A New Approach for Measuring Facial Image Quality

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Agenda

- Background
- FaceQM Purpose
- FaceQM Approach
- FaceQM Test Results
- FaceQM Current Status

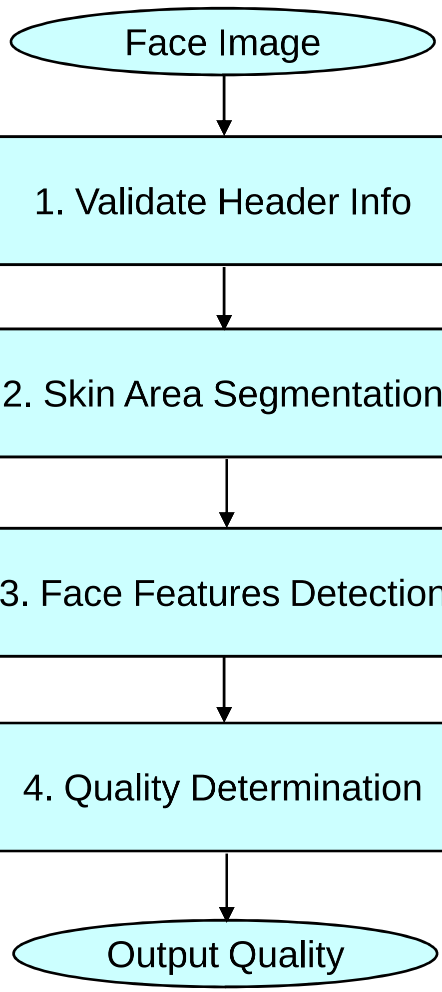
Background

- Measuring the quality of biometric samples is a crucial step in the enrollment processes.
- Use of good-quality biometric samples increases the performance of automatic recognition systems during the matching process.
- Varying operational environments (*e.g.*, lighting, deteriorating equipment, operator training) in which samples are collected result in collection of biometric samples of varying levels of quality.
- Without consistent biometric sample quality validation, poor-quality samples contaminate databases and negatively impact the performance of automatic recognition systems.

FaceQM Purpose

- Assess quality of facial images
  - Use requirements of INCITS 385-2004 (Face Recognition Format for Data Interchange) standard and other criteria as quality parameters
  - Use FaceQM quality scores as predictor of matching performance
- Evaluate matching algorithms and systems
  - Determine “sensitivity” of individual matchers to specific quality parameters
- Support customized quality scores (“mapping”)
  - For example: Acceptance-Rejection

FaceQM – Quality Measurement Flow



1. **Image Header Information Validation Module**
   - Check consistency and validate image header information
2. **Skin Area Segmentation Module**
   - Segment skin area by using Skin Color Decision Tree
   - Generate skin area mask
3. **Face Features Detection Module**
   - Locate face features – eyes, mouth, and ears
   - Measure and/or calculate face features
4. **Quality Determination Module**
   - Verify values of face features against constraints
   - Determine and output quality scores

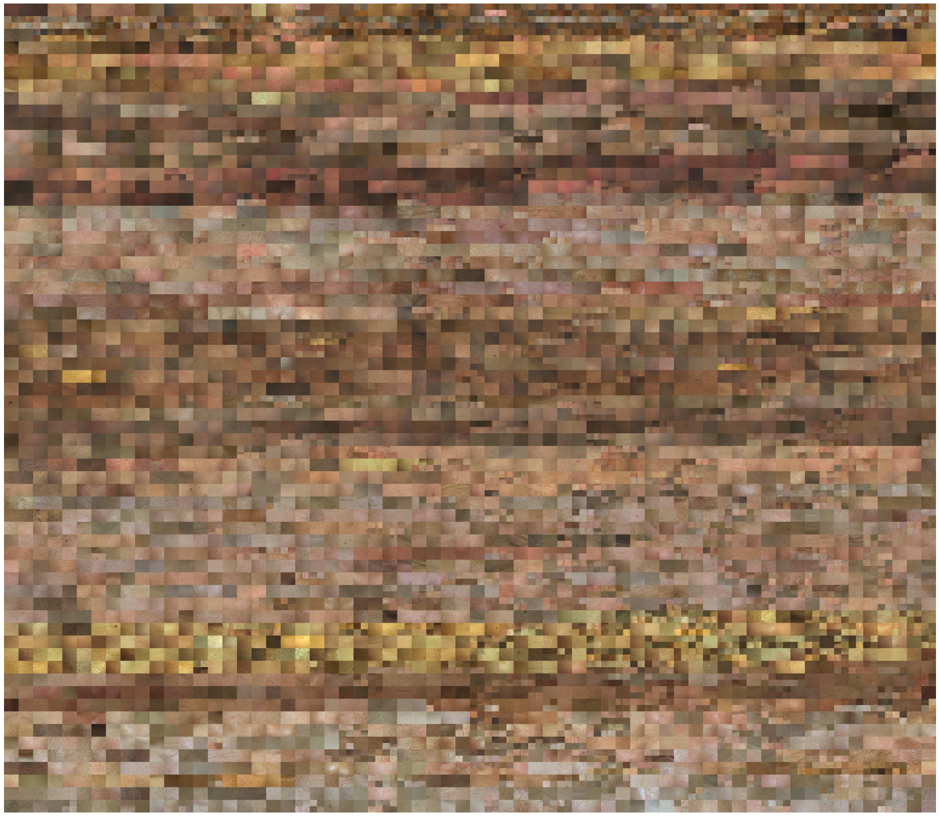
FaceQM
1. Header Information Validation

- The module verifies the following header information
  - Scanned resolution
  - Width and height values
  - Color bytes: Red-Green-Blue (RGB) bytes for each pixel
  - File size: consistency checking

