The Specification and Measurement of Face Image Quality

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U.S. Department of State (DoS) Motivation

- Face recognition (FR) accuracy is highly dependent on face image quality

- In conjunction with fingerprint matching, DoS is using FR to screen non-immigrant and immigrant visa applicants and for fraud detection in its Diversity Visa (lottery) program

- Started using FR with applicants for U.S. passports

- Many diverse sources for face images exist --- various resolution scanned photos & online digital submission

- Approaching 100M visa-applicant face images enrolled

- Applicants are required to provide images conforming to standards & DoS must verify
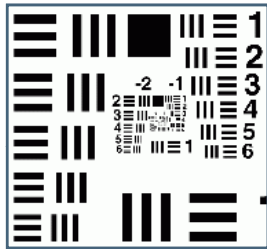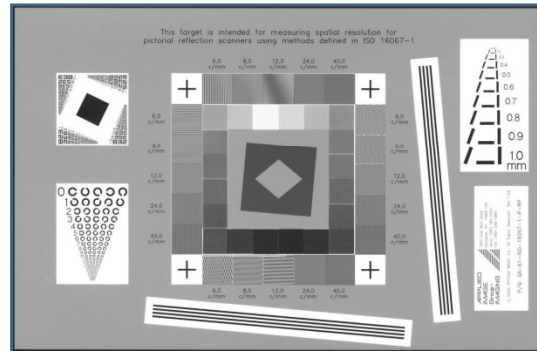
Easy: Quality Assessment with Test Targets
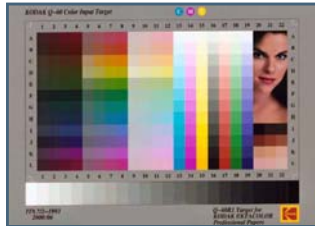
IT8.7/2
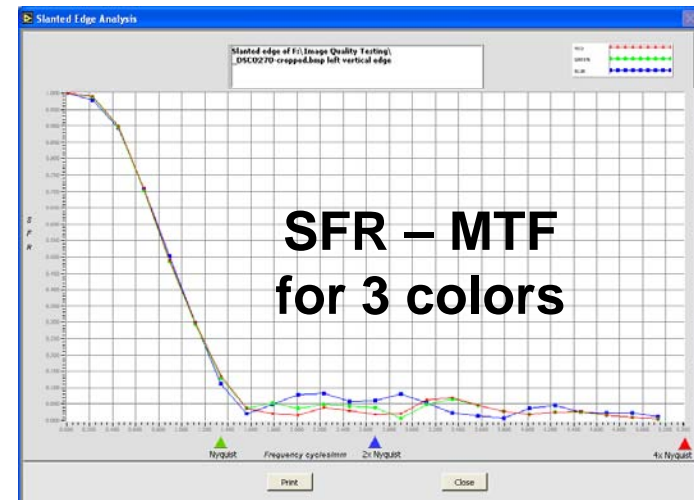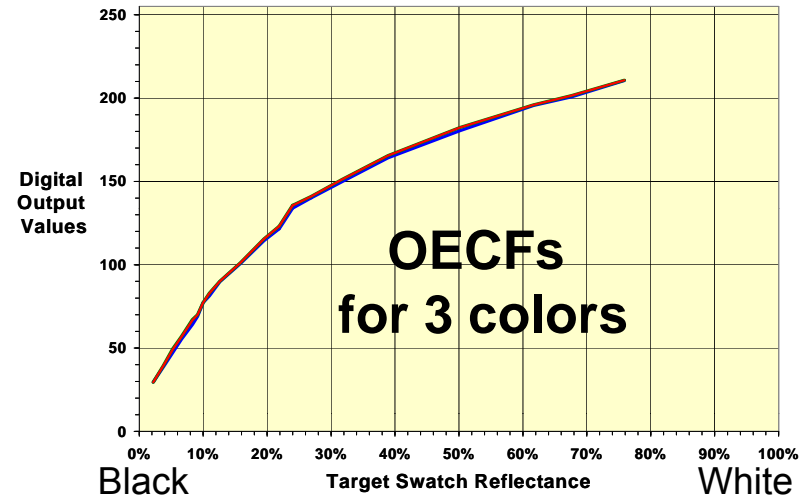
Macbeth
ColorChecker

