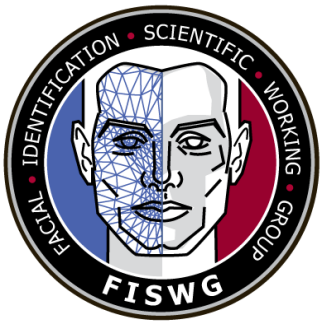

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Facial Recognition Systems Operation Assurance: Image Quality Assessment

1. Scope

1.1 The scope of this document is to provide a detailed process and example of how testing for variations in facial image quality can be used in adjusting operational workflows. Testing and verifying scoring variations with varying image quality is important so that facial search system workflows can be properly adjusted.

1.2 Topics outside of this document include, but are not necessarily limited to, setup, system tuning, workflow management and improvement, and proof-of-concept pilots.

2. Referenced Documents

2.1 *ASTM Standards:*[1]

E2916 Terminology for Digital and Multimedia Evidence Examination

E2825 Standard Guide for Forensic Digital Image Processing

2.2 *Other Standards:*

ANSI/NIST- ITL-1-2011 Data Format for the Interchange of Fingerprint, Facial & Other Biometric Information[2]

FISWG Understanding and Testing for Facial Recognition Systems Operation Assurance[3]

FISWG Face Recognition Systems Operation Assurance: Identity Ground Truth

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[1] For referenced ASTM standards, visit www.nist.gov/osac/astm-launch-code, or the ASTM website, www.astm.org, or contact ASTM Customer Service at service@asstm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[2] Available from National Institute of Standards and Technology (NIST) website https://www.nist.gov/programs-projects/ansinist-itl-standard or http://www.nist.gov.

[3] Available from Facial Identification Scientific Working Group (FISWG), http://www.fiswg.org/documents.

3. Terminology

3.1 *Definitions*:

3.1.1 See ASTM E2916 Terminology for digital and multimedia evidence examination terms.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *doppelganger—an apparition or double of a living person.*

3.3 *Acronyms:*

3.3.1 *DET—detection error tradeoff*

3.3.2 *FMR—false match rate proportion of the completed biometric non-mated comparison trials that result in a false match. This will be referred to as FAR (false acceptance rate) and does not include errors from images which do not create valid templates.*

3.3.3 *FNMR—false non-match rate proportion of the completed biometric mated comparison trials that result in a false non-match. This will be referred to as FRR (false reject rate) and does not include errors from images which do not create valid templates.*

3.3.4 *FR—face recognition*

3.3.5 *FRS—facial recognition systems*

3.3.6 *ROC—receiver operating characteristics*

3.3.7 *IPD—interpupillary distance*

4. Summary of Guide

4.1 This document provides guidelines and techniques to help administrators of automated facial recognition systems (FRS) produce recognition statistics from the FRS.

4.2 The intended audience of this document is owners, users, and administrators of existing automated face recognition systems.

4.3 The document is a continuation of the FISWG documents:

4.3.1 Understanding and Testing for Face Recognition Systems Operation Assurance

4.3.2 Facial Recognition Systems Operation Assurance: Identity Ground Truth

4.4 The information presented in this document establishes a base for other considerations when testing such as system setup and tuning.

5. Significance and Use

5.1 Introduction

5.1.1 When conducting accuracy assessment, a critical step is to understand how image quality affects the processing of the imagery to be enrolled or searched. Regardless of the specific facial biometric algorithm used, there will be some facial imagery that causes facial localization errors which then produce biometric templates of no operational value.

5.1.2 Most of the work in these processes is on creating the testing frameworks and understanding how to repeatedly run tests, make corrections, and do retesting with what has been learned. Once the frameworks and the processing are understood, then the agency can make diligent progress, but it takes time and focus. The outcomes are worth the time spent as you begin to understand how the data interacts with the algorithms which give the agency the ability to validate and trust the solution through rigorous testing and objective metrics.

5.1.3 Setting up frameworks to do enrollment, searching, and recording results is procedural as you learn the facial algorithms and the data sets to develop proper accuracy assessments. Understanding the data and building frameworks to analytically qualify the results is not trivial but must be done, so effective operational metrics can be derived and applied.

