
2010 DoD
BIOMETRICS
COLLABORATION FORUM
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www.biometrics.dod.mil
Biometric Image Quality Measurement Algorithms and Tools Development
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Agenda

- **Introduction**
- **Fingerprint Image Quality Measurement**
- **Facial Image Quality Measurement**
- **Future Development and Wrap-Up**

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Background

- **Measuring the quality of biometric samples is a crucial step in the collection processes.**
- **Biometric Matching Algorithms depend on quality of sample features (e.g.: minutiae of fingerprint image, eye location on facial image) that can be extracted from digitized samples.**
- **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.**

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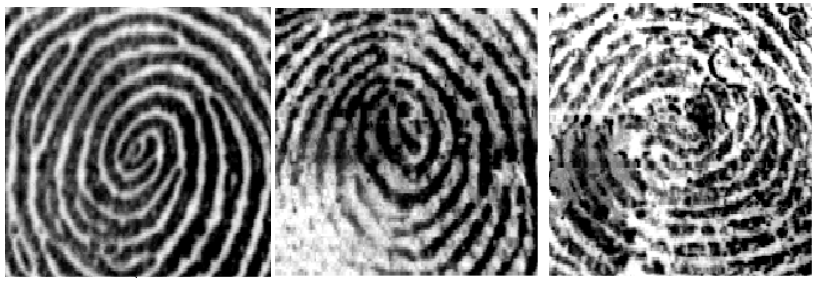
The Challenge

- **FACT:** Poor quality biometric images diminish the matching performance of biometric recognition systems, result in false matches and false non-matches, and increase search times.
- **CHALLENGE:** Develop vendor-neutral tools to assess biometric data quality.
  - At point of collection *to increase match performance results.*
  - For legacy data sets *to improve overall search efficiency.*

Fingerprint Image Examples



Excellent | Good/Fair | Poor

Frontal Facial Image Examples

Complex Background | Blurred | Dark Skin

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Biometric Sample Image Quality Requirements

- **Fingerprint**
  - INCITS 381: Finger Image Based Data Interchange Format
    - Section 7: Image acquisition requirements
    - Annex A: IAFIS Image Quality Specifications – CJIS Electronic Biometric Transmission Specification (V 8.002)
  - ISO/IEC 19794-4: Biometric Data Interchange Formats Part 4: Finger Image Data
    - Section 7: Image acquisition requirements
    - Annex A: Image Quality Specifications
- **Facial**
  - ISO/IEC WD 19794-5: Biometric Data Interchange Formats Part 5: Face Image Data
    - Section 7: The Frontal Face Image Type
    - Annex A (Informative): Best Practices for Face Images
  - ISO/IEC 19794-5 Amendment 1: Conditions for Taking Photographs for Face image Data
- **Iris**
  - ISO/IEC 19794-6: Biometric Data Interchange Formats Part 6: Iris Image Data
    - Annex A (Informative): Iris Image Capture
  - ISO/IEC JTC 1/SC 37 N3331: Biometric Sample Quality Part 6: Iris Image

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BTF Biometric Image Quality Measurement Algorithms and Tools Development Approach

- **Research, analysis, and comparison of available algorithms and tools in the market and academia.**
- **Analysis of related National and International Data Format Standards.**
- **Analysis of available datasets for evaluation purposes.**
- **Algorithm development and publication.**
- **Prototype tool development.**
- **Tool optimization with limited testing.**
- **Tool finalization.**
- **Large scale evaluation at NIST using operational data sets.**
- **Deployment.**

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Discussion

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Fingerprint Image Quality Measurement (FIQM)

- **BTF FIQM Algorithm**
- **Implementation**
- **Demonstration**
- **Key Benefits**
- **Current Status**
- **Future Enhancement**
- **Discussion**