USAF 1951

ISO-16067-1
Scanner Test Chart

- OECF (Capture γ and exposure accuracy) - ISO 14524

- Spatial Resolution (MTF) and depth of field - ISO 12233 and ISO 16067-1

- Signal to Noise Ratio (S:N) - ISO 15739 - and spatial uniformity

- Color - $\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$

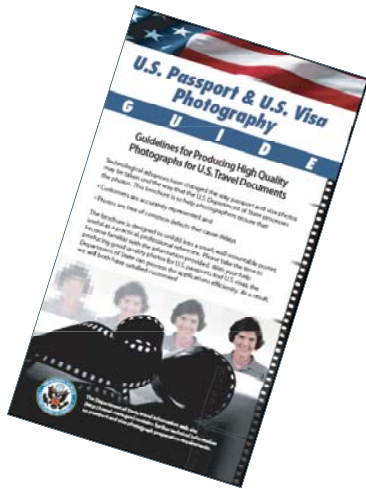noblis
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Measurement of OECF & SFR

Applied Image, Inc.
QA-62-SFR
Scanner Test Chart

OECFs
for 3 colors

SFR – MTF
for 3 colors
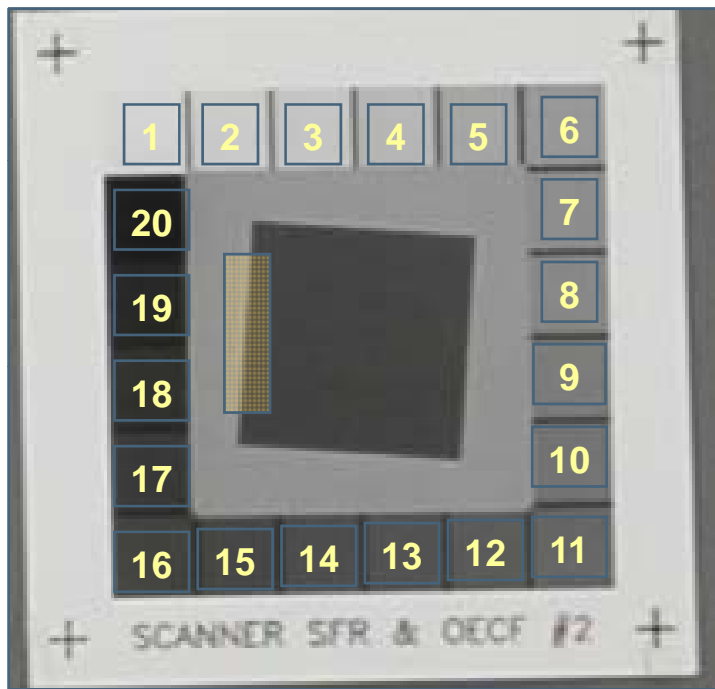
DoS Passport & Visa Photo Guidelines

Traditional Photography

U.S. Passport & U.S. Visa Photography GUIDE

Guidelines for Producing High Quality Photographs for U.S. Travel Documents

2 inch

2 inch

1 inch to 1⅜ inch

1⅛ inch to 1⅜ inch

Figure 2. Head Position & Placement

Digital Photography

Distance from camera to subject
- more than 4 feet (1.25 meters)
- include upper body and space above head in viewfinder

Eliminate shadows caused by overhead lighting

Well-lit white or off-white background
- free of patterns, objects, textures, etc.

Distance from subject to background
- minimize distance to eliminate background shadows

