Call for participation in development of

NFIQ 2.0

NIST Fingerprint Image Quality

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NIST
National Institute of
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Bundesamt
für Sicherheit in der
Informationstechnik

THIS DOCUMENT IS BEING CIRCULATED BY THE NFIQ 2.0 DEVELOPMENT TEAM COMPRISED OF

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST) - U.S., and

BUNDESAMT FÜR SICHERHEIT IN DER INFORMATIONSTECHNIK (BSI) - GERMANY.

At the NIST March 2010 workshop on "The Future of NFIQ", workshop participants overwhelmingly recommended development of a new (open source) version of NFIQ in consultation and collaboration with users and industry.

NIST and BSI invite research organizations and industry members to support development of NFIQ 2.0. Specifically, NIST and BSI request

- Submission of comparison subsystems (i.e. matchers) whose comparison scores will be used for training of NFIQ 2.0 (by May 2, 2011),
- Suggestions and technical contributions towards composition and computation of NFIQ 2.0 features (by August 29, 2011), and
- Fingerprint images demonstrating NFIQ 1.0 anomaly (by September 30, 2011).

Initial Time Table

February 25, 2011	Call for participation National Institute of Standards and Technology (NIST) and Bundesamt für Sicherheit in der Informationstechnik (BSI) invite research organizations and industry members to participate in NFIQ 2.0 development, by – Submission of biometric comparison subsystems (i.e. matchers) whose comparison scores will be used for NFIQ 2.0 training by May 2, 2011. – Technical contributions towards composition and computation of NFIQ 2.0 features by August 29, 2011, – Fingerprint images demonstrating NFIQ 1.0 anomaly (by September 30, 2011).
May 2, 2011	SDK submission period ends.
June 1, 2011	Training data set is finalized.
July 1, 2011	Initial selection of features
September 1, 2011	Feature set is finalized.
March 2012	Presentation of NFIQ 2.0 at IBPC 2012

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1. Overview

Quality measurement plays a vital role in improving biometric system accuracy and efficiency during the capture process (as a control-loop variable to initiate reacquisition), in database maintenance (sample update), in enterprise-wide quality assurance surveying, and in invocation of quality-directed processing of samples in multimodal systems. If quality can be improved, either by sensor design, by user interface design, or by standards compliance, better performance can be realized. For those aspects of quality that cannot be designed-in, an ability to analyze the quality of a live sample is needed.

Biometric quality analysis is a technical challenge because it is most helpful when the quality measures reflect the performance sensitivities of one or more target biometric comparison subsystems. NIST addressed this problem in August 2004 when it issued NIST Fingerprint Image Quality (NFIQ) algorithm. NFIQ is a fingerprint quality measurement tool; it is implemented as open-source software; and is used today in very large government both in U.S. and worldwide, and commercial deployments. NFIQ's key innovation is to produce a quality value from a fingerprint image that is directly predictive of expected recognition performance. NFIQ serves as a publicly available reference implementation. With advances in fingerprint technology since 2004, an update to NFIQ is needed. Proposed scientific approach for development of NFIQ 2.0 is outlined in Annex A.

2. Call for participation

A workshop was held in March 2010 at NIST[1] to address the technical status of fingerprint quality assessment technology. The workshop aimed at engaging industry to improve core finger image quality assessment technology based on lessons learned from recent deployments of quality assessment algorithms (including NFIQ) in large-scale identity management applications. Options for the future of NFIQ were discussed and the community overwhelmingly recommended a new (open source) version of NFIQ to be developed in consultation and collaboration with users and industry. To that end, National Institute of Standards and Technology (NIST) and Bundesamt für Sicherheit in der Informationstechnik (BSI) in Germany have teamed up to develop the new and improved open source NIST Finger Image Quality (NFIQ 2.0) and extend invitation to research organizations and industry members to provide specific support in development of NFIQ 2.0.

Specifically, NIST and BSI request participation in one or more of the following forms:

- Submission of biometric comparison subsystems (i.e. matchers) whose comparison scores will be used for NFIQ 2.0 training,
- Technical contributions towards composition and computation of NFIQ 2.0 features,
- Fingerprint images demonstrating NFIQ 1.0 anomaly.