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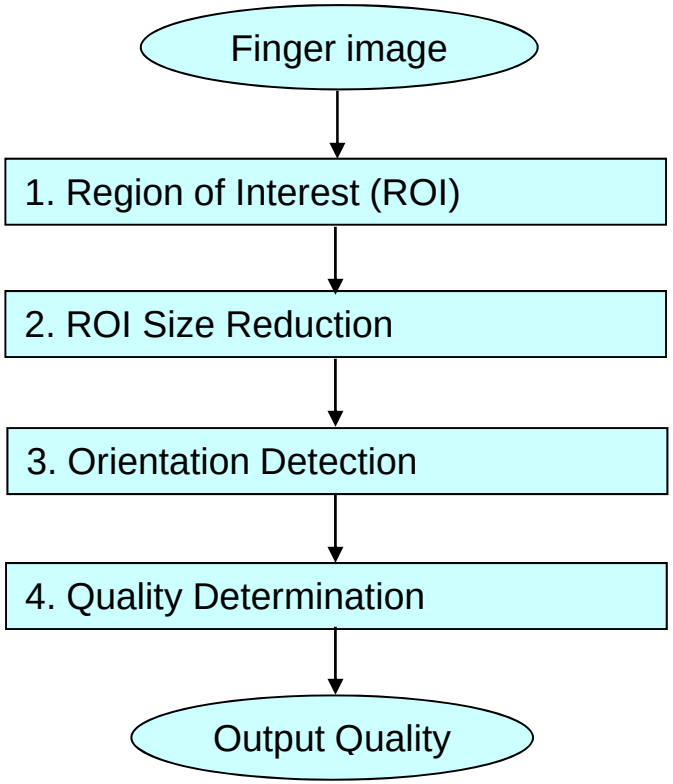
FIQM Flow Chart



1. ROI Identification Module

- Identify most important area as quality measurement target area

2. ROI Size Reduction Module

- Remove redundancy and noise and noise pixels
- Increase performance speed

3. Orientation Detection Module

- Calculate pixel's orientation information
- Calculate cell's quality level

4. Quality Determination Module

- Determine and output quality

Implementation - FIQM

- **Dynamic Link Library** – can be linked and called from main programs.
  - "FIQMC300.DLL" – FIQM Version 3.0 C Dynamic Link Library.
  - "FIQMC300.LIB" – A .LIB file is library file that needs to be included when building a "C" executable.
- **Executable** – sample applications using FIQMC300.DLL.
  - "qBatch.exe" – A FIQM GUI sample application that processes fingerprint images in batch mode and quality scores are stored in the local text file.
  - "qExamine.exe" – A FIQM GUI sample application that allows up to three "examiners" to review each finger image included in a given batch, and then enter their respective judgment as to the quality of each image with a rating of poor, medium, or good.
  - "FIQMCmd300.exe" – An example of a Visual C/C++ Command Line executable using FIQMC300.DLL.

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FIQM Demonstration

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FIQM Key Benefits

- **FIQM's quality score is a simulation of Human Visual Perception (equivalent to a human forensic examiner).**
- **FIQM's quality score can be used as a predictor of fingerprint matcher performance before a matcher is applied.**
- **FIQM's quality score can be customized (or mapped) to other scoring systems (For example: Good-Medium-Poor or Acceptance-Rejection).**
- **FIQM is agnostic of the matching algorithm's nature or image origins (i.e., is vendor independent).**
- **FIQM reproduces an identical quality score from the same image.**
- **FIQM performs high consistency on same finger scanning with 500 ppi and 1,000 ppi resolutions.**
- **FIQM C Dynamic Link Library (DLL) functions are easily to be called and linked from main source program (sample codes are included in the distribution CD).**

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Current Status of FIQM

- Published "Fingerprint Image Quality Measurement Algorithm" article on the March/April 2007 issue of Journal of Forensic Identification
- Tested and analyzed the comparison with NFIQ (NIST), EMN (ABIS) and FIQM Tools' results with 20,000 fingerprint images on DoD ABIS
- Tested and analyzed the matching-prediction performance comparison with NFIQ and FIQM Tools' results with paper- and live-scan combination 2,000 pairs (4,000 images)
- Completed Phase I Large-scale testing on over one million Live-scan images by NIST
- Analyzed over 25,000 latent fingerprint and 472,000 live-scan images on DoD ABIS
- Completed the performance comparison analysis of NFIQ and FIQM Tools on scanned resolutions 500 ppi and 1,000 ppi images

- FIQM C code product is ready to deploy
- FIQM distributed to twenty plus agencies
- FIQM Toolset adopted by the US Army Material Systems Analysis Activity (AMSAA) Scenario War-Game Seminar (SWS) in support of the Biometrics Analysis of Alternative (AoA) Studies
- FIQM Toolset adopted by the Defense Manpower Data Center (DMDC) as quality measurement function to determine quality score of each collected finger image

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Future Enhancement and Way Ahead - FIQM

- **Develop enhancement functions to implement new requirements.**
  - FIQM JAVA Version.
  - Option for passing compressed image data via memory (currently via image file).
  - Option for processing 1,000 ppi finger images – completed (version 3.00).
  - Option for processing SLAP finger images – in progress.