Approximate size picture using LCD display panel on digital camera

Field of View
- allow sufficient distance from camera to subject to properly frame the subject
- use normal or telephoto zoom setting
- include space above head and upper body in field of view
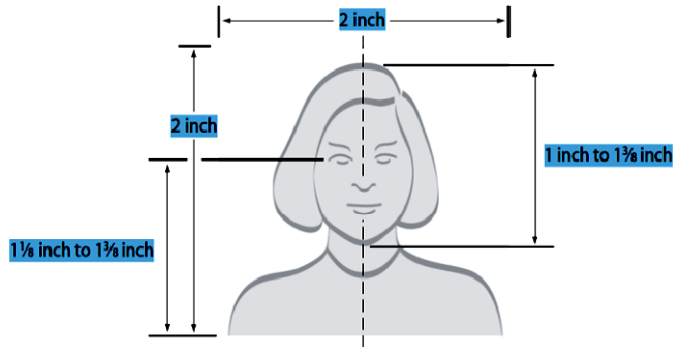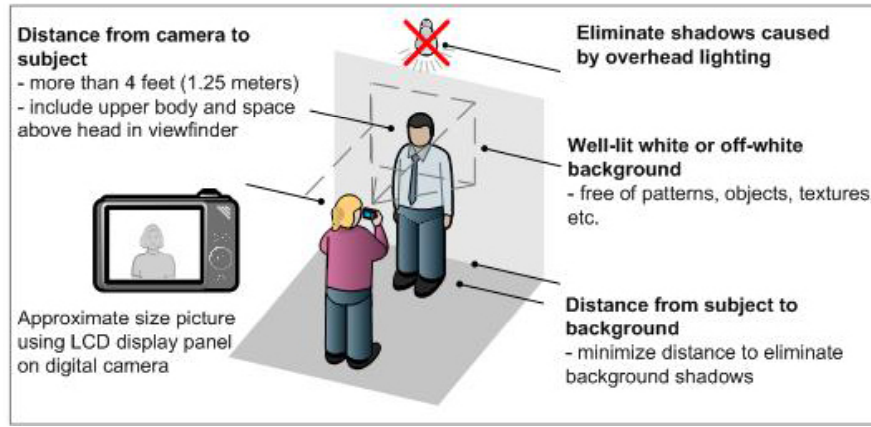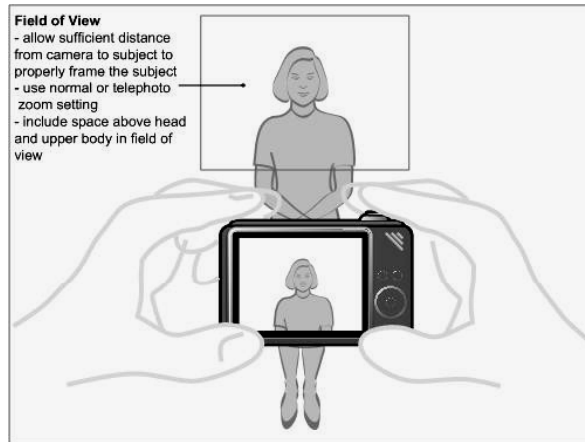
Many examples provided on Website