The algorithms and software need not be "operational," nor a production system, nor commercially available. However, the system must, at a minimum, be a stable implementation capable of being "wrapped" (formatted) in the API specification specified in Annex A. The API is similar to that used in NIST fingerprint tests (e.g. PFT) and should therefore be familiar to many commercial providers. Comparison scores (generated by biometric comparison subsystems) shall measure the similarity between finger image data contained in the two templates being compared, so larger values indicate more likelihood that the two samples are from the same finger. The terms comparison score and similarity score are being used interchangeably in this document.

Participants can submit compiled libraries to NIST or BSI or both.

NFIQ 2.0 feature set shall consist of image characteristics that model failure modes and sensitivities of current fingerprint comparison algorithms. Examples include: zonal quality, continuity of ridge flow, area of finger image impression, or number of minutiae. Some of these features like zonal quality or minutiae quality are already standardized in [ISOFIN] and [ISOMIN]. Technical report ISO/IEC 29794 Biometric sample quality – Part 4: Finger image [ISOFINQ] recommends procedures for finger image quality analysis. Final NFIQ 2.0 features will be submitted to JTC 1 ISO/IEC WG3 for possible formal standardization as revision of ISO/IEC 29794 Biometric sample quality – Part 4: Finger image.

[1] http://www.nist.gov/itl/iad/ig/ibpc2010.cfm

3. Why NIST

NIST has the largest and most diverse set of operational fingerprint images. NIST will use carefully chosen subsets of its finger image corpora for training and testing of NFIQ 2.0. Avoiding over-fitting problem and building models that could explain structures of unseen data is an important and difficult problem in training machine-learning algorithms. Use of a large and diverse set for training can mitigate this problem.

Interoperability of quality scores can be achieved by calibrating quality scores to observed false non-match rates. NIST will provide calibration curves for Class GQ and DQ participants, which will improve interpretation of quality scores.

4. Options for participation

NIST and BSI invite interested parties to submit

- Technical contribution on composition and computation of features via email to nfiq2[DOT]development[AT]nist[DOT]gov by August 29, 2011,
- SDKs that create proprietary templates for comparison and computation of real valued non-quantized and non-thresholded similarity scores resulted from comparing two templates by May 2, 2011, or
- Fingerprint images demonstrating NFIQ 1.0 anomaly by September 30, 2011.

NIST and/or BSI will use submitted SDKs for development of generalized NFIQ 2.0. Participants can optionally request development of a “customized” NFIQ 2.0 (Class C or CQ participation). For each Class C or CQ participant, a dedicated training will be done based on its comparison scores only. This produces an NFIQ 2.0 variant that specifically targets that one biometric comparison subsystem. Class C or CQ participants will receive NFIQ 2.0 training information for their submitted comparison algorithm.

Furthermore, participants have the option of computing quality scores as part of template generation (Class GQ or CQ). For Class GQ or CQ participants, NIST will provide calibration information e.g. a calibration curve that maps vendor proprietary quality values to observed false non-match rates and/or NFIQ 2.0 values.

NIST PFT or PFT II participants that consider their PFT or PFT II submissions suitable for this activity can choose Class G or Class C participation and provide NIST the correct PFT or PFT II SDK identifier code in lieu of new submission. PFT SDK identifier codes are listed at http://www.nist.gov/itl/iad/ig/pft_2003_status.cfm.

Table 1. summarizes options for participation. Note that all submissions will be used for development of generalized NFIQ 2.0.

5. Treatment of SDKs

Participants can choose either NIST or BSI or both to execute their SDKs. Comparison scores will be shared between NIST and BSI, and will be used only for the purposes laid out in this document.

NIST and BSI will treat submitted SDKs as black boxes. Particularly, NIST and BSI will not try to emulate or reverse engineer submitted algorithms.

Upon completion of this project, the participants will be asked for permission to release the comparison scores and/or the normalized comparison scores along with the final NFIQ2 feature vectors.

6. Communication

News and information on progress of NFIQ 2.0 will be posted at http://www.nist.gov/itl/iad/ig/development_nfiq_2.cfm.

General questions, comments and technical contribution on composition and computation of NFIQ 2.0 features, the makeup of the training data, anomaly of NFIQ 1.0 can be sent to nfiq2[dot]development[AT]nist[DOT]gov.