5.2 Important Notes

5.2.1 Care should be taken in selecting data sets used to perform accuracy assessments. It is recommended to select data sets which:

5.2.1.1 Have operational relevancy

5.2.1.2 Have consistent image quality aspects: type of capture, size of images, subject poses, etc.

5.2.1.3 Have sufficient identities and images to test with. This decision will be agency specific.

5.2.1.4 Includes associated identity ground truth information which links each image to a unique identity

5.3 The data set used for this document is the Labeled Faces in the Wild (LFW) data set available at: http://vis-www.cs.umass.edu/lfw/. Conceptually any other facial data set with identity ground truth can be used.

5.4 LFW is a widely used open-source data set which will work well for this specific document serving as an introductory data set. Information on this data set includes:

5.4.1 Smaller but consistent image sizes and file formats

5.4.2 Over 5,700 identities and over 13,000 images

5.4.3 A varying range of subjects: sex, pose, lighting, etc.

5.4.4 Stated identity ground truth errors

6. Procedure

6.1 Image Quality Assessment Process

6.1.1 **Step 1 -** Ensure the data set has verified ground truth.

6.1.2 **Step 2 -** Extract the facial image quality from all images to enroll and search. The image quality metrics will be vendor dependent. Care should be taken to select the quality metric(s) which have the largest value in doing an image quality assessment. Vendor specific quality metrics will have different numeric ranges and will have vendor specific usability ranges. Consulting with the provider of the facial algorithm is recommended.

6.1.3 **Step 3 -** Enroll the facial images into a facial gallery for searching.

6.1.4 **Step 4 -** Search the facial images against the facial gallery. The number of candidates returned for this document was 50. This number may vary with agency specifics. Do not use any scoring thresholds.

6.1.5 **Step 5 -** Segment facial search results based on the facial image quality of the probe.

6.1.6 **Step 6 -** For each segmentation group of the search results plot the biometric performance results and compare them. This document uses these plots:

6.1.6.1 FAR: False accept scoring

6.1.6.2 FRR: False reject scoring

6.1.6.3 DET: Detection error tradeoff

6.1.6.4 CMC: Cumulative Match Curve

6.1.7 **Step 7 -** Determine if targeted image quality assessments can be done before enrollment or searching to see if improper facial localization has occurred. This may have caused facial templates to be created which were of no operational value and should have either been manually reviewed or simply not processed.

6.2 Process Outcomes

6.2.1 Step 2 image quality outputs:

When this was done with the LFW data set the following facial metrics were recorded:

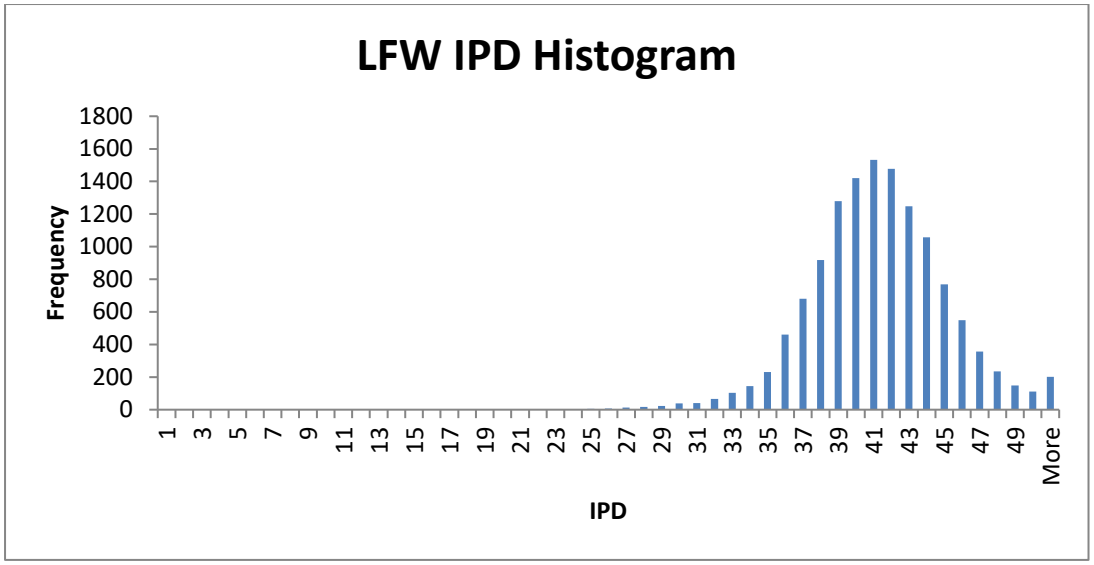


Figure 1: LFW IPD (pixels)