See http://travel.state.gov/visa/guide/guide_3882.html

CEAC: Consular Electronic Applications Center

As of February 2010, all nonimmigrant visa applicants at about 72 U.S. Embassy and Consulates are required to apply using the online DS-160 form.
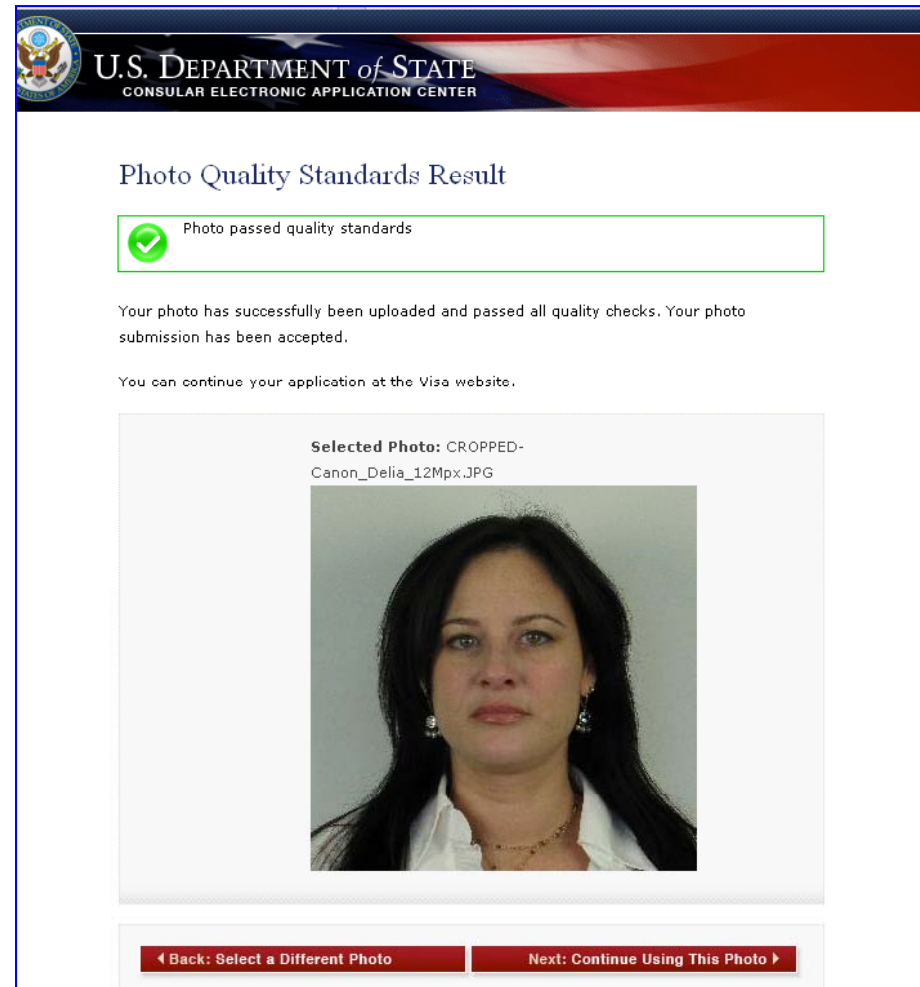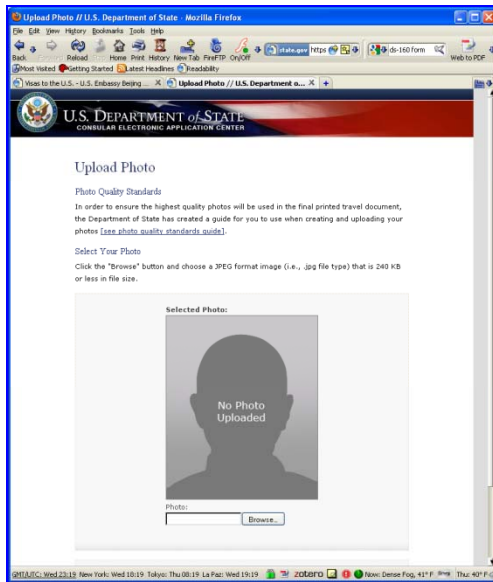
Photo Cropping Tool for Applicants

- Adobe Flash-based tool

- For use by passport and visa applicants

- Applicants choose their landscape or portrait mode photos (up to 64Mpx)

- Can interactively position, resize, and crop using min and max head outlines

- Can then save the cropped photos locally

- Later upload the cropped photos via CEAC or a possible similar Website for passports
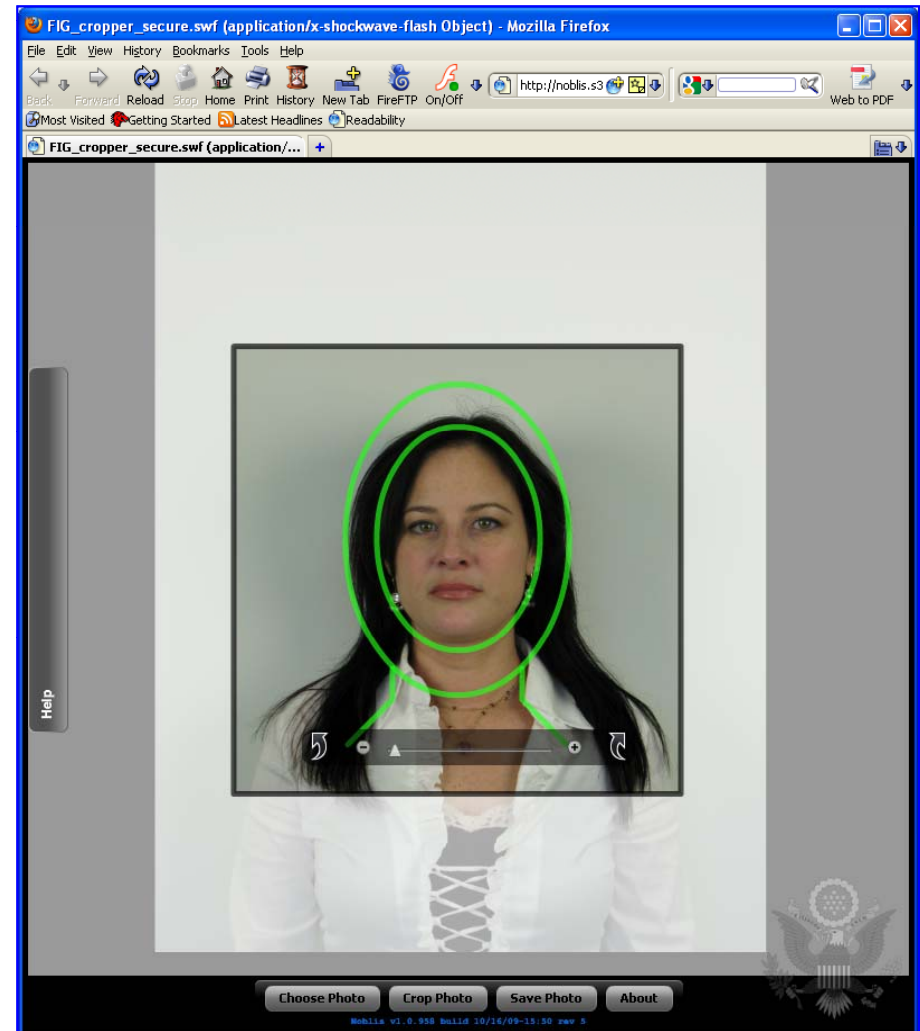
Synopsis of ISO 19794-5 Requirements