SDK submissions to NIST, or question or comments for NIST only, should be sent to nfiq2[AT]nist[DOT]gov.

SDK submissions to BSI, or question or comments for BSI only, should be sent to nfiq2[AT]bsi[DOT]bund[DOT]de.

SDK submissions to both NIST and BSI should be sent to nfiq2[AT]nist[DOT]gov and nfiq2[AT]bsi[DOT]bund[DOT]de.

Table 1. Options for participation. All submitted SDKs are considered Class G.

	Class G **"Generalized"**	**Class GQ** **Class G with Quality Computation**	**Class C** **"Customized"**	**Class CQ** **Class C with Quality Computation**
What to submit	EITHER Template generation (Input: finger image; Output: proprietary template for comparison) AND Biometric Comparator (Matcher) (Input: 2 proprietary templates; output: comparison score) OR Your PFT/PFT II SDK Code	Template generation (Input: finger image; Output: proprietary template for comparison + Quality score) AND Biometric Comparator (Matcher) (Input: 2 proprietary templates; output: comparison score).	EITHER Template generation (Input: finger image; Output: proprietary template for comparison) AND Biometric Comparator (Matcher) (Input: 2 proprietary templates; output: comparison score) OR Your PFT/PFT II SDK Code	Template generation (Input: finger image; Output: proprietary template for comparison + Quality score) AND Biometric Comparator (Matcher) (Input: 2 proprietary templates; output: comparison score).
NIST use	Comparison scores will be used to train generalized NFIQ 2.0	Comparison scores will be used to train generalized NFIQ 2.0.	Comparison scores are used to train generalized NFIQ 2.0 AND a customized NFIQ 2.0.	Comparison scores are used to train generalized NFIQ 2.0 AND a customized NFIQ 2.0.
NIST output to participant		Calibration information for the submitted quality scores.	Training information for the customized NFIQ 2.0.	Trained information for the customized NFIQ 2.0. Calibration information for the submitted quality scores.
Benefit to participant	You are part of NFIQ 2.0. NFIQ 2.0 will reflect the sensitivities of the submitted biometric comparator.	You are part of NFIQ 2.0. NIST will supply calibration information for your quality scores.	A variant of NFIQ 2.0 that specifically targets your biometric comparator.	A variant of NFIQ 2.0 that specifically targets your biometric comparator. Calibration information for your quality scores.
Possible future standardization	NFIQ 2.0 features (revision of [ISOFINQ])	Quality calibration (a new part to [ISOCAL])		

7. How to participate

Those wishing to participate in development of NFIQ 2.0 are asked to

- Indicate via email (nfiq2[AT]nist[DOT]gov and nfiq2[AT]bsi[DOT]bund[DOT]de) a non-binding "Intention to Participate"
- Send a signed and fully completed copy of this entire Call for Participation, including the form below.
- If you want us to use comparison scores of your PFT or PFT II submission, send us your PFT or PFT II SDK identifier code as is listed at http://www.nist.gov/itl/iad/ig/pft_2003_status.cfm.
- If you are providing a new SDK (Software Development Kit)
  - Request an SDK ID from NIST
  - Follow the instructions for cryptographic protection of your SDK. http://nfiq2.nist.gov/NIST_biometrics_crypto.pdf (to be posted).
  - Provide an SDK library, which complies with the API (Application Programming Interface) specified in this document (Annex B) by May 2, 2011.

The NFIQ 2.0 Application to Participate shall be sent to:

NFIQ 2.0 National Institute of Standards and Technology Information Access Division (894) 100 Bureau Drive A207/Tech225/Stop 8940 Gaithersburg, MD 20899-8940 USA	In cases where a courier needs a phone number, please use NIST shipping and handling on: 301 - 975 - 6296.

7.1. Submission of software to NIST

Participants are requested to provide NIST or BSI with binary code only (i.e. no source code). It is preferred that the SDK be submitted in the form of a single shared library file (i.e. ".DLL" for Windows or ".so" for Linux). NIST or BSI will link the provided library file(s) to a C language driver application developed by NIST. Participants are requested to provide their library in a format that is linkable using GCC with the NIST driver, which is compiled with GCC.