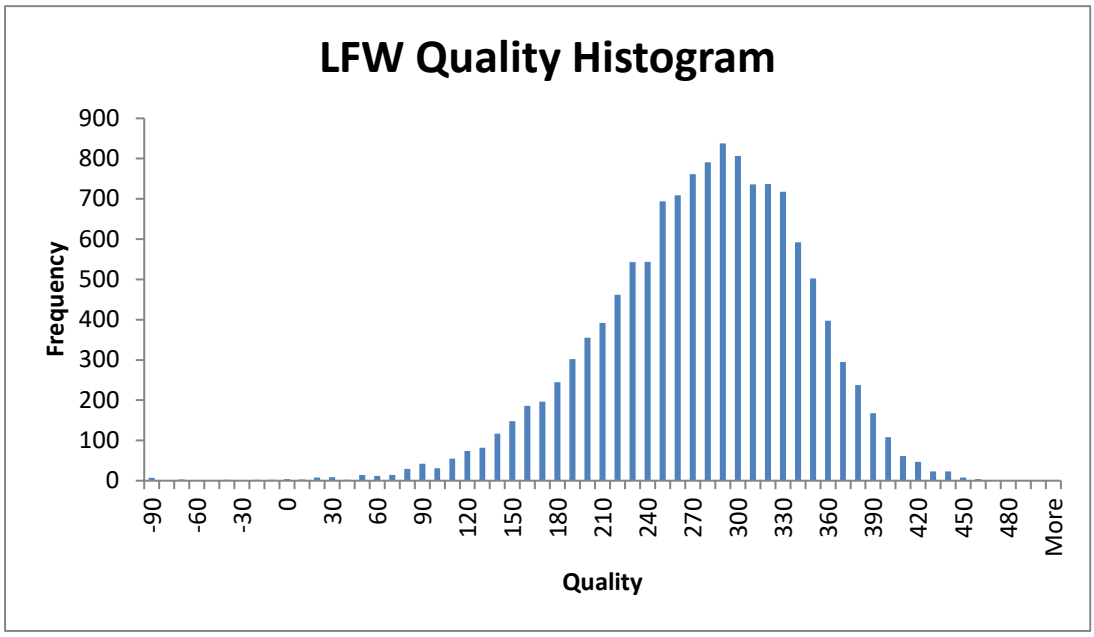


Figure 2: LFW Quality (linear Y axis)

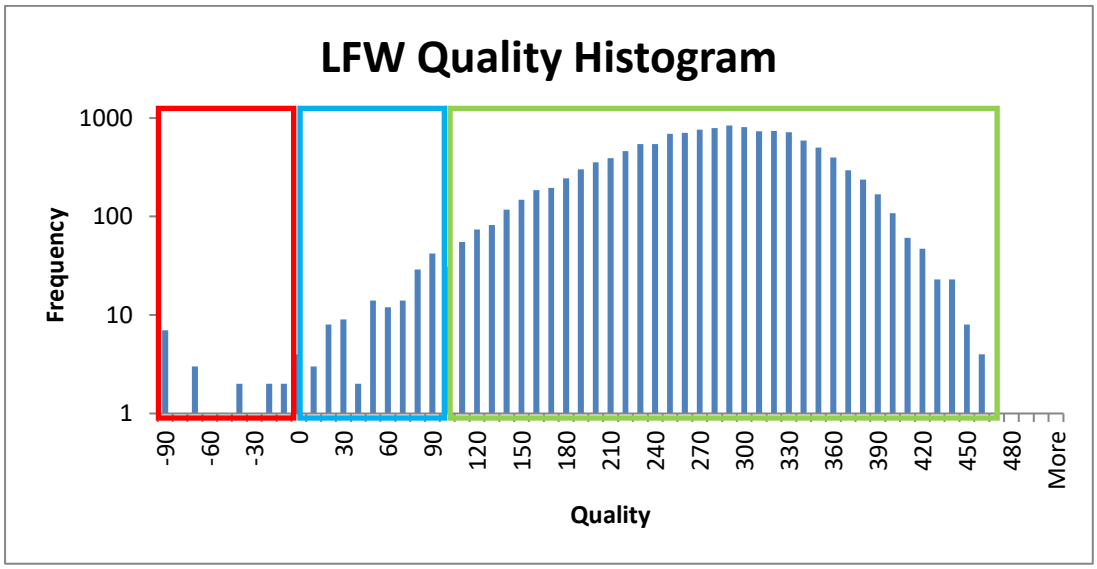


Figure 3: LFW Quality (logarithmic Y axis)

