Development of NFIQ 2.0

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http://www.nist.gov/itl/iad/ig/development_nfiq_2.cfm

September 17, 2013

Biometric Consortium
Outline

» History + Background
» Sponsors + Team Members
» Architecture
» Features
» Machine Learning
» NFIQ 2.0 prototype
» NFIQ 2.0 Lite (Mobile)
» Actionable quality
» Relation to ISO/IEC 29794-4
» Discussion
2004 - present

2004
- Release of NFIQ 1.0
- Novel definition of biometric quality
  - performance related
  - accepted by the community
- Interoperability
- Uniform interpretation
- Tuned to a class of matcher
- Open source
- Extensively examined
  - by NIST and others
- Tools for quality summarization, slap, ...

2010 workshop
- Workshop on March 6, 2010 (IBPC 2010)
- NFIQ 2.0 wish-list as of March 2010
- Several options for NFIQ 2.0 were discussed
- The community overwhelmingly recommended a new, open source, generalized version of NFIQ to be developed in consultation and collaboration with users and industry.
  - Same technical approach, but better, bigger, faster, etc.

2012 workshop
- Workshop on March 5, 2012 (IBPC 2012)

- Community asked for:
  - Actionable flags
  - ProviderID
  - Versioning
  - Latent?
NFIQ 2.0 Community

Team Members
- NIST (US)
- BSI (Germany)
- BKA (Germany)
- Fraunhofer IGD
- MITRE (US)
- Hochschule Darmstadt / CASED
- Secunet Security Networks AG
- NFIQ 2.0 Participants
- ...and the whole biometrics community

Sponsors
- Homeland Security
- MITRE
- NIST (US)
- Federal Office for Information Security
- Bundeskriminalamt
- BKA (Germany)
- Secunet Security Networks AG
- Hochschule Darmstadt / CASED
- Fraunhofer IGD
# Team Members

**US**

» Elham Tabassi (NIST)
» Patricia Flanagan (NIST)
» Greg Fiumara (NIST)
» Carol Nowacki, Carol (MITRE)
» Adam Day (MITRE)
» Marc Colosimo (MITRE)
» Martin Olsen (HDA, NIST)

**DE**

» Christoph Busch (HAD)
» Oliver Bausinger (BSI)
» Johannes Merkle (SEC)
» Michael Schwaiger (SEC)
» Christopher Schiel (BKA)
» Timo Ruhland (BKA)
» Alexander Nouak (IGD)
» Olaf Henniger (IGD)
NFIQ 2.0 Framework

NFIQ 2.0 Development Tools
- extractQualityFeatures()
- calculateUtility()
- startTraining()
- ...

NFIQ 2.0
- checkQuality()

NFIQ 2.0 light
...

Image Format Converter
- extractQualityFeatures()
- calculateUtility()
- startTraining()
- ...

Input/Output Interface
- Feature extraction

Quality Feature Extraction Module
- Feature extraction

Utility Estimation Module
- Utility computation
- Fusion & binning

Machine Learning Module
- Prediction
- Training

Database
Filesystem
...
NFIQ 2.0 comparison score provider

FNMR

FMR
NFIQ 2.0 Features

NFIQ 1.0 features
Recommended Features in ISO/IEC 29794-4:2009 + our modifications
Surveyed literature + out modifications
Open source FingerjetFx minutia extractor
NFIQ 2.0 features

<table>
<thead>
<tr>
<th>Image/signal processing</th>
<th>Minutiae based</th>
</tr>
</thead>
<tbody>
<tr>
<td>» Local clarity score</td>
<td>» FingerjetFx</td>
</tr>
<tr>
<td>» Ridge valley uniformity</td>
<td>• Open source implementation from digitalPersona</td>
</tr>
<tr>
<td>» Orientation certainty level</td>
<td>• Digitalpersona.com/fingerjetfx</td>
</tr>
<tr>
<td>» Orientation flow</td>
<td>» Total count of minutia</td>
</tr>
<tr>
<td>» Frequency domain analysis</td>
<td>» Count of minutia in region of interest</td>
</tr>
<tr>
<td>» Radial power spectrum</td>
<td>• Various selection of ROI</td>
</tr>
<tr>
<td>» Gabor filters (several variants)</td>
<td></td>
</tr>
</tbody>
</table>

Standardized features allow for plug and play of feature computation implementations that are semantically conformant to the standard (i.e., ISO/IEC 29794-4 and ISO/IEC 19794-4). Different implementations are distinguished via providerID.
MACHINE LEARNING

