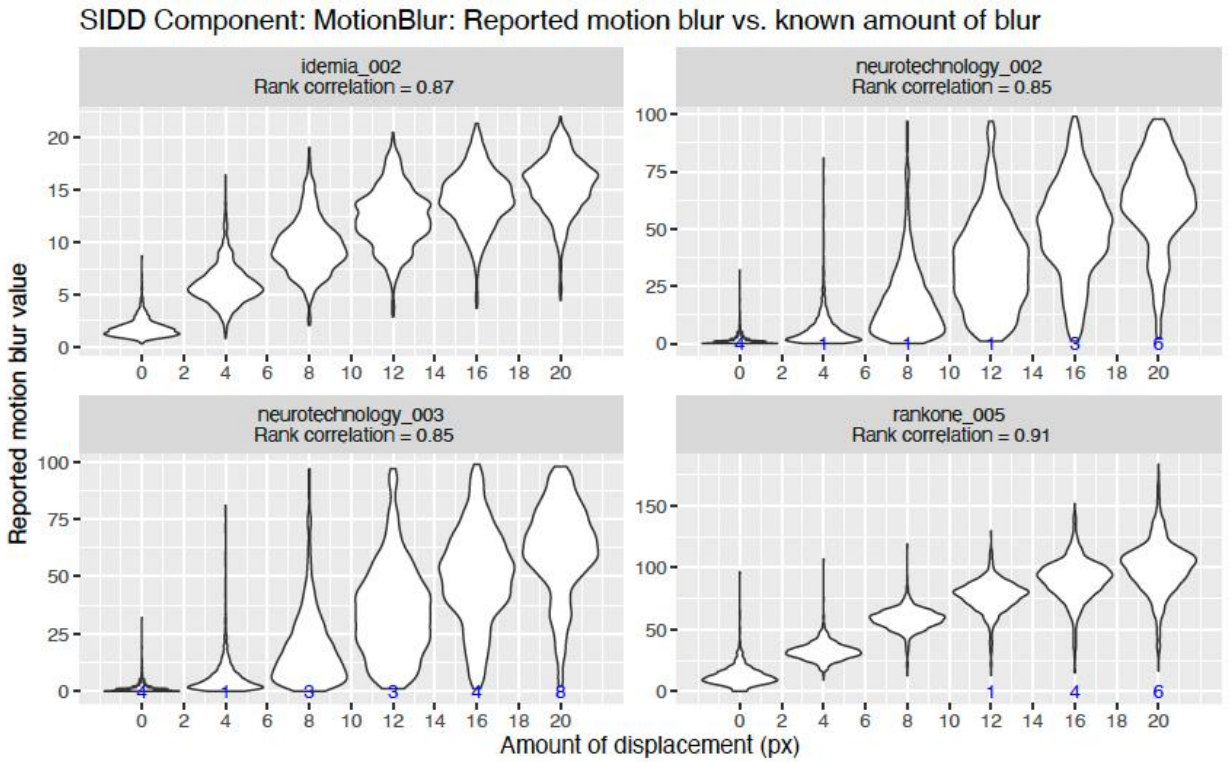
- Original images are selected to be ideal (with no pre-existing blur)
- Various amounts of blur are applied synthetically

- Generally, algorithms report decreasing resolution for increasing values of blur
- Rank One performs best based on rank correlation

FATE SIDD Report – Results for Motion Blur

ISO/IEC 29794-5 Quality Check: Motion Blur Prevention (7.3.9)

Displacement d	0	8	16
Result of convert -motion-blur 0xd			



- Original images are selected to be ideal (with no pre-existing blu ,
- Images are blurred with various values of displacement

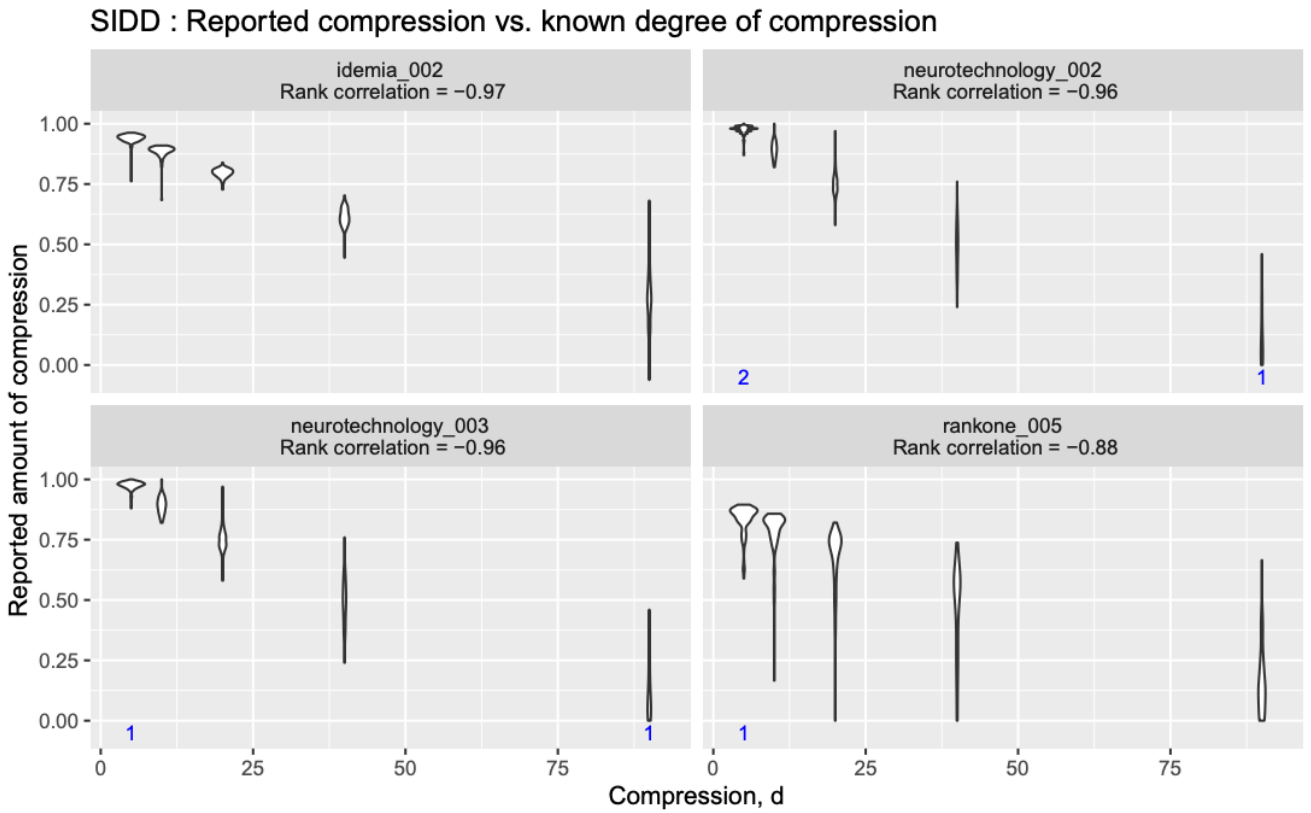
- Rank One performs best based on rank correlation

FATE SIDD Report – Results for Compression Artifacts

ISO/IEC 29794-5 Quality Check: Compression Ratio (7.3.10)

Compression parameter *d*	90	40	10
Result of convert -quality *d*			

- Varying levels of compression are applied
- Lower values indicate more compression