The face, from the crown to the base of the chin, and from ear-to-ear, shall be clearly visible and free of shadows.

≤ +/- 5 degrees from frontal in every direction – roll, pitch and yaw

No other face in the image

Shoulders "square on"

Lighting equally distributed on the face

After conversion to greyscale, there should be 7 bits of intensity variation in the facial region of the image.

Face must be in focus from nose to ears and chin to crown. Sufficient depth of focus to maintain better than two millimeter resolution.

The iris and pupil of the eyes shall be clearly visible.

Eyeglasses shall allow the eye pupils and irises to be clearly visible.

There shall be no lighting artifacts or flash reflections on glasses.
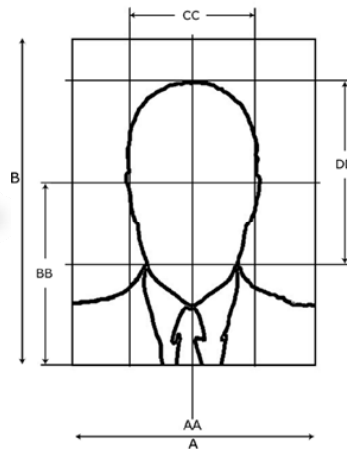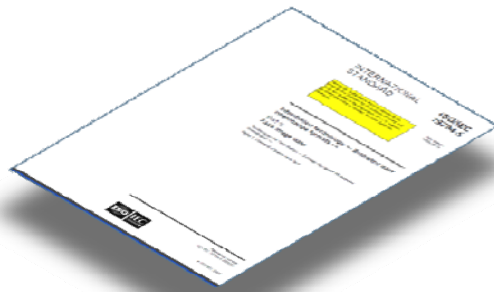
Section	Definition	Requirements
8.3.3	Vertical Position of Face	0.5 B ≤ BB ≤ 0.7 B
8.3.3	Vertical Position of Face (Children under the age of 11)	0.4 B ≤ BB ≤ 0.7 B
8.3.4	Width of Head	A ≥ 1.4 CC
8.3.5	Length of Head	B ≥ 1.25 DD

Desired Metrics and Their Characteristics

1. **Dynamic range in face**
2. **Eyes closed/obstructed**
3. **Color balance**
4. **Lighting uniformity on face**
5. **Background consistency**
6. **Head width to image width ratio**
7. **Centering of face**
8. **Distance between eyes**
9. **Focus/Sharpness of face**
10. **Rotation (yaw)**
11. **Tilt (roll)**
12. **Confidence in face**
13. **Brightness and contrast**