FaceQM
2. Skin Area Segmentation

- Considerations: Accuracy and Efficiency
  - Our approach: Non-Uniform Binary Splitting Algorithm
- Uses trained skin color features as reference
- Based on the training process; establishes Decision Tree (DT)
- Uses the DT to segment face area

Skin Color Training Dataset



- All pixels belong to human skin color
- 2,048 x 2,048 = 4,194,304 pixels in total
- Collected from FERET Database

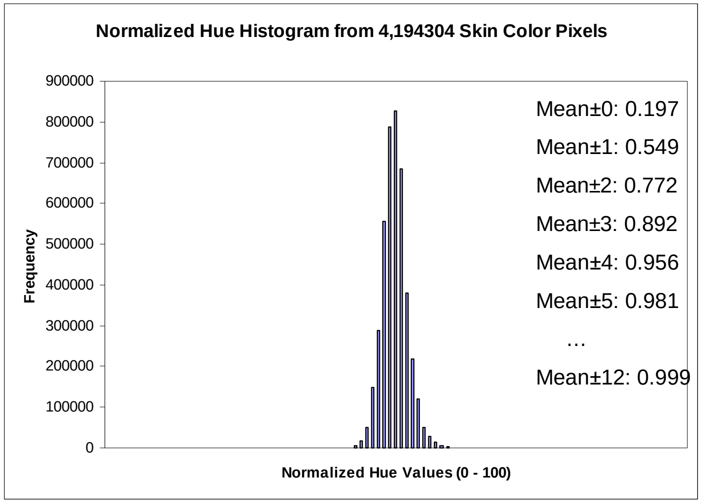
Skin Color Space

- Total combination of RGB bytes: $2^8 \times 2^8 \times 2^8 = 16,777,216$
- Skin color spectrum is narrow
- Skin color is a combination of red, yellow, and brown colors
- Several color spaces related to skin are available:

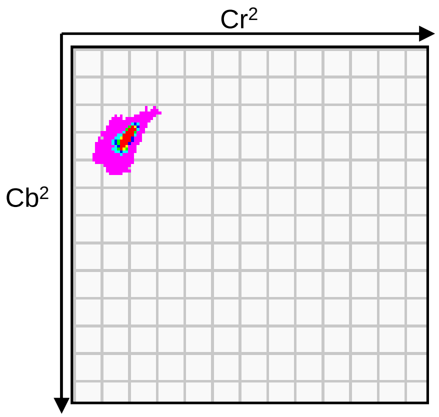
Color Space	Advantage	Disadvantage
RGB (Red-Green-Blue)	Easy to form from current capture devices	Not a good color space to present skin-tone value
YUV (Luminance-Hue-Saturation)	Good for broadcast television and compression/decompression	Has no chrominance components
YCrCb (Luminance-Chrominance)	Good for handling video information	Has no hue component
HIS (Hue-Intensity-Saturation)	Good for providing Intensity and Saturation information of color	Has no chrominance components