- IDEMIA performs best based on rank correlation

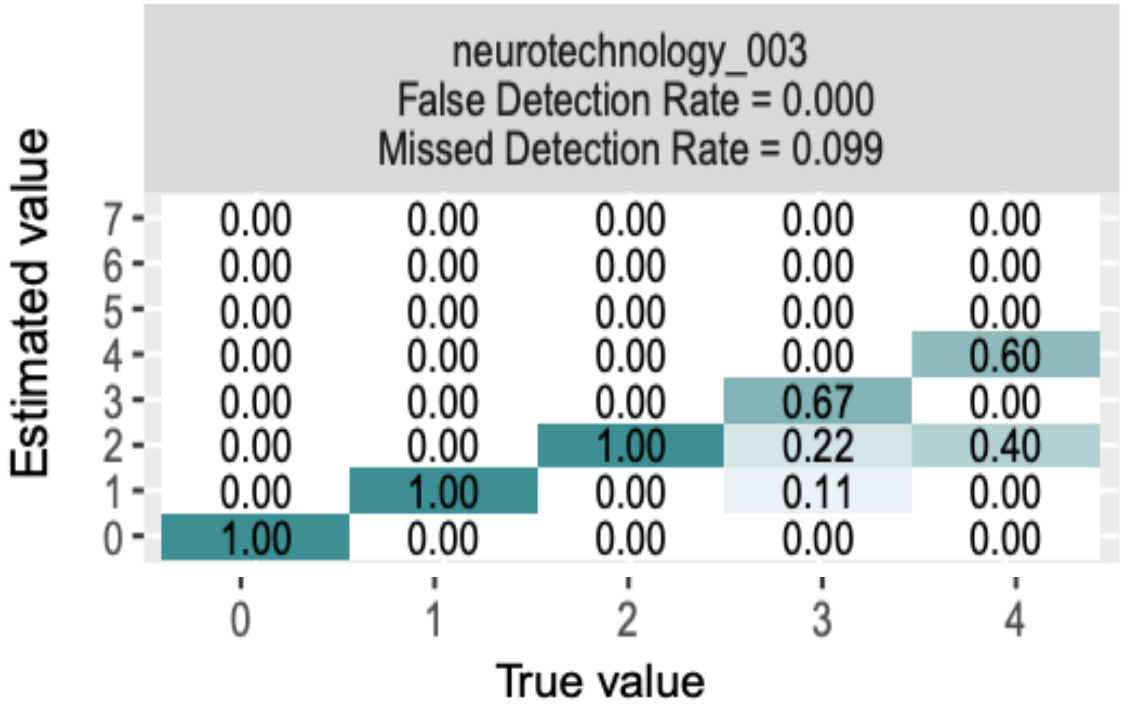
Subject-Related Measures

FATE SIDD Report – Results for Total Faces Present

ISO/IEC 29794-5 Quality Check: Single Face Present (7.4.2)

Image from NIST Special Dataset 32, MEDS

- Faces should be counted if the estimated inter-eye distance is greater than or equal to 0.02W, where W is the image width



- There are more missed detections than false detections
- Neurotechnology_003 has lowest missed detection rate

FATE SIDD Report – Results for Eyes Open

ISO/IEC 29794-5 Quality Check: Eyes Open (7.4.3)

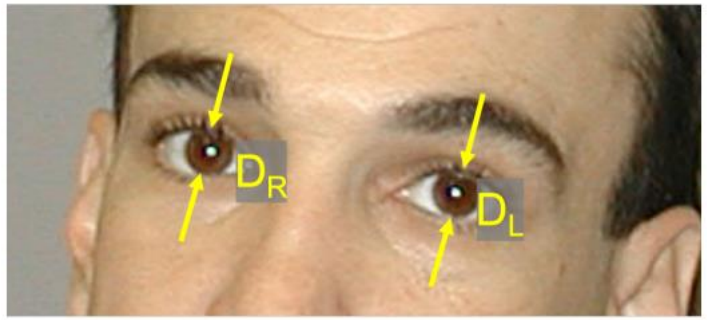
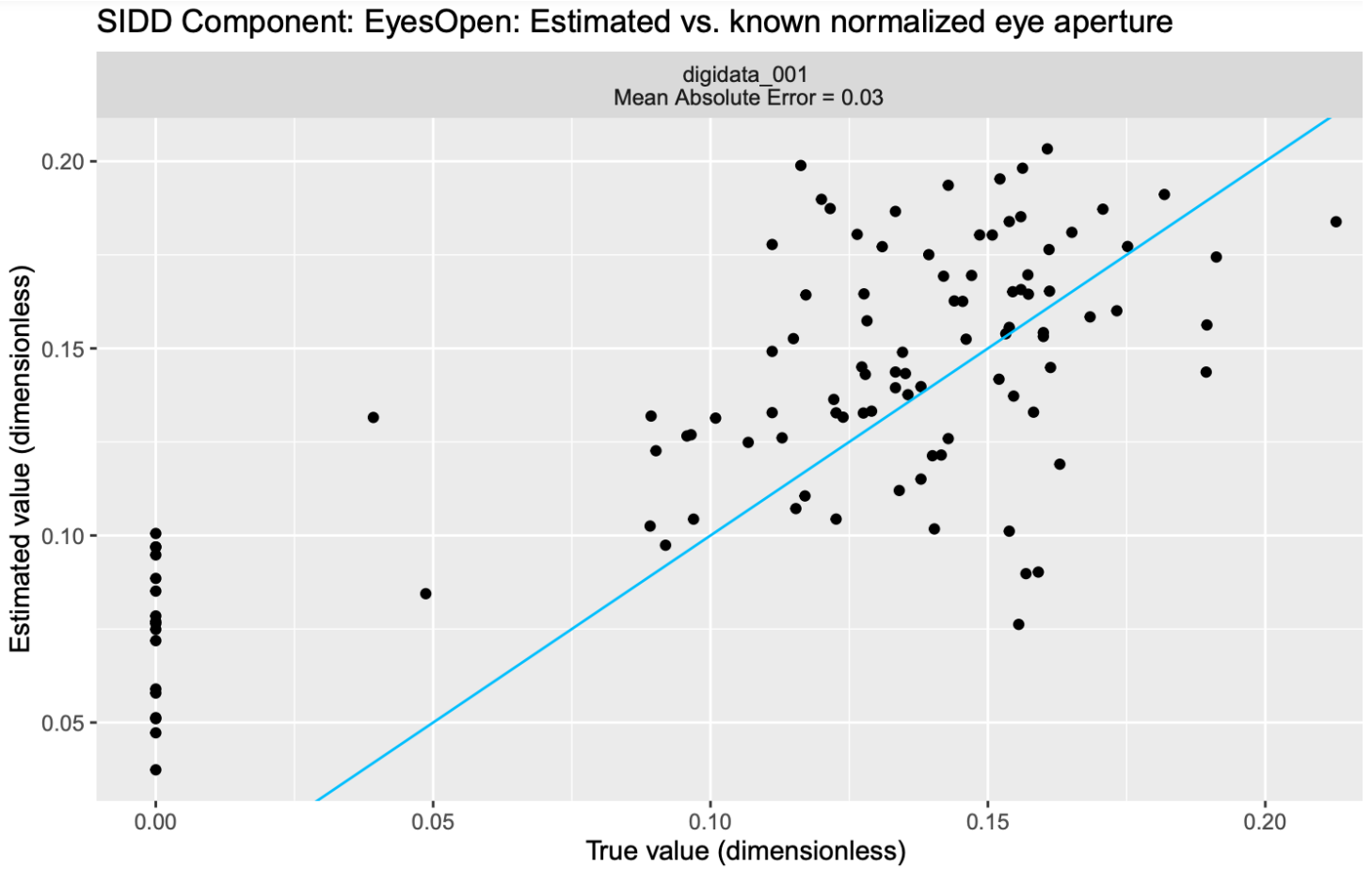
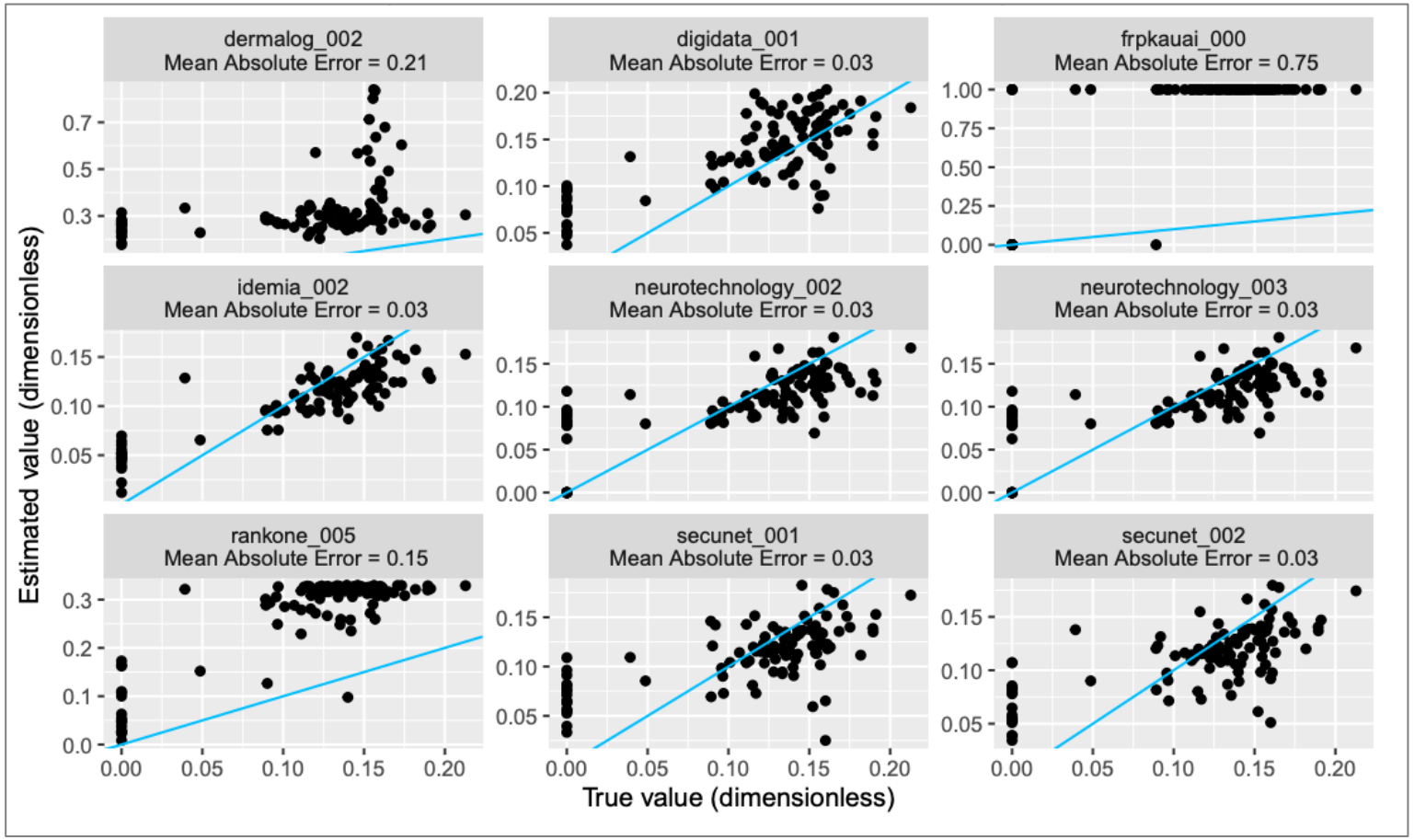