- **Work with NIST to evaluate FIQM on latent print finger images, paper-scan finger images, and multiple scanned resolutions (500 ppi vs. 1,000 ppi).**

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Discussion

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Facial Image Quality Measurement (FaceQM)

- **BTF FaceQM Algorithm**
- **Implementation**
- **Demonstration**
- **Key Benefits**
- **Current Status**
- **Future Enhancement**
- **Discussion**

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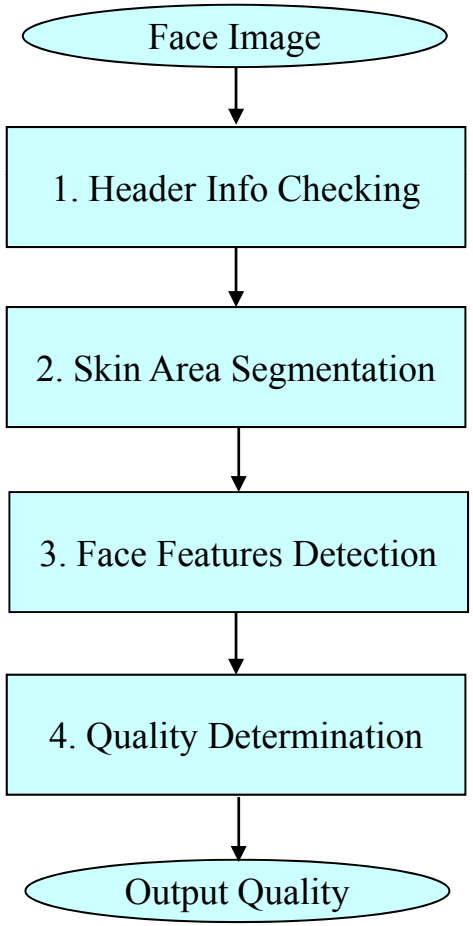
FaceQM Flow Chart



1. Image Header Information Checking 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 eyes, mouth, and ears
- Measure and calculate face features

4. Quality Determination Module

- Verify values of face features with constrains
- Determine and output quality

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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

* ISO/IEC 19794-5 / INCITS 385 full frontal or token facial image's parameters tested by FaceQM

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Implementation - FaceQM

- **Dynamic Link Library – can be linked and called from main programs.**
  - "FaceQM_C.DLL" – FaceQM Version 1.0 C Dynamic Link Library.
  - "FaceQM_C.LIB" – A .LIB file is library file that needs to be included when building a "C" executable.
- **Executable – sample applications using FaceQM_C.DLL.**
  - "FaceQMC.exe" – A FaceQM GUI sample application that processes fingerprint images in batch or single mode and quality scores are stored in the local text file.
  - "FaceQM.exe" – An example of a Visual C/C++ Command Line executable using FaceQM_C.DLL.

FaceQM Demonstration

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FaceQM Key Benefits

- FaceQM's quality score can be used as a predictor of face recognition matcher before a matcher is applied.
- FaceQM tool can also be used to evaluate the performance of a face recognition matching algorithm.
  - Determine "sensitivity" of individual matchers to specific quality parameters (i.e., contrast, lighting, face position, etc.).
- FaceQM's quality score can be customized (or mapped) to other scoring systems (For example: Acceptance-Rejection).
- FaceQM is agnostic of the matching algorithm's nature or image origins (i.e., is vendor independent).
- FaceQM C Dynamic Link Library (DLL) functions are easily to be called and linked from main source program (sample codes are included in the distribution CD).