6.2.1.1 The LFW images were then enrolled and searched. Based on the image quality histograms three segments were selected:

- All search results
- All searches with a quality less than 0
- All searches with a quality between 0 and 100
- All searches with a quality greater than 100

6.2.2 Step 6 search results:

Once the accuracy plots were created, they can be analyzed. FAR and FRR were analyzed first.

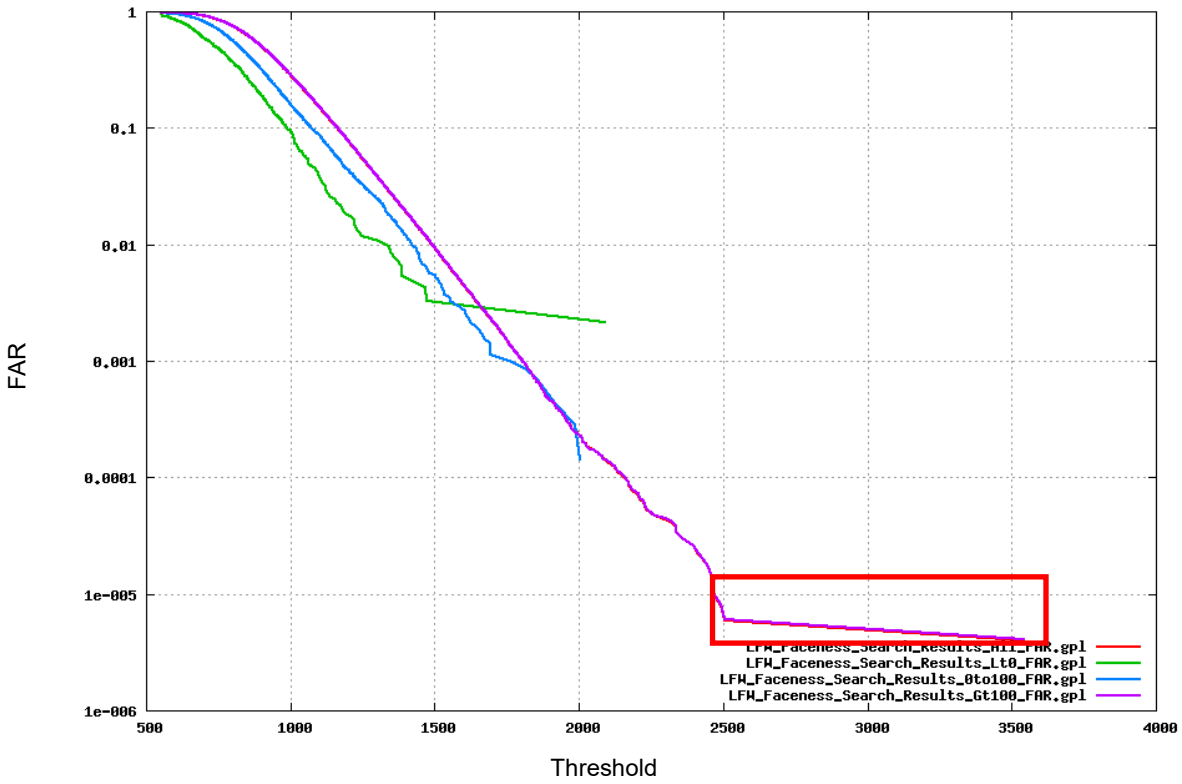


Figure 4: LFW FAR Imposter Scores (logarithmic Y axis)