✓ Reasonably shaped histogram

poor   good

unacceptable | acceptable

Or

acceptable
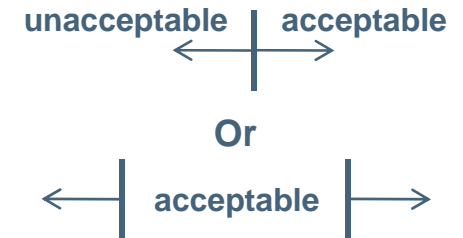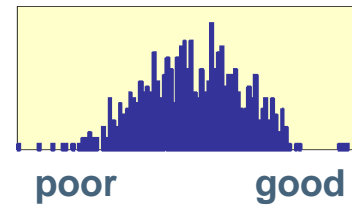
✓ Good correlation with human perception
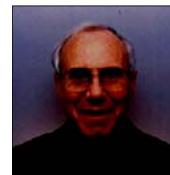
✓ Correlation with FR match scores

✓ Well defined algorithm

Assessing Face Metric Performance

- In 2006, Noblis tested four products (SDKs) that claimed to measure face image quality

  - Tested using same set of passport, visa, and other photos

  - Comparison proved difficult – lack of standardization in terminology & insufficient description of algorithms

  - Some products had poorly distributed histograms – threshold determination sometimes proved problematic

  - Values exhibited little correlation with match scores

  - In some cases, values had no obvious correspondence to perceived quality

- DoS is now using one of these products for image quality checks before FR and during online photo submission

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Results from Sorting Metric Values - by Dynamic Range

Record 1	
Metric	**Value**
Dynamic range	**29**
Eyes closed/ obstructed	
Color balance	
Lighting uniformity	
Background consistency	

Record 2	
Metric	**Value**
Dynamic range	**34**
Eyes closed/ obstructed	
Color balance	
Lighting uniformity	
Background consistency	

......

Record n-1	
Metric	**Value**
Dynamic range	**89**
Eyes closed/ obstructed	
Color balance	
Lighting uniformity	
Background consistency	

Record n	
Metric	**Value**
Dynamic range	**92**
Eyes closed/ obstructed	
Color balance	
Lighting uniformity	
Background consistency	

......
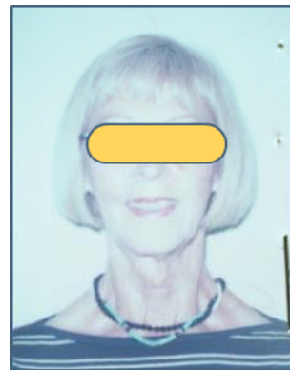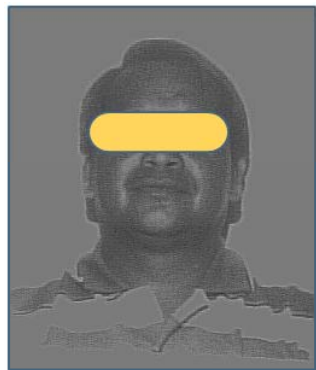
Results from Sorting Metric Values - by Lighting Uniformity

Record 1			Record 2			Record n-1			Record n	
Metric	**Value**		**Metric**	**Value**		**Metric**	**Value**		**Metric**	**Value**
Dynamic range			Dynamic range			Dynamic range			Dynamic range	
Eyes closed/ obstructed			Eyes closed/ obstructed			Eyes closed/ obstructed			Eyes closed/ obstructed	
Color balance			Color balance			Color balance			Color balance	
Lighting uniformity	**0**	......	Lighting uniformity	**2.2**		Lighting uniformity	**100**		Lighting uniformity	**100**
Background consistency			Background consistency			Background consistency			Background consistency	
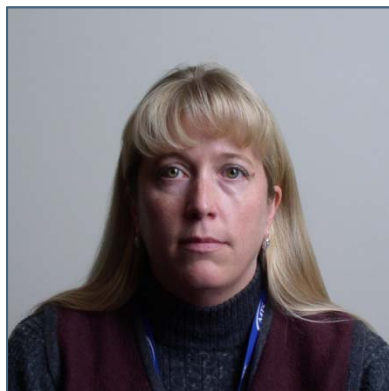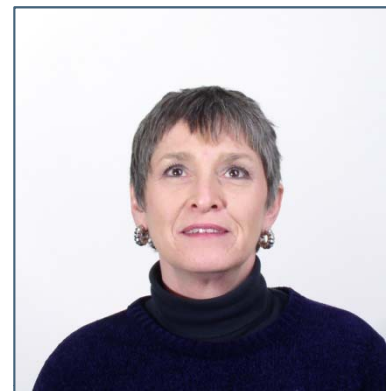
Results from Sorting Metric Values - by Background Consistency