Image from NIST Special Database 32, MEDS.



The EyesOpen measure is computed by comparing the left and right maximum apertures of the eyes, taking the minimum of the two values, and dividing the result by inter-eye distance.

FATE SIDD Report – Results for Eyes Open



- Estimated vs. known values of the ratio of eye aperture to inter-eye distance are shown. The blue line (y = x) represents perfect performance.
- The vertical line of dots at true value zero corresponds to closed eyes.
- Digidata, Idemia, Neurotechnology, and Secunet perform best by mean absolute error.

FATE SIDD Report – Results for Mouth Open

ISO/IEC 29794-5 Quality Check: Mouth Closed (7.4.4)

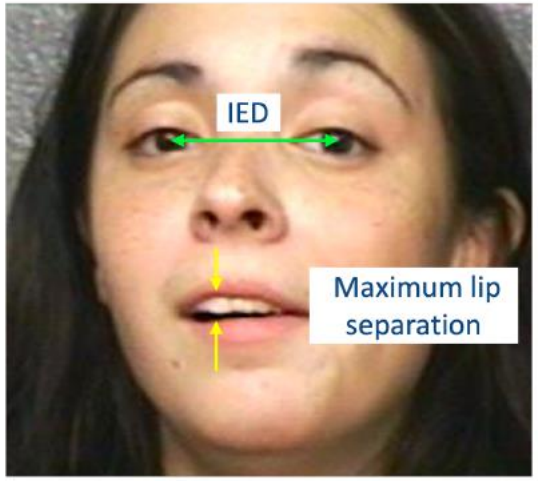
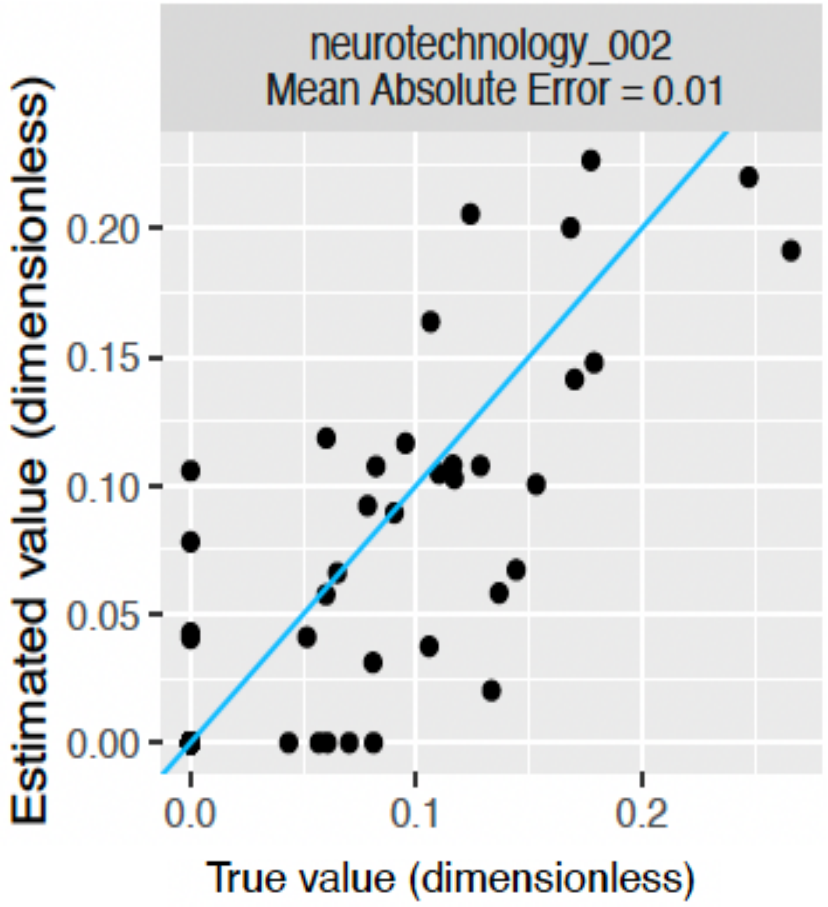
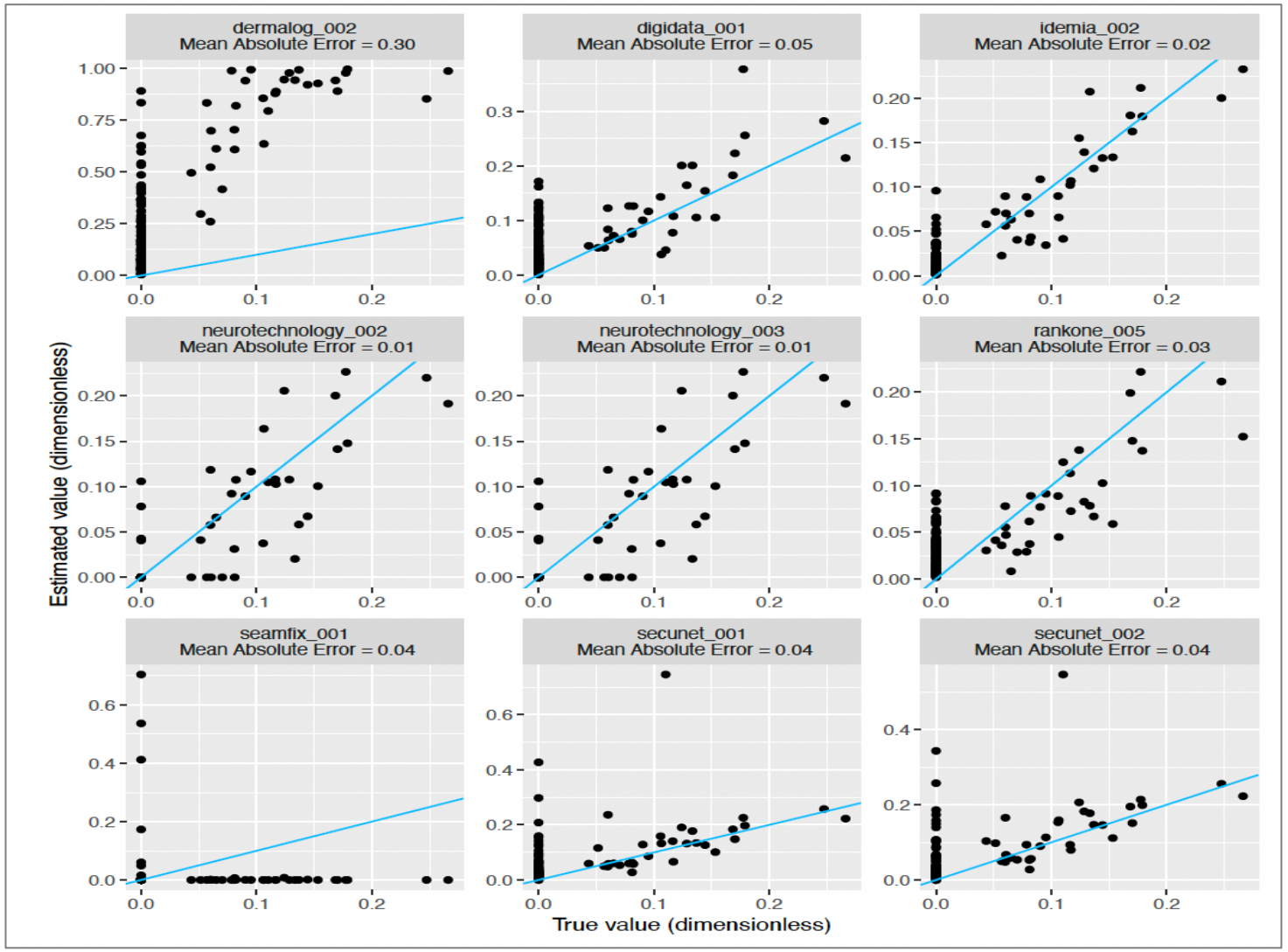


Image from NIST Special Database 32, MEDS.