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Current Status of FaceQM

- **Published "A New Approach for Measuring Facial Image Quality" article in the January/February 2009 issue of Defense Standardization Program Journal.**
- **Tested and analyzed the FaceQM Tool's results with ABIS 120,000 facial images.**
- **Completed Phase I Large-scale testing with over 9,000 face frontal images by NIST.**
- **Tested and analyzed over 36,000 facial images in the ABIS/NGA repository.**

- **FaceQM C code product is ready for evaluation.**
- **FaceQM distributed to twenty plus agencies.**
- **FaceQM Toolset adopted by the Defense manpower data Center (DMDC) as quality measurement function to determine quality score of each collected facial image.**
- **FaceQM Toolset adopted by the National Security Agency (NSA) as main quality measurement function in facial image collection and enhancement processes.**

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Future Enhancement and Way Ahead - FaceQM

- **Develop enhancement functions to implement new requirements:**
  - FaceQM JAVA Version.
  - Option for processing TIFF and PNG compressed images.
  - Option for passing compressed image data via memory (currently via image file).
- **Work with NIST to perform Phase II evaluation of FaceQM.**
- **Possibly – Initiate development of the Biometric Quality Assessment Workstation (NSA).**

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Discussion

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Future Development and Wrap-up

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Iris Image Quality Measurement (IrisQM)

- **Evaluated current state of the iris quality measurement research – industry, academia, market.**

- **Identified the most feasible approach to develop a DoD-owned, vendor-agnostic algorithm and toolset:**
  - Develop IrisQM algorithm and toolset based on the existing approach that is currently available at the Indiana University-Purdue University Indianapolis (IUPUI) or West Virginia University (WVU).
  - Modify an existing algorithm and tool to meet the DoD requirements.
  - Perform the development as a joint DoD/IUPUI or WVU project.

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Iris Image Features Detection

Item Number	Name of Features
1	Gray level spread (density)
2	Iris size (iris diameter in pixel)
3	Pupil iris ratio (ratio of pupil diameter over iris diameter)
4	Usable iris area (percentage of usable iris area)
5	Iris-sclera contrast
6	Iris-pupil contrast
7	Iris sclera boundary shape (iris shape)
8	Iris pupil boundary shape (pupil shape)
9	Margin
10	Sharpness (defocus)
11	Motion blur
12	Signal-to-noise ratio
13	Magnification
14	Head rotation
15	Gaze angle
16	Interlace

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Other Modalities

- **Voice**
- **Vein**

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Multi-Modalities Fusing with Quality Scores

- **Minimum quality score selected from measured quality scores.**
- **Mean quality score calculated by averaging all measured quality scores.**
- **Weighted quality score calculated by weighting coefficients with measured quality scores.**
- **Dempster-Shafer Theory: Combining each modality's quality score with a "belief (certainty)" function to arrive at a degree of belief that can be used to represent the fused quality score.**
- **Others.**

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References

- **FIQM:**
  - "Fingerprint Image Quality Measurement Algorithm" - article on the March/April 2007 issue of Journal of Forensic Identification
  - "FIQM Tool Study and Comparative Analysis" - BTF technical report in June 2005
  - "Phase I Report Evaluation of DoD BTF FIQM by NIST" – NIST's report in March 2008
  - "Additional Analysis to Phase I Report Evaluation of DoD BTF FIQM by NIST" – NIST's report on April 2008
  - INCITS 381-2004 Finger Image-Based Data Interchange Format
  - ISO/IEC 19794-4 Biometric Data Interchange Formats – Part 4: Finger Image Data

- **FaceQM:**
  - "A New Approach for Measuring Facial Image Quality" – article will be published on the January/February 2009 issue of the Defense Standardization Program Journal
  - "Summary Report of BAH Facial Image Quality Tools" – summary report by ABIS Development Group (Locket Martine)
  - INCITS 385-2004 Face Recognition Format for Data Interchange
  - ISO/IEC 19794-5 Biometric Data Interchange Formats – Part 5: Face Image Data

- **IrisQM:**
  - "IrisQM Algorithms Study and Comparative Analysis" – BTF technical report in December 2009
  - ISO/IEC 19794-6 Biometric Data Interchange Formats – Part 6: Iris Image Data
  - ISO/IEC 29794-6 Biometric Sample Quality – Part 6: Iris Image
  - NIST Iris Quality Calibration and Evaluation 2009 – Concept, Evaluation Plan and API

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