NIST requests that all software submitted by the participants be signed and encrypted. Signing is done with the participant's private key, and encrypting is done with the NIST public key, which will be published on the NFIQ 2.0 Web site. NIST will validate all submitted materials using the participant's public key, and the authenticity of that key will be verified using the key fingerprint. This fingerprint must be submitted to NIST by writing it on the signed participation agreement.

By encrypting the submissions, we ensure privacy; by signing the submission, we ensure authenticity (the software actually belongs to the submitter). NIST will not accept any submission that is not signed and encrypted. NIST accepts no responsibility for anything that is transmitted to NIST that is not signed and encrypted.

The detailed commands for signing and encrypting are given here: (to be posted).

8. Bibliography

Label	**Document**
ISOCAL	SO/IEC 29159 Biometric fusion, calibration and augmentation (2010 edition)
ISOFIN	ISO/IEC 19794 Biometric data interchange formats – Part 4: Finger image (201X edition)
ISOFINQ	ISO/IEC 29794 Biometric sample quality – Part 4: Finger image
ISOMIN	ISO/IEC 19794 Biometric data interchange formats – Part 2: Finger minutiae (201X edition)
ISOQ	ISO/IEC 29794 Biometric sample quality – Part 1: Framework (2009 edition)

1	**This form shall be completed by all suppliers electing to participate in the NFIQ 2.0 development.**				
2	NIST assigned identifier for the supplied SDK.				
3	Responsible Party for supplier of finger image encoding and/or comparison technologies.				
4	Company / Organization Name				
5	Title	First Name	MI	Last Name	Suffix
6	Street Address				
7	City	State	Zip	Country	
8	Phone	Fax	Email		
9	Technical point of contact (if different from Responsible Party)	Phone	Email		
10	Participant's public-key fingerprint (Enter here)				
11	NIST’s public-key fingerprint				
12	BSI’s public-key fingerprint				
13	Option for participation (All submissions are considered Class G)	X Class G — Class C — Class GQ — Class CQ — Use my PFT or PFT II submission (insert your PFT SDK Identifier Code below) —			
14	Submission to (mark all that applies)	— NIST nfiq2[AT]nist[DOT]gov	— BSI nfiq2[AT]bsi[DOT]bund[DOT]de		

With my signature, I hereby express my willingness to participate in development of NFIQ 2.0. I gave my permission to organization(s) identified in row 14 above to use comparison scores computed by my submitted SDK in the development of NFIQ 2.0.

With my signature, I also state that I have the authority to accept the terms stated in this document.

SIGNATURE OF SOFTWARE SUPPLIER RESPONSIBLE PARTY DATE

Annex A
Proposed scientific approach for development of NFIQ 2.0

1. NFIQ 2.0

We propose development of a set of standardized finger image quality components plus multivariate statistics techniques to relate biometric performance metrics such as false non-match to the standardized quality components (i.e. features). The outcome will be an open source quality assessment algorithm for finger image. Same as NFIQ 1.0, the new NFIQ 2.0 will have two major computation steps:

- Feature extraction, and
- Training of a machine-learning algorithm.

1.1. Feature Extraction

Feature extraction consists of measuring appropriate image characteristics that convey information for comparison algorithms. The feature set may be comprised of elements such as local noise, continuity of ridge flow, area of the finger image impression, and number of minutiae. A feature vector is computed from each image and its components are combined using a trained machine-learning algorithm so that the image quality score is reflective of positive or negative contribution of the sample to the overall performance of the system. Part 4 of ISO/IEC 29794 [ISOFIN Q] defines defect factors for finger images and recommends features and characteristics of finger images at both local and global structures that are related to performance of fingerprint recognition systems. Additionally parts 2 [ISOMIN] and 4 [ISOFIN] of ISO/IEC 19794 Biometric data format standard define features such as zonal quality or minutiae quality.

In collaboration with industry, a set of quality components will be defined and perhaps formally standardized. These quality components shall model failure modes and sensitivities of current fingerprint recognition algorithms. Examples include: zonal quality, clarity of ridges, size of fingerprint, or number of minutiae. **Technical comments and contributions towards the formation and computation of features are requested.**

NIST and BSI will develop open-source reference implementations for standardized quality components.