- Our approach: Combinations of Y, Cr, Cb, Hue, and Saturation

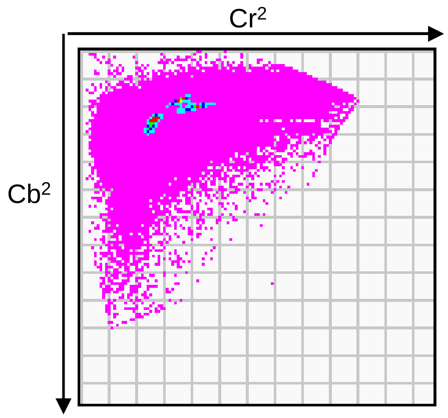
Skin Color Space - Statistic

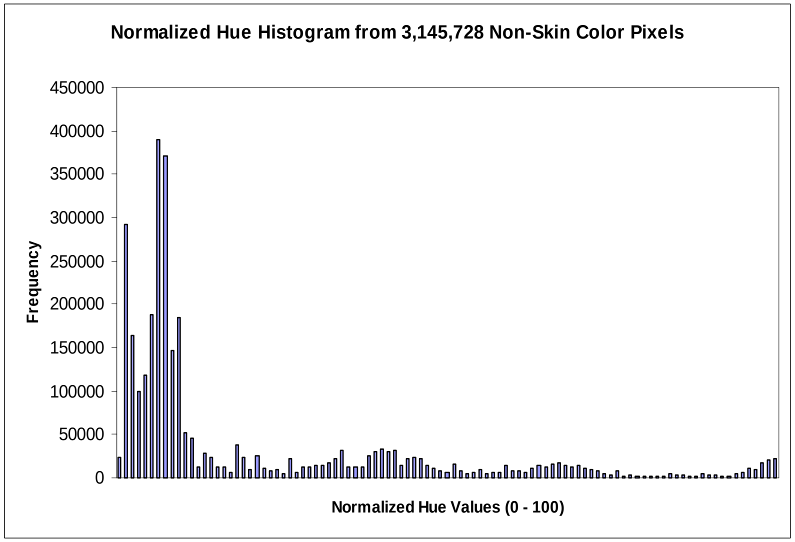


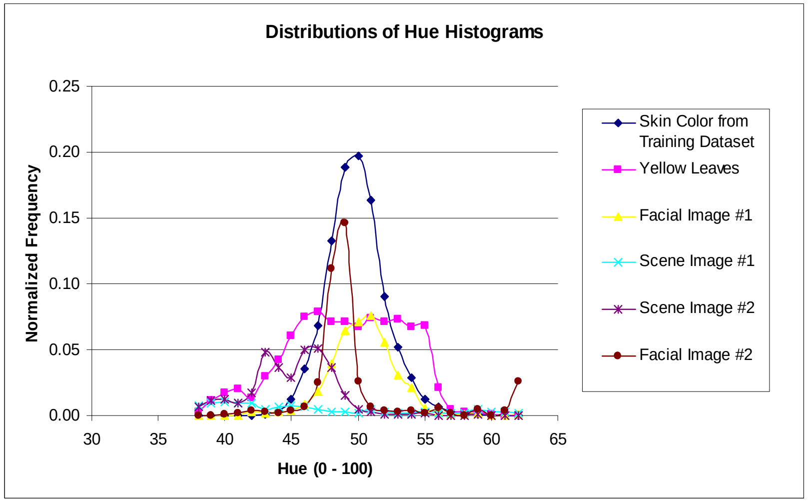
Skin Color – Cr^2 vs. Cb^2



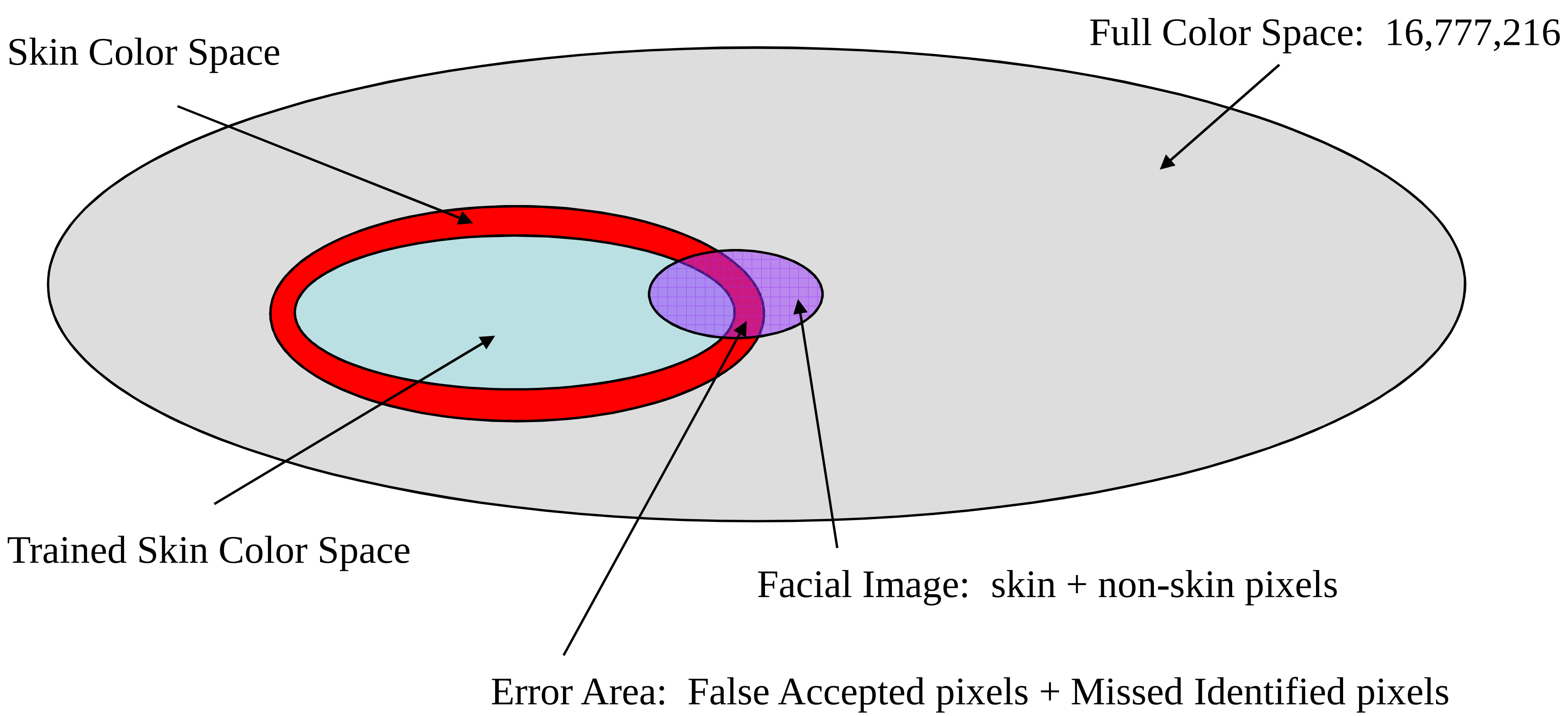
Non-Skin Color – Cr^2 vs. Cb^2





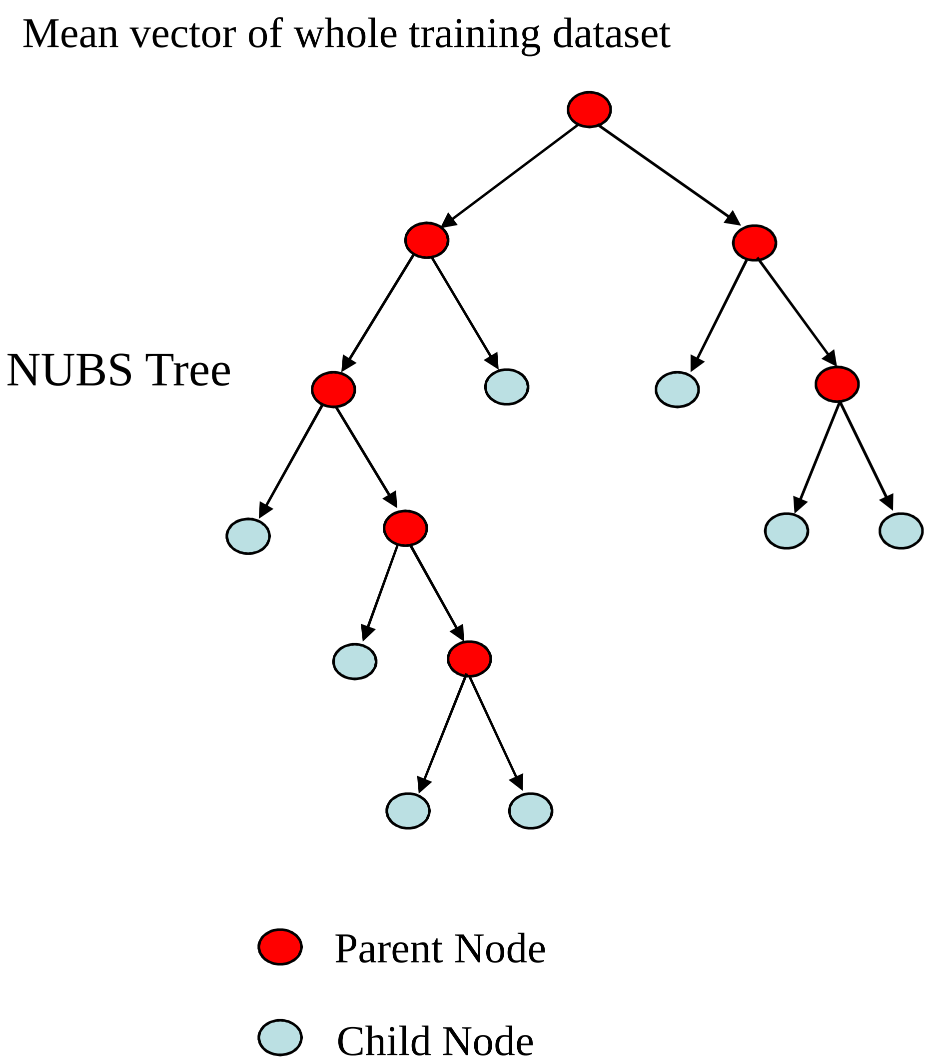


Skin Color Segmentation Analysis



Non-Uniform Binary Splitting

BIOMETRICS TASK FORCE



Each node has (1) mean vector, (2) node variance, and (3) number of pixels.

Node Splitting Rule:

(1) node's variance > pre-defined value

(2) number of pixels > pre-defined value

(3) each parent node only splits to two child nodes

NUBS Tree:

For each parent node, need to record the child node's number and mean vector.

Skin Color Training Process

Step 1: Set the ε (variance threshold)

Step 2: Convert each pixel's RGB bytes to a skin feature vector, v

Step 3: Calculate the mean vector and variance of whole training dataset

Step 4: Split current node all pixels into two sub-classes by using NUBS algorithm

Step 5: Calculate the mean vectors and variances for both sub-classes

Step 6: Register the nodes, mean vectors, and variance into the Decision Tree (DT)

Step 7: Repeat Step 4 to Step 6 for all nodes that need to split

Skin Color Detection Process

BIOMETRICS TASK FORCE

Step 1: Convert each pixel's RGB bytes to a skin feature vector, v

Step 2: Calculate the mean vector and variance of whole image

Step 3: Split current node all pixels into two sub-classes by using NUBS algorithm