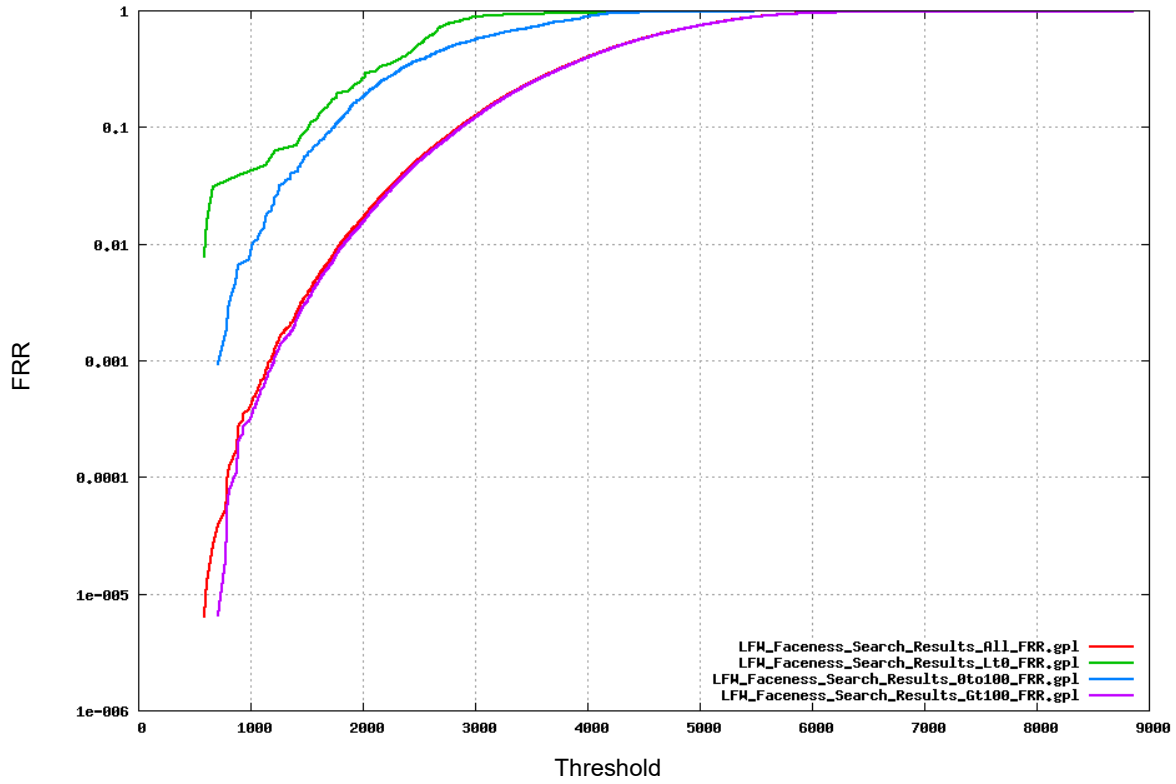


Figure 5: LFW FRR Mate Scores (logarithmic Y axis)