We examined:
Random forest
Support vector machine
K-nearest neighbor
<table>
<thead>
<tr>
<th>Random Forest</th>
<th>Two class prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>» Ensemble classifier using stochastic process</td>
<td>» High vs. Low performers</td>
</tr>
<tr>
<td>• Use vote to determine class memberships</td>
<td>• 1: High performers are images that</td>
</tr>
<tr>
<td>• Provides class probability in predictions</td>
<td>result in high genuine scores</td>
</tr>
<tr>
<td>• Analysis of features importance and their</td>
<td>• $&gt; \text{CDF}^{-1}(0.95)$</td>
</tr>
<tr>
<td>ranking</td>
<td>• 0: Low performers are images that</td>
</tr>
<tr>
<td>• We used this to do our final feature selection</td>
<td>result in false reject</td>
</tr>
<tr>
<td></td>
<td>• Threshold at $\text{FMR}=0.0001$</td>
</tr>
<tr>
<td></td>
<td>• Quality score is the probability</td>
</tr>
<tr>
<td></td>
<td>that a given image belongs to class 1.</td>
</tr>
<tr>
<td></td>
<td>» Map quality score to recognition rate.</td>
</tr>
</tbody>
</table>
Training
- Features: image processing + #minutiae + minutiae quality
- ~5000 samples in each of the low and high performers classes
- 1000 trees in forest

Test
- 30000 comparison scores

So, Does It Work?
NFIQ 2.0 test – all features
NFIQ 2.0 prototype
(current selection of features)
NFIQ 2.0 prototype performance

Features:
- Gabor
- Gabor Shen
- Local Clarity Score (LCS)
- Orientation Certainty Level (OCL)
- Ridge Valley Uniformity (RVU) w/o padding
- Ridge Valley Uniformity with padding
- Orientation Flow (OF)
- Radial Power Spectrum (RPS)
- Minutia count
- Minutiae quality based on Mu
- Minutia quality based on OCL
- ROI (foreground size)
Feed back to user/operator

» Wet / dry
  • High/low pressure
  • MS Thesis (M. Dusio, C. Busch)

» Centeredness
  • Singularity detection

» Incompleteness
  • Entropy of orientation flow

» Ghost images

Questions?

» Sensor sensitivity?
» Algorithm sensitivity?
» Already covered by features?
» Any addition or deletion?
  • Fingerness?
  • Alteredness?
  • correctness of phalanx?
NFIQ 2.0 LITE (MOBILE)
NFIQ 2.0 Lite/Mobile

Requirements

» Low computation complexity
  • processing power
  • Processing time

» Therefore, feature computation not feasible!

» Look up table?

SOM

» Unsupervised clustering (unlabelled training data)

» Training phase
  • Iteratively present training vectors to build clusters (codebook vectors)

» Prediction phase
  • Input vector is assigned a class based on distance to learned clusters

» Topology preserving - similar classes will have similar spatial locations in the map
Self organizing maps

SOM unsupervised training
Divide fingerprint image into blocks and look up nearest cluster to get a label.

Finger image is transformed into cluster histogram.

Quality Score

Random Forest

Self organizing maps for NFIQ2.0 Lite-1
NFIQ 2.0 Lite prototype

Features

performance

Features

performance

Features

performance
### NFIQ 2.0 computation time

#### Lite

- ~65 ms/image
  - PC - 2.3 GHz Intel Core i7
  - 16 GB of memory.
  - network size of dim = 24
  - block size of n = 24
  - With gray scale normalization

- ~82 ms/image.
  - PC - 2.3 GHz Intel Core i7
  - 16 GB of memory.
  - network size of dim = 24
  - block size of n = 64

- This is prior to any code optimization

#### NFIQ 2.0

- **Feature computation time**
  - ~19.45 msec/image for OCL - Expect about the same for other features
    - MacBook Air, Mid 2011
    - Processor: 1.7 GHz Intel Core i5 (dual core)
    - Memory: 4 GB 1333 MHz DDR3 (256 KB L2 cache, 3MB L3 cache)
    - Software: OS X 10.8.3 (12D78)
  - ~85 msec/image for Minutia based features

- This is prior to any code optimization
## Current Status

### Completed

- **Framework design**
  - Modular, plug and play
- **Framework implementation**
- **Feature selection and prototype implementation complete**
  - [http://biometrics.nist.gov/cs_links/quality/NFIQ_2/NFIQ-2_Quality_Feature_Definition_Ver05.pdf](http://biometrics.nist.gov/cs_links/quality/NFIQ_2/NFIQ-2_Quality_Feature_Definition_Ver05.pdf)
- **Feature evaluation complete.**
- **Feature Implementation - MATLAB to to C/C++**
  - Thanks to FBI + MITRE
- **Exploring machine learning**
  - Random forest, SVM.
- **Feature selection (almost – contingent on their computation time).**
- **Implementation of actionable flags for detection and mitigation of bad presentations**
  - Incomplete finger (tip, etc.) + Wet / dry + Pressure

### Underway

- **Finalizing training**
  - After this workshop
- **NFIQ 2.0 Lite**
  - Self organizing map
- **Evaluation of Implementation of actionable flags for detection and mitigation of bad presentations**
  - Incomplete finger (tip, etc.) + Wet / dry + Pressure
  - But, tricky – since we do not have groundtruth for this.
- **Mapping of NFIQ 2.0 → NFIQ 1.0**
NFIQ 2.0