Record 1		Record 2		Record n-1		Record n	
Metric	**Value**	**Metric**	**Value**	**Metric**	**Value**	**Metric**	**Value**
Dynamic range		Dynamic range		Dynamic range		Dynamic range	
Eyes closed/ obstructed		Eyes closed/ obstructed		Eyes closed/ obstructed		Eyes closed/ obstructed	
Color balance		Color balance		Color balance		Color balance	
Lighting uniformity		Lighting uniformity		Lighting uniformity		Lighting uniformity	
Background consistency	**0**	Background consistency	**21**	Background consistency	**98**	Background consistency	**98**

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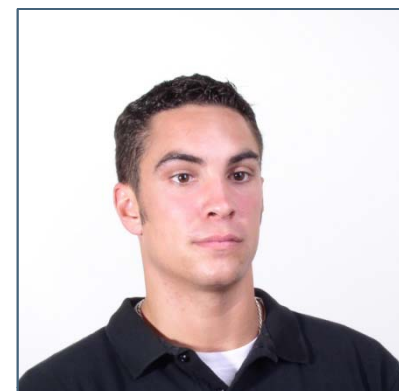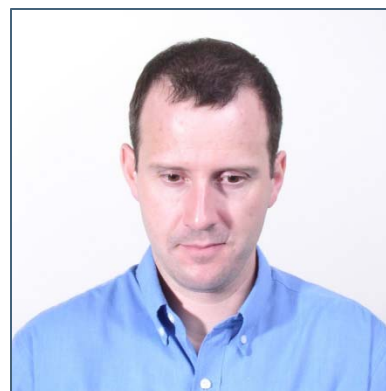
Correlations Among Quality Factors

	Brightness	Contrast	Cropping	Darkness	Exposure	Face likeness	Focus	Glasses	Resolution	Texture	Face Confidence
Brightness	1										
Contrast	-0.07	1									
Cropping	0.01	0.03	1								
Darkness	-0.12	0.33	0.03	1							
Exposure	**0.86**	0.11	0.02	0.4	1						
Face likeness	-0.05	0.26	0.17	0.28	0.09	1					
Focus	0.07	0.09	0.02	0.04	0.09	-0	1				
Glasses	-0	-0.01	-0.34	-0.02	-0.01	-0.08	-0.02	1			
Resolution	-0.04	0.05	-0.3	0.04	-0.02	-0.14	0.05	0.21	1		
Texture	-0.04	-0.06	0.02	-0.03	-0.05	0.01	0.11	-0	0.05	1	
Face Confidence	-0.01	0.13	0.1	0.13	0.06	0.34	0.08	-0.06	0.02	0.02	1