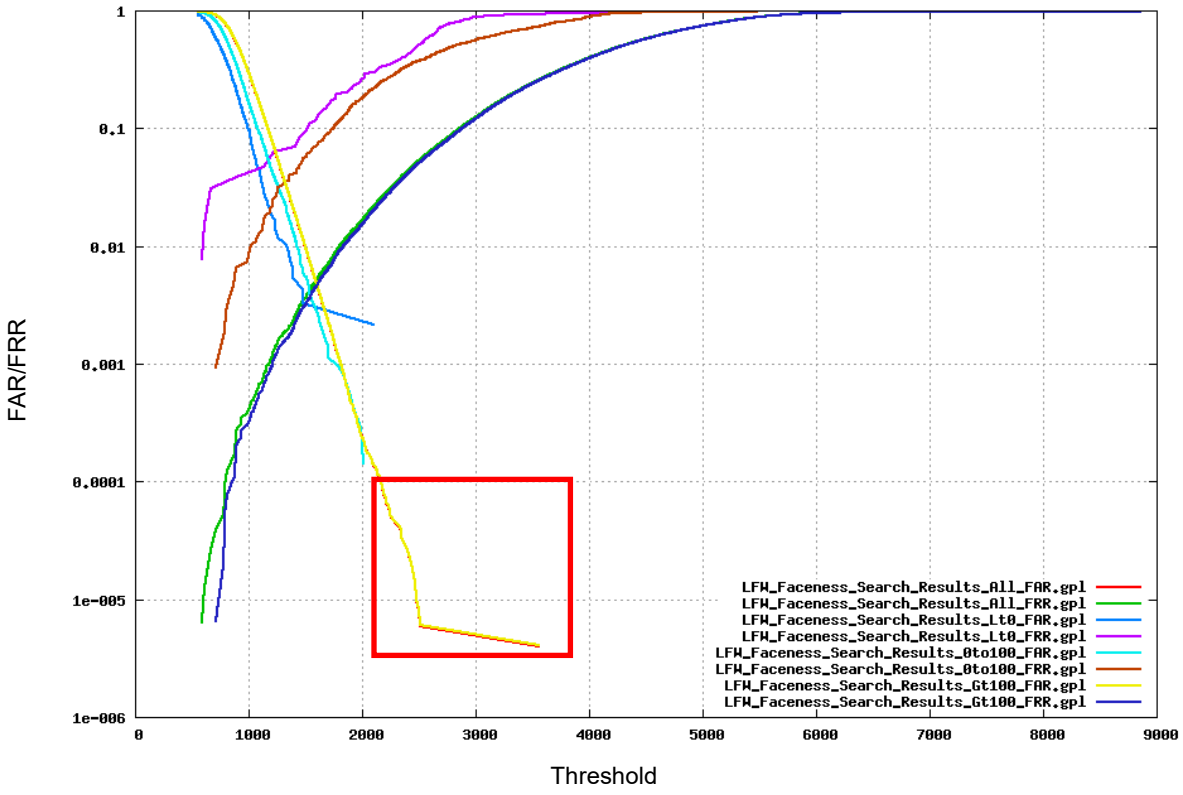


Figure 6: LFW Mate and Imposter Scores (FAR and FRR)

6.2.2.1 Notes on this step:

- The overall imposter (FAR) scoring in Figures 4 and 6 were relatively consistent regardless of probe image quality with high values of ~2500.
- The higher imposter (FAR) scoring in Figures 4 and 6 (red box) were due to the presence of several siblings and doppelgangers.
- The highest imposter (FAR) score of ~3500 in Figures 4 and 6 (red box) were due to known twins in the LFW data set.
- The overall mate scoring (FRR) in Figures 5 and 6 did vary with probe image quality with the lowest values of ~750.