Step 4: Calculate the mean vectors and variances for both sub-classes

Step 5: Label the nodes, mean vectors, and variance into the Tree

Step 6: Repeat Step 3 to Step 5 for all nodes that need to split

Step 7: Use Trained Decision Tree (DT) to verify each region

Skin Color Segmentation Example

Original Facial Image

Segmented Image

FaceQM
3. Face Features Detection

Feature	Constraints
24-bit color	To be examined
Red-eye	To be examined
Blur	To be identified
Near/Far*	Image width : head width = 7:4
Centered image*	Δ(mid of detected eyes or detected face width – mid of image width) < 5% of half image width
Position of eyes*	50% - 70% of the vertical distance up from the bottom edge of the captured image
Pose angle – roll*	$\pm 5^0$
Pose angle – yaw*	$\pm 5^0$
Color contrast	0.45 < average contrast value < 0.95
Color saturation*	Top half : bottom half area and Left half : right half area should have close to 1 in both saturation distributions
Luminance density*	The dynamic range of the image should have at least 7 bits of intensity variation in the facial region of the image
Eyes' locations	To be detected
Mouth location	To be detected
Ears' locations	To be detected

* INCITS 385 full frontal or token facial image's parameters tested by FaceQM

FaceQM
4. Quality Score Determination

- Quality Score is measured by the Face Features Detection and Quality Determination modules
  - Quality score indicates the “GOOD IMAGE” or “NEED TO RE-SCAN” from the validation results of all face features
- The value of the quality score can be presented in two forms:
  - D-Score: the total number of facial features that satisfy the constraints
  - C-Score: the minimum value from the quality levels of 12 facial features

Notes

1: New Quality measurement features can be increased if necessary.

2: Each feature’s weighting coefficient is adjustable – all 1s for equal weighting.

3: Each feature’s quality level is converted from measured value with it’s piece-wise mapping function that is formed by the constraint.

FaceQM – Example Results

BIOMETRICS TASK FORCE

Sight Features

24-Bit Color:	Yes	
No Red-Eye:	Yes	
Non-Blurred Degree:	Yes	-0.94 (<= 0.0)
Near/Far:	Passed	1.33 (1.17 - 1.75)
Centered Image:	Passed	4% (< 10%)
High/Low:	Passed	59% (50 - 70%)

Orientation Features

Roll Angle:	Passed	0 (< +- 5 Deg.)
Yaw Angle:	Passed	-1 (< +- 5 Deg.)

Lighting Features

Contrast:	Passed	57% (>= 45%)
Vertical Saturation Ratio:	Passed	0.13 (< +- 0.25)
Horizontal Saturation Ratio:	Passed	-0.01 (< +- 0.25)
Luminance Dynamic Range:	Passed	146 (>= 128)

Face Area, Eyes, Mouth, and Ears Detection

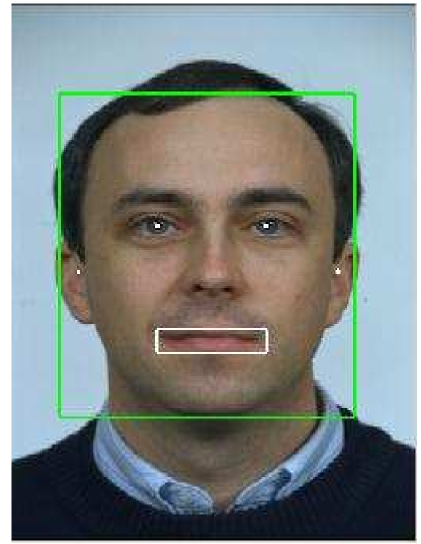
Face Area:	Detected
Eyes (Right - Left):	Y & Y
Mouth:	Y
Ears (Right - Left):	Y & Y

Quality Examined Result

D-Score:	GOOD IMAGE (D-QS = 12/12)
C-Score:	GOOD IMAGE (C-QS = 84/100)

Header Information

Image Type:	BMP
Color Bits:	24
Image Height:	768
Image Width:	512
Image Size:	1179702
Consistency Check:	PASSED