Correlation with Match Scores

Minimum Probe/Mate Face Quality Value versus True Match Score

$y = 0.1538x + 71.108$
$R^2 = 0.0102$
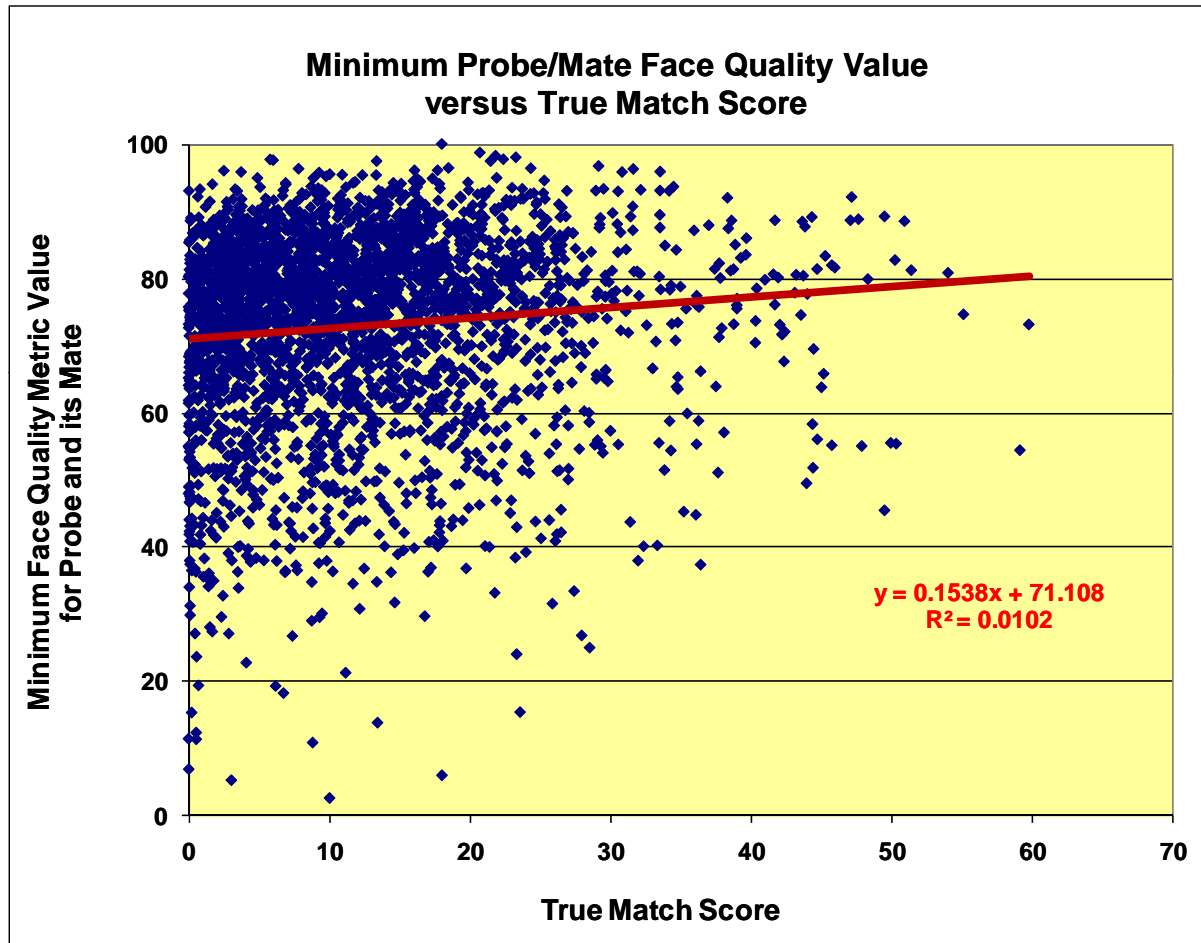
Low correlation found for any single metric, but others have found better correlation with same vendor's FR scores by using multi-variate linear regression to combine multiple quality metrics

Training & Testing Databases

- Pose, illumination, & expression databases

  – Yale Face Database [Georghiades et al., IEEE PAMI, 2000]

  – CMU PIE Database of Human Faces
  [Sim et al., CMU-RI-TR-01-02, 2001]

- PIE, etc. database characteristics --- should have:

  – Only a single changing variable for each sequence

  – Good resolution, accurate color, plain background, diverse &
  representative ethnicities

- Alternative might be to categorize many pre-existing visa or passport
  photos – but privacy issues might prove prohibitive for distribution of
  the database

- Can artificially generated or suitably altered faces be employed?

Some Challenges

➢ Vendors are very reluctant to divulge their algorithms - we don't need the code, but we do want very clear descriptions

➢ Some flesh tones, hair styles and head coverings have resulted in rejected images that are otherwise acceptable

➢ To accommodate the wide range of flesh tones, head coverings, etc. from consular posts all over the world, we have had to lower thresholds for some metrics to the point that they're no longer of value

➢ Providing clear feedback to applicants and face examiners to correct defective images has proven difficult

➢ Combining multiple metrics into a single, readily understood, overall face image quality value has been particularly difficult

➢ Finding evidence of intentional digital alteration (i.e., Photoshopping)

Recommendations

➢ Insist upon best practices for image capture and enforce through periodic measurement with test patterns

➢ Prepare training and testing databases of face images with visual assessment of image quality

➢ Request clear descriptions of face quality metrics from the product's providers

➢ Conduct objective testing of the accuracy of face quality metrics, similar to FRVT/FRGC

➢ Consider development and publication of a face image quality standard, similar to NFIQ, as well as additions to the NIST Biometric Image Software (NBIS) suite for face image processing

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Thanks for your attention…..

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