- The MouthOpen measure is the ratio of the (vertical) maximum separation of the lips to the inter-eye distance.

FATE SIDD Report – Results for Mouth Open

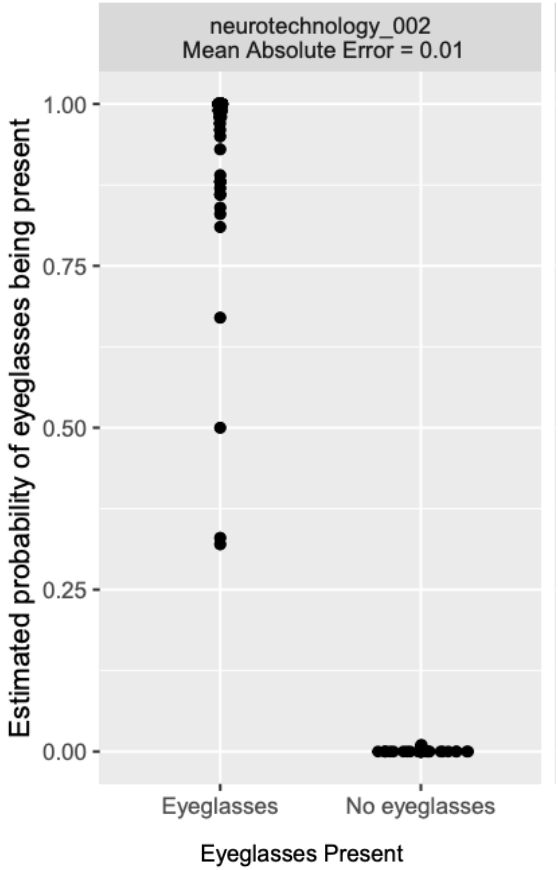


- Estimated vs. known values of the ratio of lip separation to inter-eye distance are shown. The blue line (y = x) represents perfect performance.
- The vertical line of dots at true value zero corresponds to closed mouths.
- Neurotechnology performs best based on mean absolute error

FATE SIDD Report- Results for Eyeglasses

ISO/IEC 29794-5 Quality Check: Eyes Visible (7.4.5)

Image from NIST Special Dataset 32, MEDS

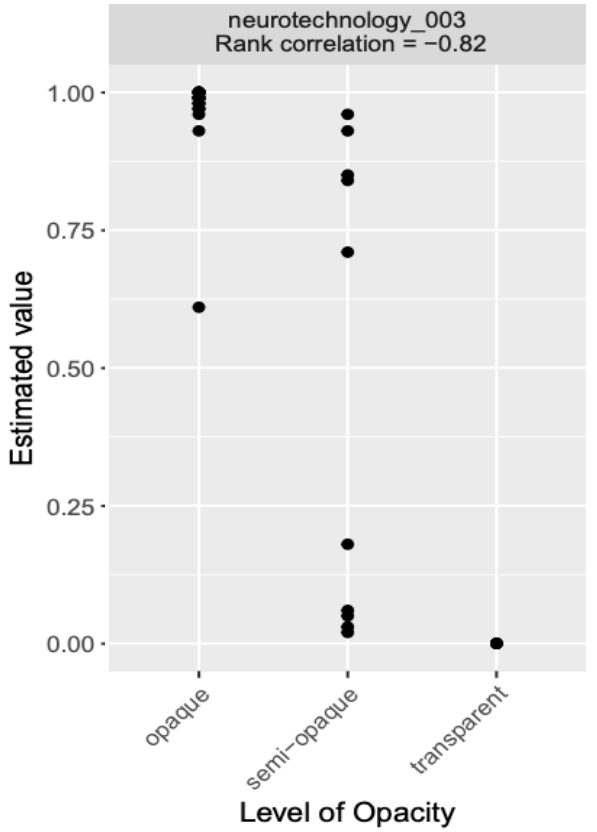


- For eyeglasses set, two categories: with eyeglasses and without eyeglasses
- Neurotechnology_002 and Neurotechnology_003 perform best based on mean absolute error