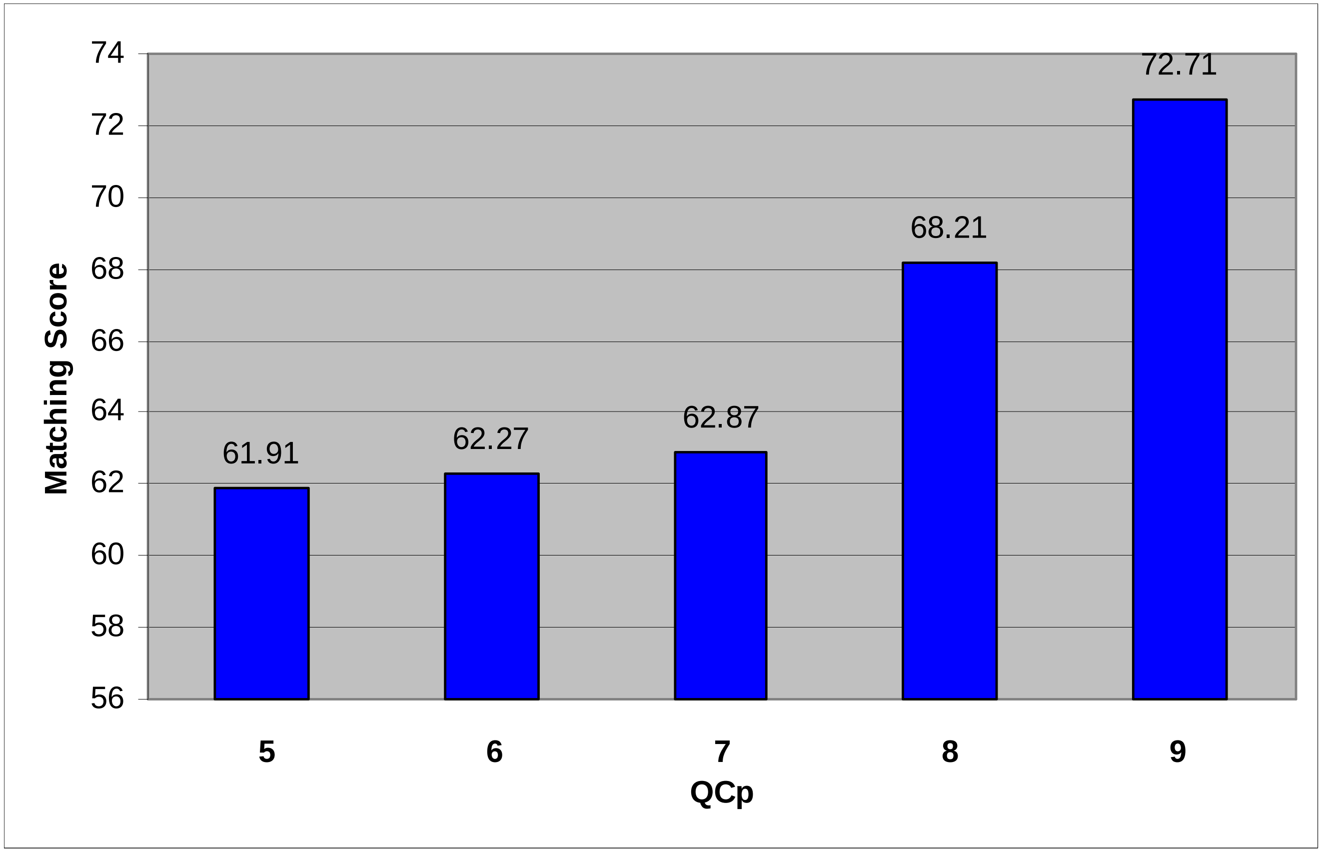


Preliminary Test Results

Training & Testing

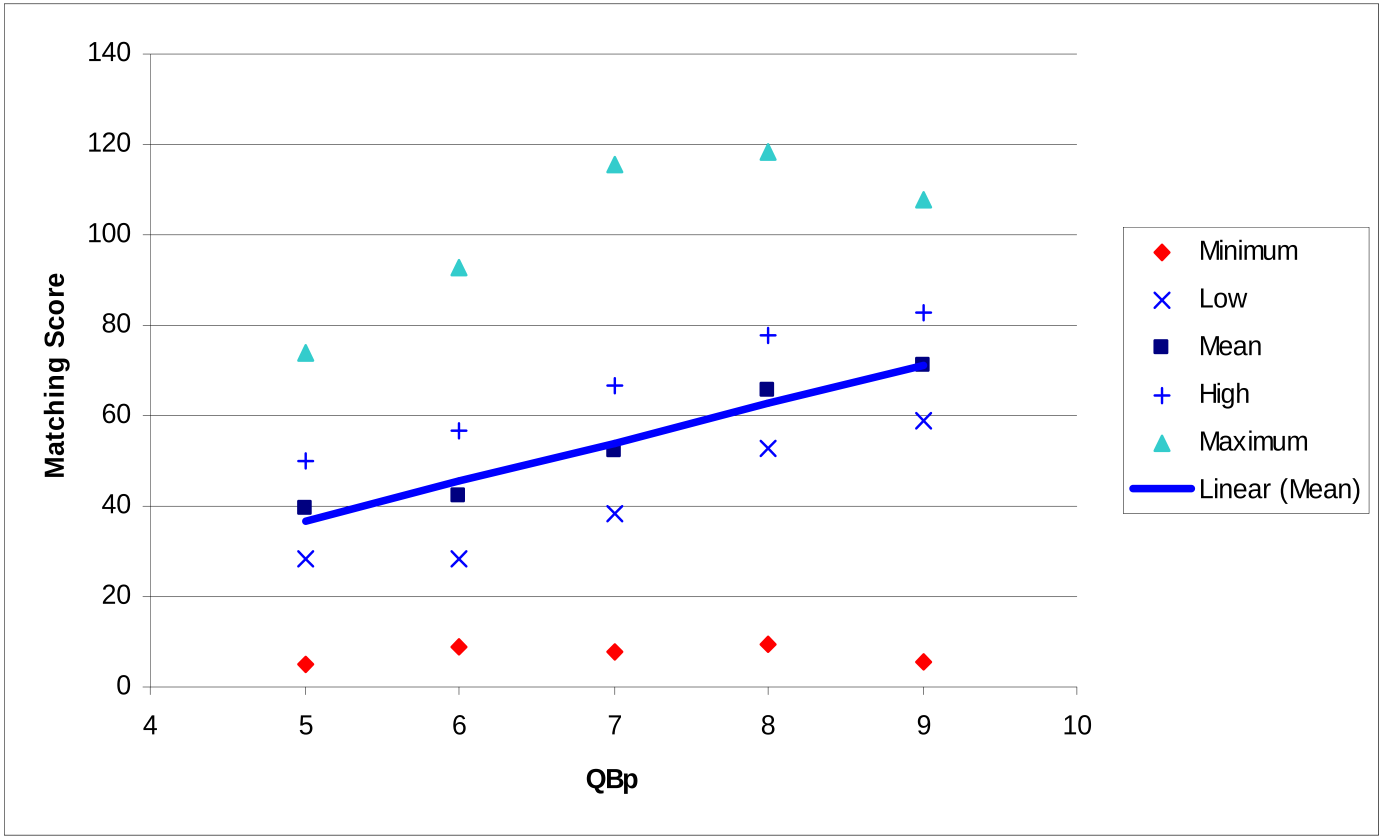
- Training Data:
  - BTF skin color training dataset – created from Color FERET Facial Image Database
- Test Data:
  - 1,806 (903 pairs) facial images
    - Color FERET Facial Image Database
    - AR (Aleix Martinez & Robert Benavente) Facial Image Database
    - No 24-bit color, Red-eyes, and Blurred detection
    - Matching scores analysis
  - 500 plus individual facial images
    - DoD ABIS Facial Image Database
    - University of Notre Dame Biometrics Database
    - Face Features testing
- Matcher:
  - One of the leading Face Recognition products in the market