Promises, promises

» Improved feature
» More level (0-100)
» Faster, lighter
» Actionable feedback
» NFIQ 2.0 mobile
» Slap
» Better performance
» Modular design
» Calibration
» Conformance testing

So far, we have achieved

» Improved feature
» Standard features
» More level (0-100)
» Faster – we hope
» Actionable feedback
» Towards NFIQ Mobile
» --
» Better performance – we hope
» Plug and play
ISO/IEC IS 29794-1:2009

- Information technology - Biometrics sample quality Part 1: Framework
- Definitions
  - quality: "the degree to which a biometric sample fulfils specified requirements for a targeted application"
  - quality score: "a quantitative expression of quality"
  - utility: "the observed performance of a biometric sample or set of samples in one or more biometric systems"
- Quality score from 0 to 100

## 5-byte Quality Block

<table>
<thead>
<tr>
<th>description</th>
<th>size</th>
<th>valid values</th>
<th>notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Quality Blocks</td>
<td>1 byte</td>
<td>[0,255]</td>
<td>This field is followed by the number of 5-byte Quality Blocks reflected by its value (see Fehler! Verweisquelle konnte nicht gefunden werden.). A value of zero (0) means that no attempt was made to assign a quality score. In this case, no Quality Blocks are present.</td>
</tr>
<tr>
<td>Quality Score</td>
<td>1 byte</td>
<td>[0,100] 255</td>
<td>0: lowest 100: highest 255: failed attempt to assign a quality score</td>
</tr>
<tr>
<td>Quality Algorithm Vendor ID</td>
<td>2 bytes</td>
<td>[1,65535]</td>
<td>Quality Algorithm Vendor ID shall be registered with IBIA as a CBEFF biometric organization. Refer to CBEFF vendor ID registry procedures in ISO/IEC 19785-2.</td>
</tr>
<tr>
<td>Quality Algorithm ID</td>
<td>2 bytes</td>
<td>[1,65535]</td>
<td>Quality Algorithm ID may be optionally registered with IBIA as a CBEFF Product Code. Refer to CBEFF product registry</td>
</tr>
</tbody>
</table>
ISO/IEC 29794-1:201X

- Information technology - Biometrics sample quality Part 1: Framework
- Definitions
  - Same as before, but allow for a vector of quality components
  - Goal: Actionable quality
- Each element of quality vector has a score from 0 to 100.

<table>
<thead>
<tr>
<th>Description</th>
<th>Size</th>
<th>Valid values</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Quality Blocks (N)</td>
<td>1 byte</td>
<td>0 to 255</td>
<td>This field is followed by the number of 5-byte Quality Blocks reflected by its value. A value of zero (0) means that no attempt was made to assign a quality score. In this case, no Quality Blocks are present.</td>
</tr>
<tr>
<td>Quality Indicator</td>
<td>1 byte</td>
<td>0 to 100</td>
<td>250 (FA&lt;sub&gt;avg&lt;/sub&gt;): a vector of quality metrics is encoded in bytes 6-9. 255 (FF&lt;sub&gt;noa&lt;/sub&gt;) an attempt to calculate a quality score has failed</td>
</tr>
<tr>
<td>Quality Algorithm Vendor ID</td>
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</tr>
<tr>
<td>Overall quality score</td>
<td>1 byte</td>
<td>0 to 100</td>
<td>A quality score should express the predicted comparison performance of a representation. A quality score shall be encoded in one byte as an unsigned integer. Allowed values are 0 to 100 with higher values indicating better quality.</td>
</tr>
<tr>
<td>Number of quality vector elements</td>
<td>1 byte</td>
<td>Defined in each Part of this Standard</td>
<td>If the number of quality vector elements mod 5 is not equal to three then padding bytes should be added such that the length of the block is a multiple of five. This will ensure backward compatibility with the implementations conformant with ISO/IEC 29794-1:2009 and ISO/IEC 19794-3:2011. For example, if the number of quality vector elements is 14, 4 padding bytes shall be added so that the length of the image quality record is 25 = 4(paddings) + 14(number of quality vector elements) + 7(as shown in rows 1-7).</td>
</tr>
<tr>
<td>Quality metrics</td>
<td></td>
<td>As defined in modality specific parts of this International Standard</td>
<td></td>
</tr>
</tbody>
</table>
Support standardization of finger image quality

**ISO/IEC 29694-4**

- Provide quantitative support to development of Information technology – Biometric sample quality – Part 4: Finger image
  - Currently at 2nd working draft
- Contribute feature computation method + codes
  - Allows for plug-and-play of features for implementations that satisfy semantic conformance to the requirements of the ISO/IEC 29794-4 standard
Thank You.

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the main advantage of NFIQ—by far—is that it is universal and common to all, so I clearly recommend that we keep this universality for NFIQ 2 and hence have no option in the definition. NFIQ score on a given image should remain an absolute and universal value.