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 workshop
- 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)
- NFIQ 2.0 wish-list as of March 2010
- Community asked for:
  - Actionable flags
  - ProviderID
  - Versioning
  - Latent?
# NFIQ 2.0 Community

<table>
<thead>
<tr>
<th>Team Members</th>
<th>Sponsors</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIST (US)</td>
<td>Homeland Security</td>
</tr>
<tr>
<td>BSI (Germany)</td>
<td>Science and Technology</td>
</tr>
<tr>
<td>BKA (Germany)</td>
<td></td>
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<tr>
<td>Fraunhofer IGD</td>
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<tr>
<td>MITRE (US)</td>
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<tr>
<td>Hochschule Darmstadt / CASED</td>
<td></td>
</tr>
<tr>
<td>Secunet Security Networks AG</td>
<td></td>
</tr>
<tr>
<td>NFIQ 2.0 Participants</td>
<td></td>
</tr>
<tr>
<td>...and the whole biometrics community</td>
<td></td>
</tr>
</tbody>
</table>

...and the whole biometrics community
## 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()

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

Input/Output Interface
- Fingerprint images
- Quality features
- Comparison scores
- Utility values

Quality Feature Extraction Interface
- Feature extraction

Utility Estimation Interface
- Utility computation
- Fusion & binning

Machine Learning Interface
- Prediction
- Training

Database

Filesystem

Quality feature x

Utility x

MLP
NFIQ 2.0 comparison score provider

FNMR vs FMR graph with multiple lines representing different providers.
NFIQ 2.0 Features

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

### Image/signal processing
- Local clarity score
- Ridge valley uniformity
- Orientation certainty level
- Orientation flow
- Frequency domain analysis
- Radial power spectrum
- Gabor filters (several variants)

### Minutiae based
- FingerjetFx
  - Open source implementation from digitalPersona
  - [digitalpersona.com/fingerjetfx](https://digitalpersona.com/fingerjetfx)
- Total count of minutia
- Count of minutia in region of interest
  - Various selection of ROI

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.
NFIQ 2.0 :: performance per features

Comparator 2B – Dataset poebva – Finger 02

fraction of genuine comparisons rejected
false non-match rate

0.00 0.05 0.10 0.15 0.20 0.25 0.30
0.07 0.08 0.09 0.10 0.11
MACHINE LEARNING

We examined:
Random forest
Support vector machine
K-nearest neighbor
## Machine Learning

### Random Forest

- Ensemble classifier using stochastic process
  - Use vote to determine class memberships
  - Provides class probability in predictions
  - Analysis of features importance and their ranking
    - We used this to do our final feature selection

### Two class prediction

- High vs. Low performers
  - 1: High performers are images that result in high genuine scores
    - $> \text{CDF}^{-1}(0.95)$
  - 0: Low performers are images that result in false reject
    - Threshold at $\text{FMR}=0.0001$
    - Quality score is the probability that a given image belongs to class 1.

- Map quality score to recognition rate.
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

[Chart showing probability distribution for NFIQ 2.0 test across various 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)
Actionable quality

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

[Diagram of NFIQ 2.0 Lite/Mobile processes]
Self organizing maps


SOM code book
Self organizing maps for NFIQ2.0 Lite-1

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
NFIQ 2.0 Lite prototype

Features

performance

Features

performance
# NFIQ 2.0 computation time

<table>
<thead>
<tr>
<th>Lite</th>
<th>NFIQ 2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>» ~ 65 ms/image</td>
<td>» Feature computation time</td>
</tr>
<tr>
<td>» ~ 82 ms/image.</td>
<td>» ~ 19.45 msec/image for OCL - Expect about the same for other features</td>
</tr>
<tr>
<td>» This is prior to any code optimization</td>
<td>» MacBook Air, Mid 2011</td>
</tr>
<tr>
<td>» PC - 2.3 GHz Intel Core i7</td>
<td>» Processor: 1.7 GHz Intel Core i5 (dual core)</td>
</tr>
<tr>
<td>» 16 GB of memory.</td>
<td>» Memory : 4 GB 1333 MHz DDR3 (256 KB L2 cache, 3MB L3 cache)</td>
</tr>
<tr>
<td>» network size of dim = 24</td>
<td>» Software: OS X 10.8.3 (12D78)</td>
</tr>
<tr>
<td>» block size of n = 24</td>
<td>» ~85 msec/image for Minutia based features</td>
</tr>
<tr>
<td>» With gray scale normalization</td>
<td>» This is prior to any code optimization</td>
</tr>
</tbody>
</table>
# Current Status

## Completed

- Framework design
  - Modular, plug and play
- Framework implementation
- Feature selection and prototype implementation complete
- 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
<table>
<thead>
<tr>
<th>Promises, promises</th>
<th>So far, we have achieved</th>
</tr>
</thead>
<tbody>
<tr>
<td>» Improved feature</td>
<td>» Improved feature</td>
</tr>
<tr>
<td>» More level (0-100)</td>
<td>» Standard features</td>
</tr>
<tr>
<td>» Faster, lighter</td>
<td>» More level (0-100)</td>
</tr>
<tr>
<td>» Actionable feedback</td>
<td>» Faster – we hope</td>
</tr>
<tr>
<td>» NFIQ 2.0 mobile</td>
<td>» Actionable feedback</td>
</tr>
<tr>
<td>» Slap</td>
<td>» Towards NFIQ Mobile</td>
</tr>
<tr>
<td>» Better performance</td>
<td>» --</td>
</tr>
<tr>
<td>» Modular design</td>
<td>» Better performance – we hope</td>
</tr>
<tr>
<td>» Calibration</td>
<td>» Plug and play</td>
</tr>
<tr>
<td>» Conformance testing</td>
<td></td>
</tr>
</tbody>
</table>
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. 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>

NIST
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 2 - Data fields**

<table>
<thead>
<tr>
<th>Byte</th>
<th>Quality Indicator</th>
<th>Size</th>
<th>Valid values</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Quality Block 1</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>1</td>
<td>Quality Algorithm Vendor ID</td>
<td>2 bytes</td>
<td>1 to 65535</td>
<td>Quality Algorithm ID shall be registered with IBA as a CBEFF biometric organization. Refer to CBEFF vendor ID registry procedures in ISO/IEC 19785-2.</td>
</tr>
<tr>
<td>2-3</td>
<td>Quality Algorithm ID</td>
<td>2 bytes</td>
<td>1 to 65535</td>
<td>Quality Algorithm ID may be optionally registered with IBA as a CBEFF Product Code. Refer to CBEFF product registry procedures in ISO/IEC 19785-2.</td>
</tr>
<tr>
<td>4-5</td>
<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>6</td>
<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 19784-2:2011. 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(padding) + 14(number of quality vector elements) + 7(as shown in rows 1-7).</td>
</tr>
<tr>
<td>8</td>
<td>Quality metrics</td>
<td>As defined in modality specific parts of this International Standard</td>
<td></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.

Elham Tabassi
301 975 5292
tabassi@nist.gov
» Greg Cannon (CrossMatch)

» John Dowden (NEC)

» Anne Wang (3M Cogent)

» Timo Ruhland (BKA)

» Jean Christophe FONDEUR (MORPHO)
  • 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.