1.2. Training a machine leaning algorithm

Training looks for structure in the data and ultimately building a model to relate the response variable (e,g. performance as false non-match rate, or area-under-ROC-curve) to the exploratory variables (i.e. features or quality components). We explore different multivariate statistical techniques to obtain the optimal model. Training could be customized to a comparison algorithm or generalized to a class of comparison algorithms. NIST and BSI will train a machine-learning algorithm to predict performance of a particular comparison algorithm (i.e. customized NFIQ 2.0) or a general class of comparison algorithms (generalized NFIQ 2.0).

NIST and BSI will perform the training. **For customized NFIQ 2.0**, **NIST will return the training parameters on the machine-learning algorithm to the provider of the biometric comparison subsystem (matcher) used for training**.

The outcome will be a family of quality algorithms that could be application-independent or tuned to particular applications. Interoperability is achieved by uniform interpretation of quality scores; therefore, it expands a marketplace of interoperable products.

2. Generalized vs Customized

NFIQ has been designed to be agnostic to biometric comparison algorithm. For applications where the comparison algorithm is not known a priori or subject to change, a generalized (i.e. biometric comparison independent) image quality assessment algorithm (IQAA) is needed. However, when the comparison algorithm is known, use of an IQAA that is tuned to predict the performance of the deployed comparison algorithm is more suitable. Therefore the next generation of finger image quality, should provide both options of “generalized” (i.e. comparison algorithm-independent) or “customized” (i.e. comparison algorithm dependent).

3. Calibration

Interoperability of quality scores is another challenge in exchange of quality scores. Part 1 of the multipart ISO/IEC 29794 Biometric sample quality standard [ISOQ] defines a binary record structure for the storage of a sample’s quality data. It establishes requirements on the syntax and semantic content of the structure. Specifically, it states that the purpose of assigning a quality score to a biometric sample shall be to indicate the expected utility of that sample in an automated comparison environment. That is, a quality algorithm should produce quality scores that target application-specific performance variables. For verification, the default metric would usually be false-non-match rates that are likely to be realized when the sample is verified. This, by itself, is not sufficient for accurate interpretation of quality scores generated by different quality assessment algorithms and therefore some normalization or calibration is needed.

Annex B
Application Programming Interface (API)

1. Proprietary template creation

This function converts a raw finger image into an opaque proprietary template. Two options are provided - one to convert an image into a generic enrollment or verification proprietary template and another to allow two functions, one for enrollment and another for verification. This "output type" aspect will be respected in Table B.2. It supports comparison algorithms that are asymmetric.

Table B.1. NFIQ2 API proprietary template creation

Prototype	uint32_t convert_image _to_ proprietary_template(const uint8_t *image_data, const uint16_t image_width, const uint16_t image_height, const uint8_t image_format, const uint8_t intensity_depth, const uint8_t which_finger, const uint32_t allocated_bytes, uint8_t template_role, uint32_t *template_size, uint8_t *proprietary_template, uint8_t *quality_score, uint8_t *image_enhanced);	
Description	This function takes a raw finger image, and outputs a proprietary template. This function is first called for a generic template output. If it fails with return code 10, it will be called for enrollment and verification template creation. The memory for the output proprietary template is allocated before the call i.e. the implementation shall not allocate memory for the result. In all cases, even when unable to extract features, the output shall be a proprietary template that may be passed to the compare_proprietary_templates (see Table 2) function without error. That is this routine must internally encode "proprietary template creation failed" and the comparison algorithm must transparently handle this.	
Input Parameters	image_data	The image used for proprietary template creation.
	image_width	The number of pixels indicating the width of the image.
	image_height	The number of pixels indicating the height of the image.
	Image_format	NIST anticipates using only raw uncompressed 8 bit grayscale data, so the image format will be 0x02, and the intensity depth will be 8.
	intensity_depth	

	which_finger	FINGER_UNDEF = 0 (0x00)
		RIGHT_THUMB = 1 (0x01) LEFT_THUMB = 6 (0x06)
		RIGHT_INDEX = 2 (0x02) LEFT _INDEX = 7 (0x07)
		RIGHT_MIDDLE = 3 (0x03) LEFT _MIDDLE = 8 (0x08)
		RIGHT_RING= 4 (0x04) LEFT _RING= 9 (0x09)
		RIGHT_LITTLE= 5 (0x05) LEFT _LITTLE= 10 (0x0A)
		These are the values used in [ISOFIN].