FATE SIDD Report – Results for Sunglasses

ISO/IEC 29794-5 Quality Check: Eyes Visible (7.4.5)

Image from NIST Special Dataset 32, MEDS

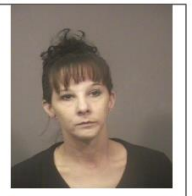
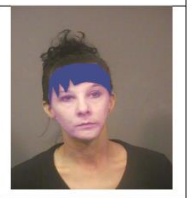


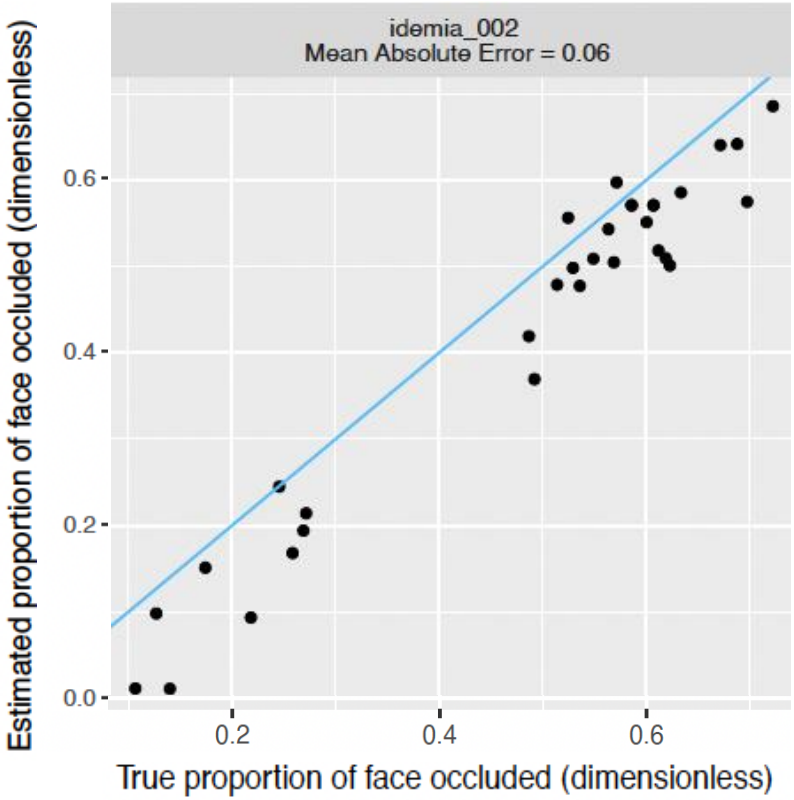
- The sunglasses set contains images with glasses that are opaque, semi-opaque, and transparent
- Neurotechnology_003 performs best based on rank correlation

FATE SIDD Report- Results for Face Occlusion

ISO/IEC 29794-5 Quality Check: Face Occlusion (7.4.7)

Table 15. Face Occlusion Illustration. The first and third images are from NIST Special Database 32, MEDS; the second image is used with permission of the subject.

Original image			
Image with occluded area shown in blue			
Ratio of occluded area to total area	0.27	0.11	0.36



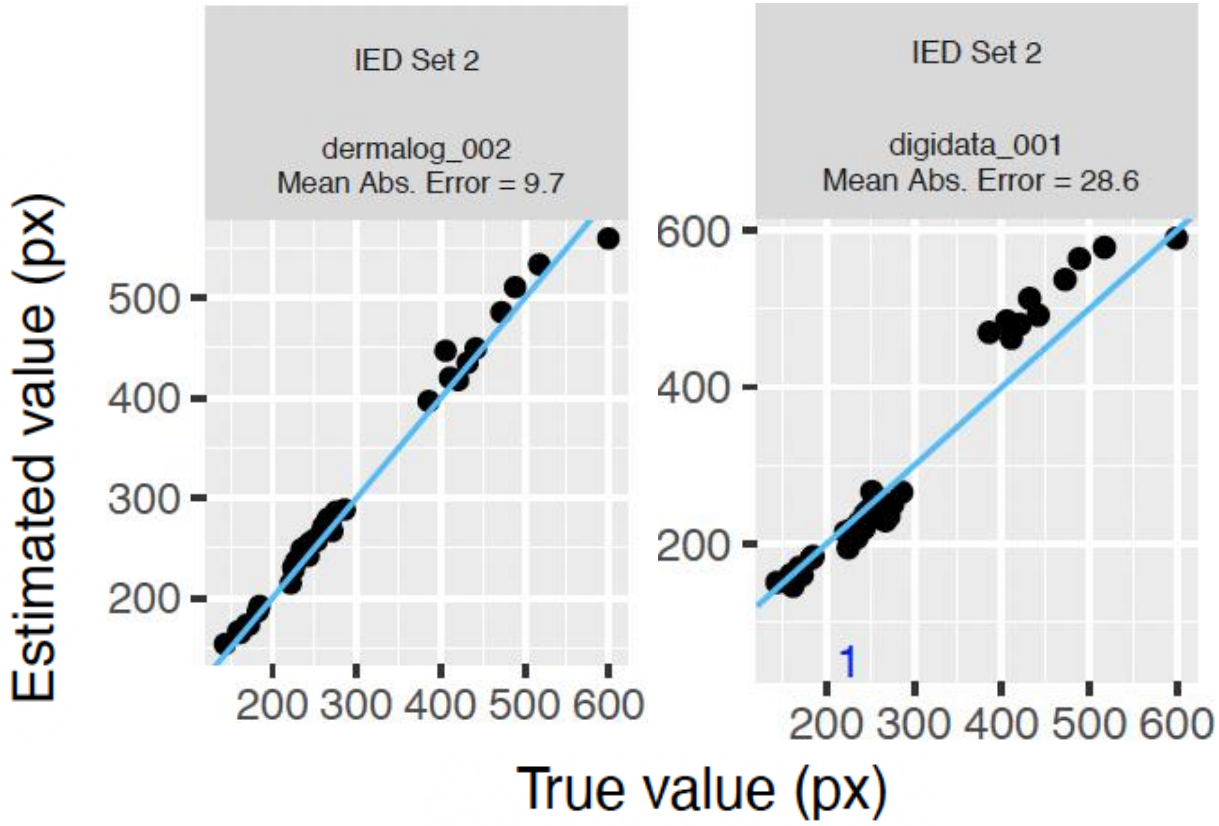
- The Face Occlusion measure is the ratio of the occluded area of the face region to the total area
- For the images in this set, the occlusion consists mostly of hair and masks

- IDEMIA performs best based on mean absolute error.
- Error for FTEs is set to 0.5.

FATE SIDD Report – Results for Inter-Eye Distance

ISO/IEC 29794-5 Quality Check: Inter-Eye Distance (7.4.8)

Fig. 10. Inter-eye distance is calculated by averaging the canthi for each eye and taking the distance of the two resulting points. Image from NIST Special Database 32, MEDS.