Experiment Results (1/4)



The FaceQM tool has a very high confidence in predicting the higher matching score on the Gq ≥ 8 and Pq ≥ 8 paired combination on both gallery and probe datasets.

Experiment Results (2/4)



Gallery Quality Scores: 8 or 9

Probe Quality Scores: 5, 6, 7, 8, and 9

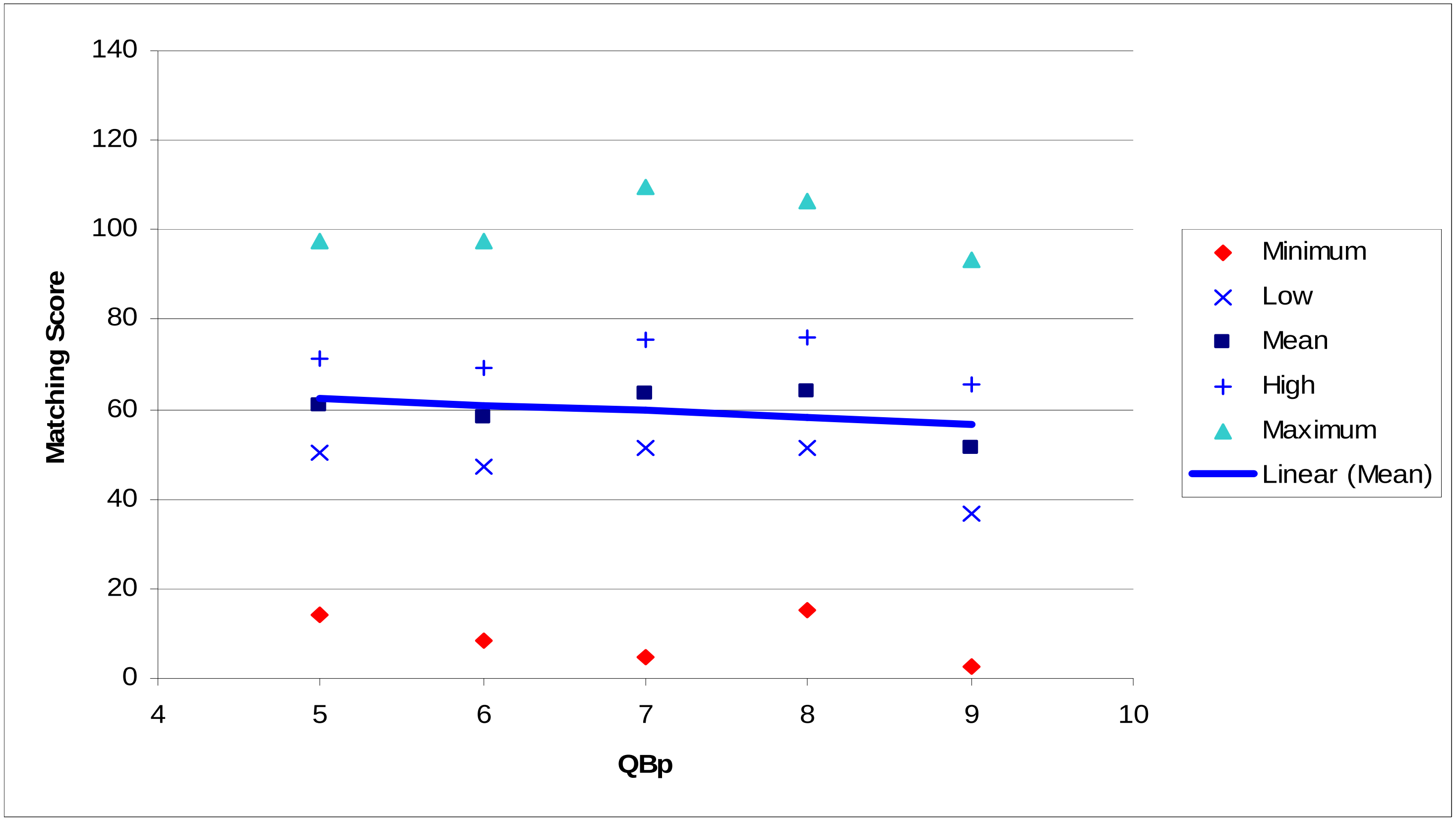
Where QB_p is Quality Scores bin of Probe Group