LFW Twin	
	
LFW High Scoring Imposters	
	
The images above are siblings	
	
The images above are doppelgangers	

6.2.3 Step 6 search results: DET was analyzed next.

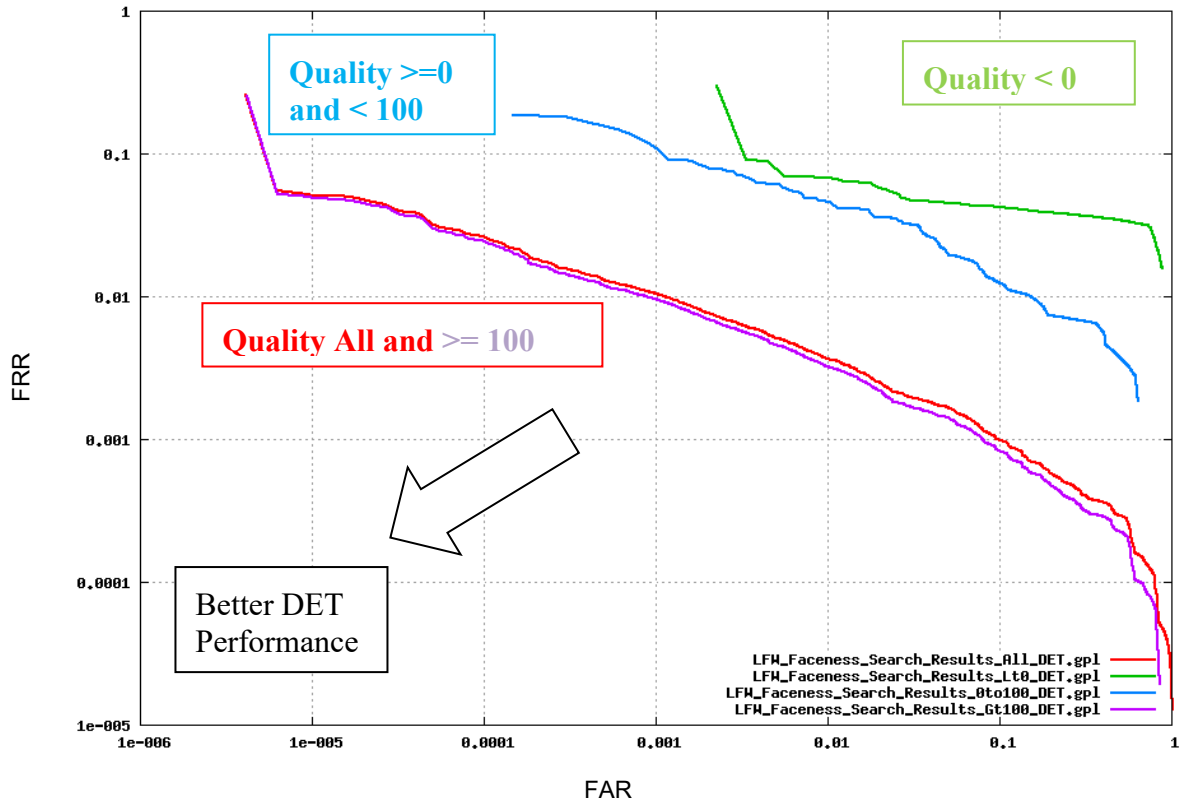


Figure 7: LFW DET Curve

6.2.3.1 Notes on this step:

- The DET curve performance in Figure 7 was better with higher probe image quality.