- Rank One performs best based on mean absolute error for Set 1
- $IED_{3D}=(IED_{2D})$ (1/cos(yaw)) will be tested in the future

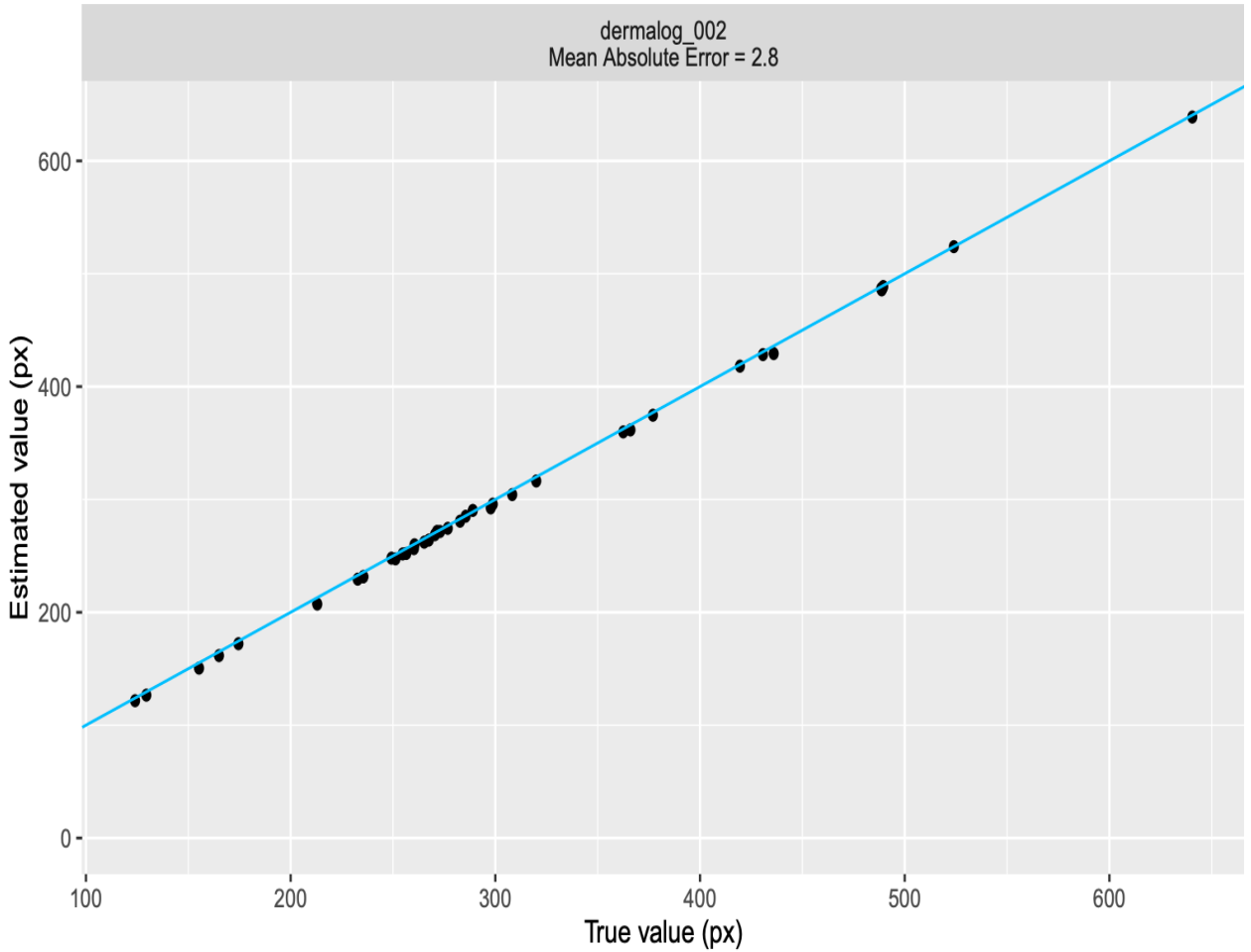
- Dermalog performs best for Set 2
- Error for FTEs is set to 50 pixels.

FATE SIDD Report- Results for Distance from Eyes to Edges

ISO/IEC 29794-5 Quality Check: Head Size (7.4.9) and Crop of the Face Image (7.4.10)

Fig. 24. Image from NIST Special Database 32, MEDS.

- We compute the distance from the left edge to the **closest** eye-center and the distance from the right edge to the **closest** eye-center
- We compute the distance from the average of the eye-centers to the top and bottom of the image

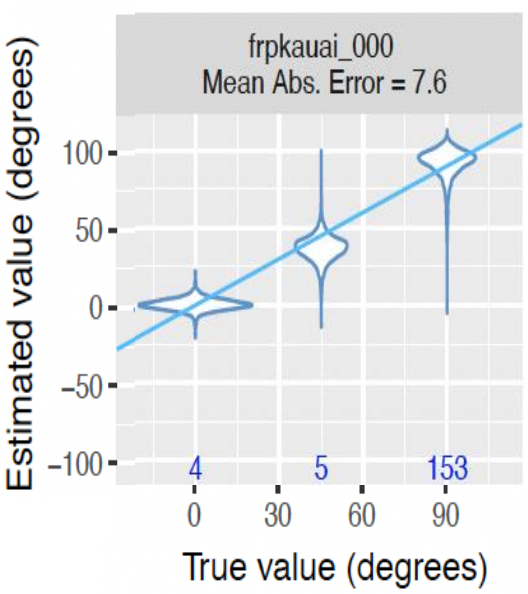


- Dermalog performs best based on mean absolute error

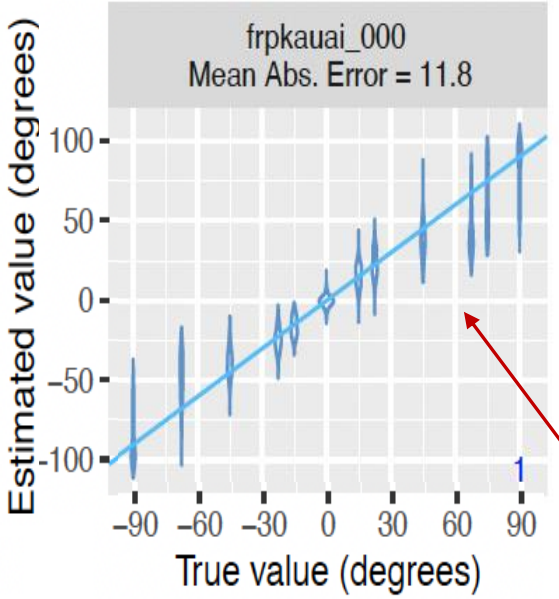
FATE SIDD Report- Results for Pose Yaw

ISO/IEC 29794-5 Quality Check: Pose (7.4.11)