	allocated_bytes	Number of bytes NIST allocated for the output proprietary template. NIST will pre-allocate 65,536 bytes. **Question to participants: Email us if 64K is not enough.**

	template_role	Generic or enrollment and verification.
		PROP_TEMPLATE_GENERIC = 0 (0x00)
		PROP_TEMPLATE_ENROL = 1 (0x01)
		PROP_TEMPLATE_VERIF = 2 (0x02)

Output Parameters	template_size	The size, in bytes, of the output proprietary template.
	proprietary_template	The output proprietary finger template. The format is entirely unregulated. Maximum allocated memory is 65,536 bytes.
	quality_score	The output (integer) quality score computation results, if quality computation is done at the same time as proprietary template creation (image in, proprietary and quality out). NIST allocates and initializes quality score to 255. If quality computation is not done at the time of proprietary template creation, the quality vector shall be 255.
	image_enhanced	1: alteration and enhancement performed 0: no alteration/enhancement
Return Values	0	Success
	2	Elective refusal to produce a proprietary template (e.g. insufficient finger area)
	4	Elective refusal to process the input image
	6	Involuntary failure to extract features (e.g. could not find finger in the input-image)
	8	Not enough memory – need more than allocated bytes
	10	Output type not supported
	12	Null pointer
	14	Bad arguments
	Other	Vendor-defined failure

2. Proprietary templates comparison

This function compares two proprietary templates and returns a real-valued comparison score, which shall be a measure of the similarity between finger image data contained in the two proprietary templates. Therefore, higher values indicate more likelihood that the two images are from the same finger. The terms comparison score and similarity score are being used interchangeably throughout this document.

Table B.2. NFIQ 2 Proprietary templates comparison

Prototype	uint32_t compare_ proprietary_templates(const uint8_t *verification_template, const uint32_t verification_template_size, const uint8_t *enrollment_template, const uint32_t enrollment_template_size, double *similarity);	
Description	This function compares two proprietary templates and outputs a non-negative comparison score. The returned score is a non-negative similarity measure. NIST will allocate memory for this parameter before the call. When either or both of the input proprietary templates are the result of a failed proprietary template generation (see Table B.1), the similarity score shall be -1 and the function return value shall be 2.	
Input Parameters	Verification_template	A proprietary template from convert_image_to_proprietaryTemplate().
	verification_template_size	The size, in bytes, of the input verification proprietary template $0 \leq N \leq 2^{16} - 1$
	enrollment_template	A proprietary template from convert_image _to_proprietaryTemplate().
	enrollment_template_size	The size, in bytes, of the input enrollment proprietary template $0 \leq N \leq 2^{16} - 1$
Output Parameters	similarity	A similarity score resulting from comparison of the proprietary templates.
Return Values	0	Success
	2	Either or both of the input proprietary templates were result of failed template generation.
	12	Null pointer
	14	Bad arguments
	Other	Vendor-defined failure

3. Implementation identifiers

The implementation shall support the self-identification function of Table B.3. This function is required to support internal NIST book keeping. The version numbers should be distinct between any versions, which offer different algorithmic functionality.

Table B.3. NFIQ2 API get_pids function

Prototype	uint32_t get_pid(uint32_t *nist_assigned_identifier, char *email_address);	
Description	This function retrieves an identifier that the provider must request from NIST nfiq2[AT]nist[DOT]gov (if submitting to NIST or NIST and BSI) or nfiq2[AT]bsi[DOT]bund[DOT]de (if submitting to BSI only) , and hardwire into the source code. NIST or BSI will assign the identifier that will uniquely identify the supplier and the SDK version number.	
Output Parameters	nist_assigned_identifier	A PID, which identifies the SDK under test. The memory for the identifier is allocated by NIST's calling application, and shall not be allocated by the SDK.
	email_address	Point of contact email address as null-terminated ASCII string. NIST will allocate at least 64 bytes for this. SDK shall not allocate memory.
Return Values	0	Success
	14	Bad arguments
	Other	Vendor-defined failure