6.2.4 CMC was analyzed next.

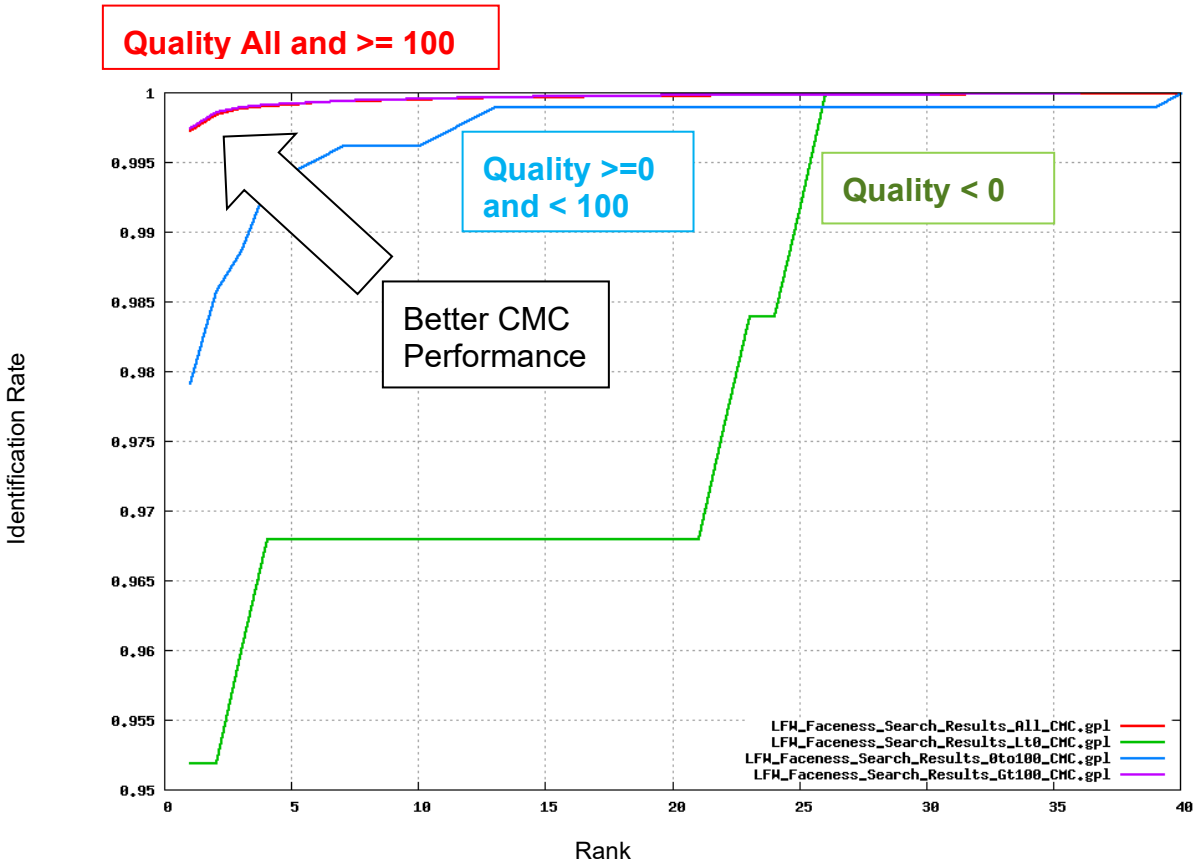


Figure 8: LFW CMC Curve

6.2.4.1 Notes on this step:

- The CMC curve performance in Figure 8 was better with higher probe image quality.

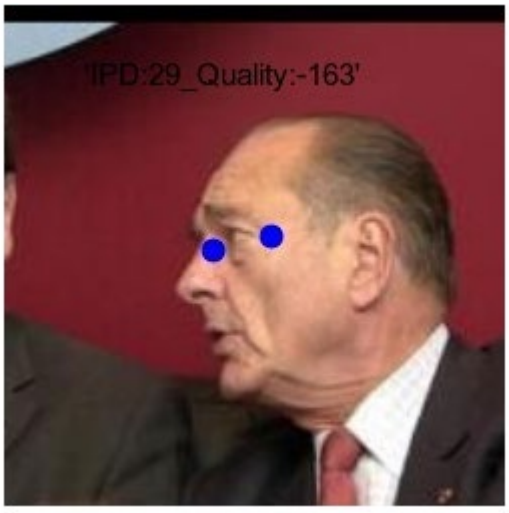
6.2.4.2 Perhaps the largest outcome of this testing is presented in the CMC curves and can be described as follows:

- The lowest image quality plots (< 0) have a 100% CMC point at a search results candidate of ~27.
- The medium image quality plots (>= 0 and < 100) has a 100% CMC point at a search results candidate of ~13.
- The highest image quality plots (>= 100) has a 100% CMC point at a search results candidate of ~10.
- So, in order to achieve the 100% CMC point for all image quality variations, the number of candidates a human examiner must review is ~27.

- If the overall biometrically usable data quality can be improved through proper image quality assessment during enroll and searching, then it would be possible to lower number of candidates a human examiner must review to achieve a desired 100% CMC point.

6.2.5 Step 7 Outputs:

6.2.5.1 The search probe where then analyzed to locate low quality imagery so that the candidate lists returned could be reviewed to see if any mates were returned.

This probe had 51 mates in the gallery. Only one was returned at rank 3. The probe quality was -186.	
This mate which was returned at a rank 3 with a score of 1213. Note the bad eye locations which were similar. The probe quality was -163.	

This probe had 0 mates in the gallery. The probe quality was -164. This example shows how the incorrect face in the image was localized.	
This probe had 0 mates in the gallery. The probe quality was -123. This example shows how improper facial localization occurred.	
This probe had 7 mates in the gallery. Only two were returned. The probe quality was -84.	

This mate which was returned at a rank 26 with a score of 575.	
This probe had 530 mates in the gallery. No mates were returned. The probe quality was -19.	
This probe had 8 mates in the gallery. No mates were returned. The probe quality was 22.	

6.3 Outcomes

6.3.1 Based on this data set and the testing process documented here:

6.3.1.1 Facial search performance is affected by facial image quality which will be vendor dependent. Various image quality metrics needed to be analyzed to assess the facial image quality into specific ranges of interest.

6.3.1.2 The ability to segment search results based on facial image quality is shown.

6.3.1.3 Mates and imposter scoring can change with mates being more susceptible to image quality issues.

6.3.1.4 FAR, FRR, DET and CMC curves were utilized in these processes.

6.3.1.5 How the facial image quality scoring and resultant operational ramifications need to be assessed to properly locate low scoring mates in search results which have lower image quality.

6.3.1.6 Detecting and correcting low quality facial imagery which could be manually corrected could improve overall facial accuracy.

6.3.1.7 Enrolling and searching all facial imagery without attention to image quality will negatively affect facial workflows.

FISWG documents can be found at: www.FISWG.org