Set 1

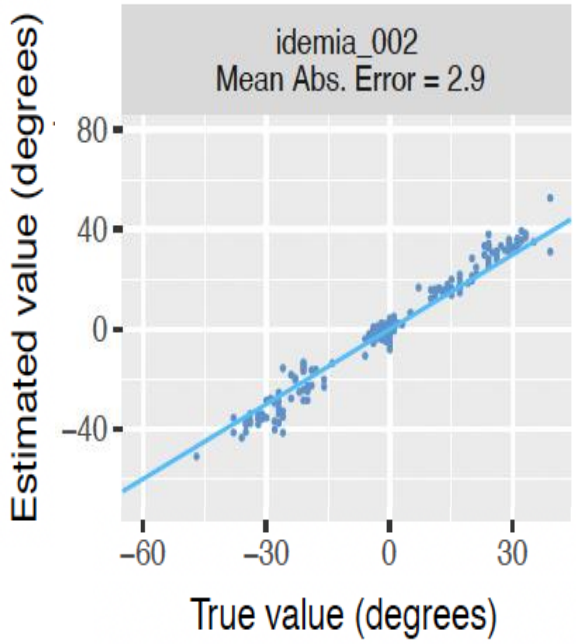


Set 2



Error bars increase with magnitude of true yaw

Set 3

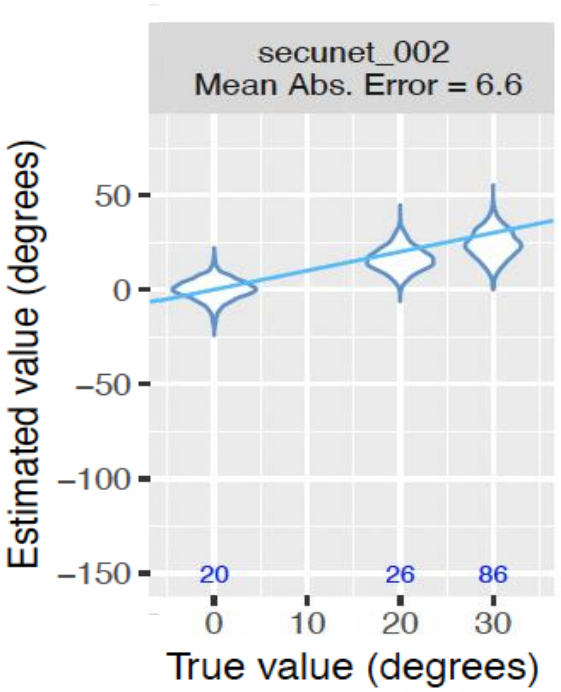


- FRP Kauai performs best by mean absolute error for Yaw Set 1 and 2
- IDEMIA performs best by mean absolute error for Yaw Set 3
- For FTEs, error is set to 45 degrees.

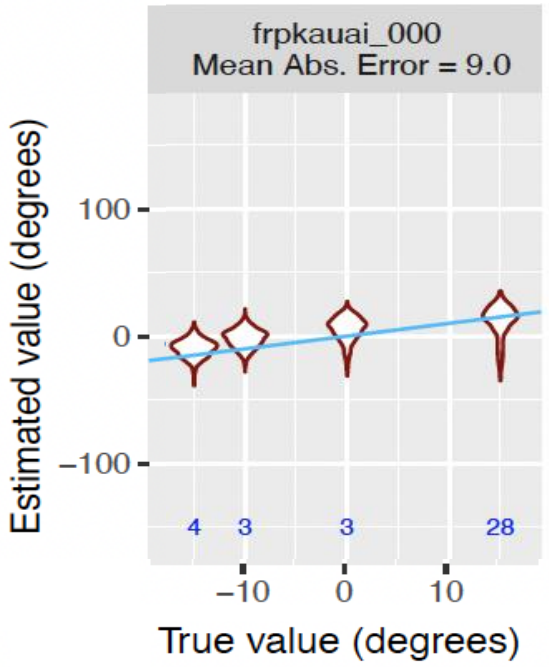
FATE SIDD Report- Results for Pose Pitch

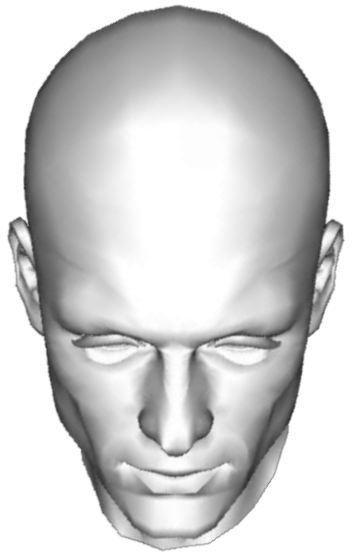
ISO/IEC 29794-5 Quality Check: Pose (7.4.11)

Set 1

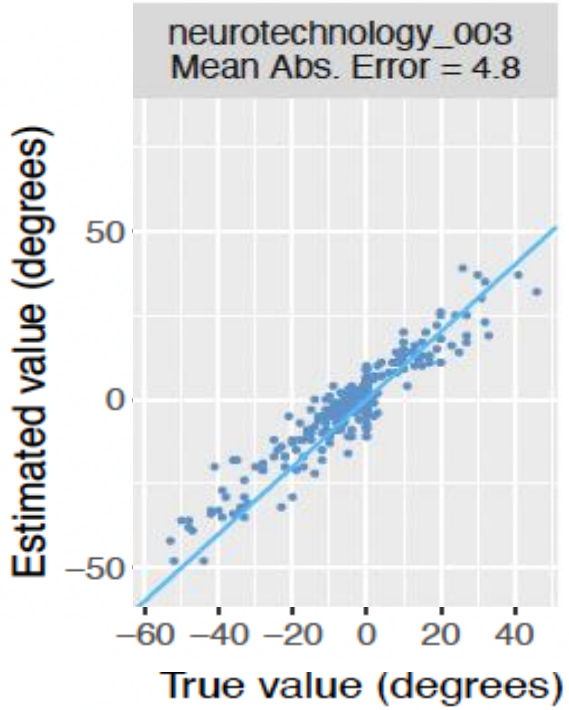


Set 2





Set 3

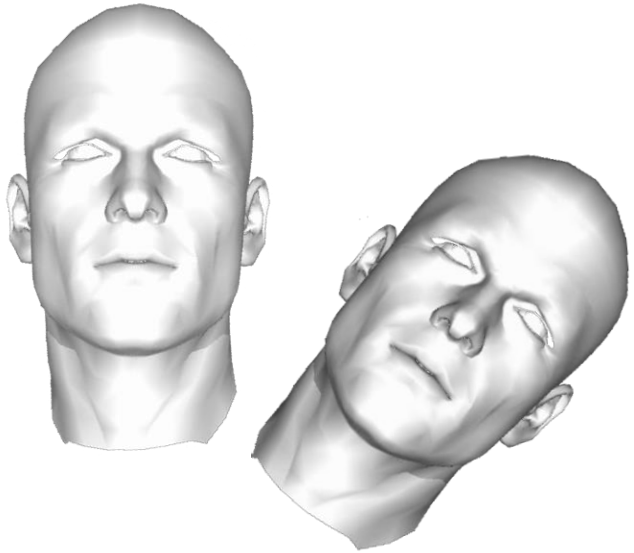


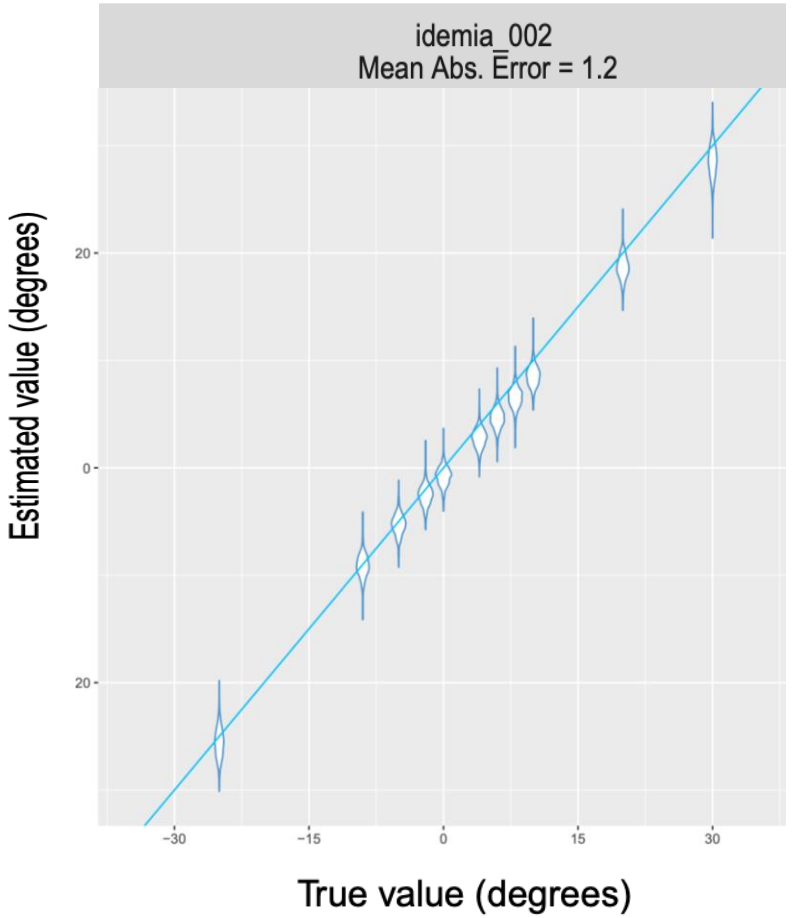
- Secunet_002 performs best by mean absolute error for Pitch Set 1
- FRP Kauai performs best for Set 2

- Neurotechnology_002 and IDEMIA perform best for Pitch Set 3
- For all pitch sets, error for FTEs is set to 30 degrees.