$ms_e = -6.39 + 8.64 \times QBp$

rms = 2.22

Correlation Coeff. = 0.984

Experiment Results (3/4)



Gallery Quality Scores: 5, 6, or 7

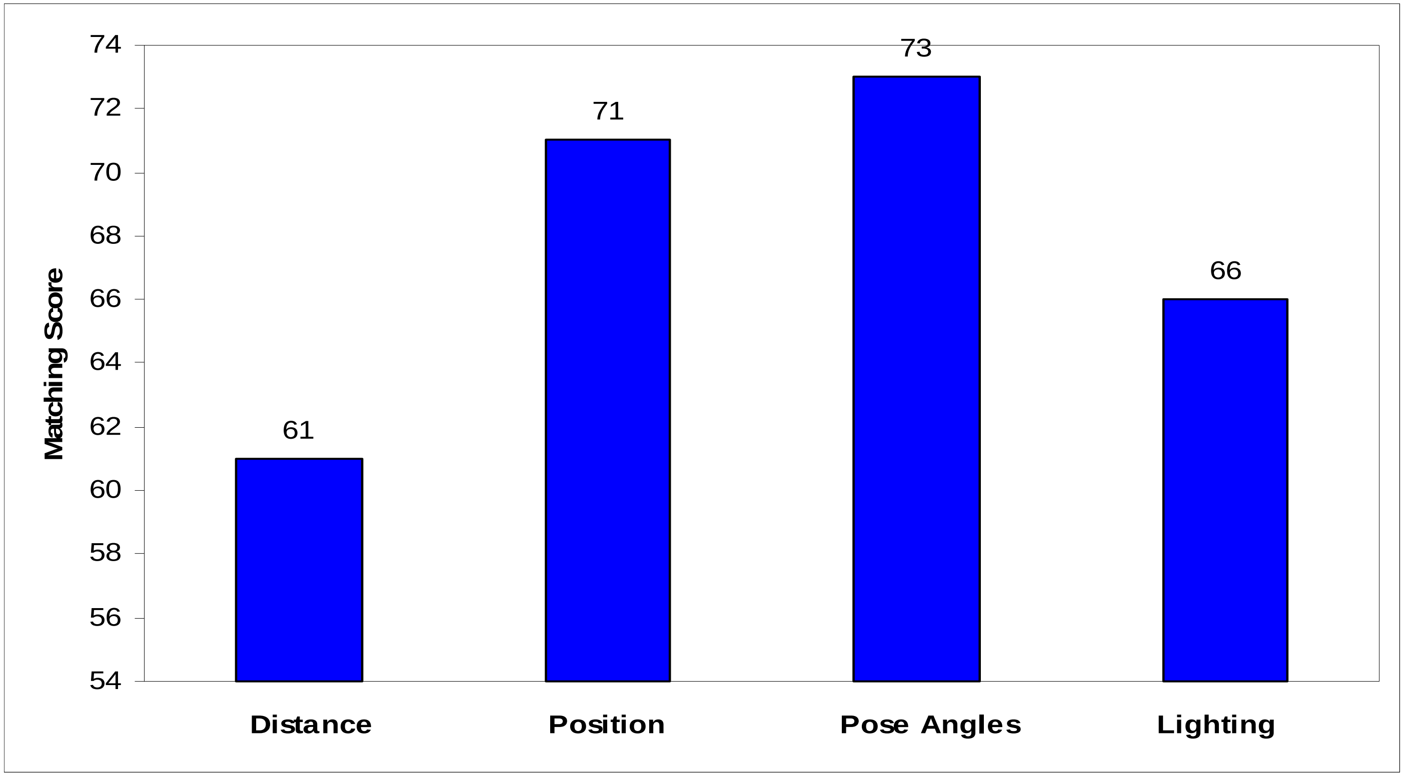
Probe Quality Scores: 5, 6, 7, 8, and 9

$ms_e = 69.3 - 1.392 \times QBp$

rms = 4.19

Correlation Coeff. = -0.425

Experiment Results (4/4)



"Sensitivity" measurement of the tested matcher to specific quality parameters

Distance category: Near/Far
Position category: Centered image and Position of eyes
Pose Angles category: Rolled and Yaw
Lighting category: Contrast, Horizontal Saturation, Vertical Saturation, Luminance density

FaceQM Current Status

- Algorithm development completed, preparing for publication
- Prototype development completed, tested with limited number of images
- Production version development in final stages, testing and debugging is underway
- Large-scale testing is underway and being conducted by NIST

Contact Information

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