FATE SIDD Report- Results for Pose Roll

ISO/IEC 29794-5 Quality Check: Pose (7.4.11)





- For Roll, IDEMIA performs best by mean absolute error
- Error for FTEs is set to 45 degrees.

FATE SIDD- How to Participate

- Read the API
- Read the participation agreement; agree to it, sign it, scan it to PDF.
- Implement one or more image quality components enumerated in the API
- Download the FATE quality validation package; compile, link, run, check output
- tar the combined software and validation output; sign and encrypt the tar.gz
- Subscribe to FRVT news
- Visit https://pages.nist.gov/frvt/html/frvt_quality.html and submit using the online form

Next Steps and Further Information

- Include test for IED with nonzero yaw
- Add new algorithms; at least one more expected by December.
- Add additional sets and images
- FATE SIDD remains open; at this time, there is no time limit for participation

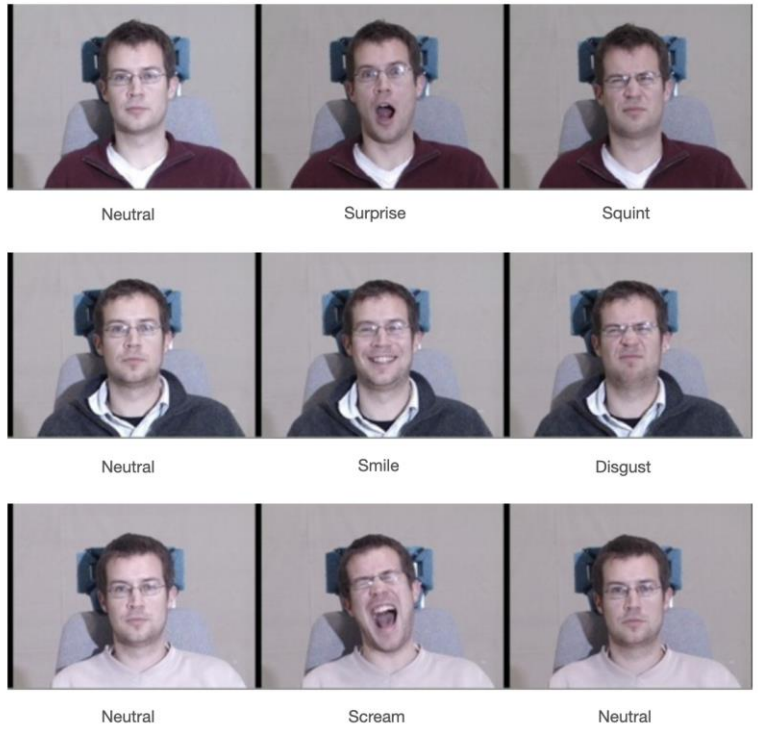
- For more information and updates, see https://pages.nist.gov/frvt/html/frvt_quality.html

Note on Expression Neutrality

Q: Will FATE SIDD introduce a quality measure for expression neutrality?

A: We are currently looking into test sets for expression neutrality. If expression neutrality is included, there will likely be two categories– neutral expression and non-neutral expression.

Datasets such as M-PIE have finer categories for expression but are not sequestered, and we anticipate that developers have trained on them.



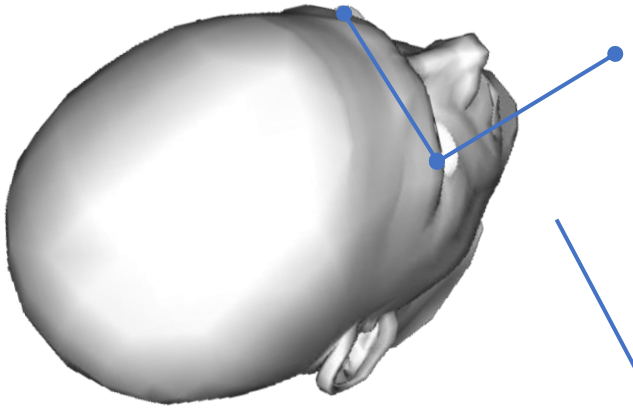
https://www.cs.cmu.edu/afs/cs/project/PIE/MultiPie/Multi-Pie/Content.html

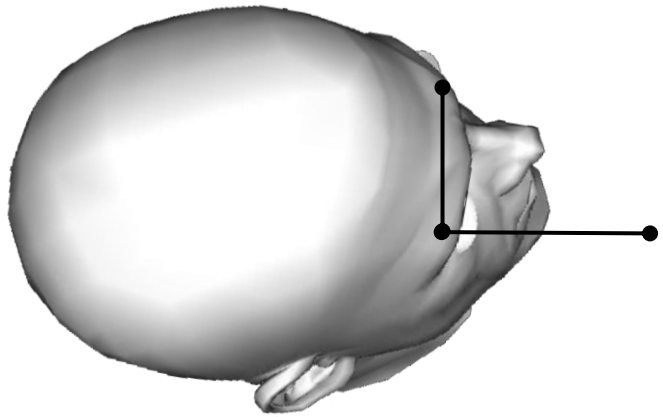
Questions?

For more information:
Contact frvt@nist.gov
Visit https://pages.nist.gov/frvt/html/frvt_quality.html
View SIDD report at
https://pages.nist.gov/frvt/reports/quality_sidd/frvt_quality_sidd_report.pdf

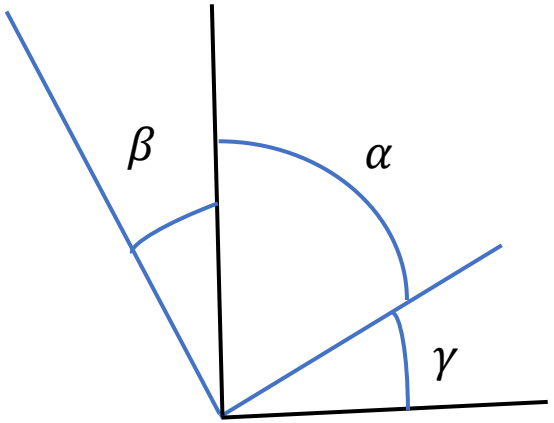
Explanation of IED with Yaw

In both original and rotated position, draw a line segment connecting the eyes and a line segment perpendicular to it.

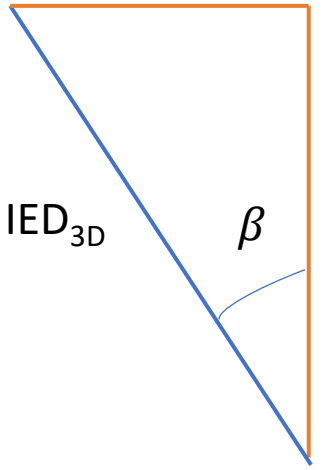




Since both angles β and γ are complementary to the angle α, they are equal.



Since γ is the yaw angle, β is the yaw angle as well.



$IED_{3D} (\cos \beta) = IED_{2D}$

The implied 3D IED is $IED_{3D} = IED_{2D}/\cos \beta$.