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for Information Security

Fingerprint Image Quality
NFIQ2.0

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Outline

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- Fingerprint applications and challenges
- Problem statement and requirements
- NFIQ2.0 framework and development
- Identifying candidate features
- NIFQ2.0 Light
- Summary and outlook

Official fingerprint applications

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- Official documents with fingerprints
  - European ePassports
  - European Residence Permits
  - Identity Cards (partially)
- European Visa Information System (VIS)
  - Tenprints from all Schengen (short-time) Visa applicants
    - Data stored for 5 years
  - Biometric verification at Schengen border checks has started
- Criminal AFIS
- Future programs might also use fingerprints
  - EU Smart Borders Package (Entry-Exit-System, RTP)

Challenges for operators

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- Technical aspects
  - Heterogenous environments
  - Different hardware and software vendors and versions
  - Interoperability issues
- System design
  - At enrolment stage, typically the biometric verification or identification system vendor is unknown
  - Large scale identification scenarios (AFIS) have high quality requirements
    - 100 million records or more!

Challenges in fingerprint biometrics deployment

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- Timing considerations
  - Timing constraints are the biggest driver in the design of an enrolment and verification process
  - In many cases, quality correlates directly with time
    - Not only technical, but also organizational (e.g. regarding user guidance)
  - Time is money!
    - Officers are expensive
    - Space is expensive
- Which quality is required by the system?
  - How much time (on average) do I need to reach the desired level?
  - Not: How do I achieve maximal quality?

Standardization - then

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- Based on 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

description		size	valid values	notes
Number of Quality Blocks		1 byte	[0,255]	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.
Quality Block	Quality Score	1 byte	[0,100] 255	0: lowest 100: highest 255: failed attempt to assign a quality score
	Quality Algorithm Vendor ID	2 bytes	[1,65535]	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.
	Quality Algorithm ID	2 bytes	[1,65535]	Quality Algorithm ID may be optionally registered with IBIA as a CBEFF Product Code. Refer to CBEFF product registry

Standardization - now

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- Based on ISO/IEC 29794-1:201X "Information technology - Biometrics sample quality Part 1: Framework"
- Definitions
  - Same as before, but allows 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

		Description	Size	Valid values	Notes
		Number of Quality Blocks (N)	1 byte	0 to 255	This field is followed by the number of 5-byte Quality Blocks reflected by its value.
Quality Block 1	Byte 1	Quality Indicator	1 byte	0 to 100 250 255	0 to 100: the encode value is the overall quality score of the representation. It should express the predicted recognition performance of a representation with higher values indicating better quality. 250 (FA_{Hex}): a vector of quality metrics is encoded in bytes 6-N. 255 (FF_{Hex}), an attempt to calculate a quality score has failed
	Bytes 2-3	Quality Algorithm Vendor ID	2 bytes	1 to 65535	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.
	Bytes 4,5	Quality Algorithm ID	2 bytes	1 to 65535	Quality Algorithm ID may be optionally registered with IBIA as a CBEFF Product Code. Refer to CBEFF product registry procedures in ISO/IEC 19785-2.
Bytes 6 – 5 x (Number of quality blocks) exist only if quality indicator (Byte 1) is 250 (FA_{Hex}).					
Quality Blocks 2-N	6	Overall quality score	1 byte	0 to 100	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
	7	Number of quality vector elements	1 byte	Defined in each Part of this Standard	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-x: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).
	8	Quality metrics			As defined in modality specific parts of this International Standard.

Motivation

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- There‘s no common understanding of a term like *fingerprint of sufficient quality*
  - Sufficient for which application?
  - Quality requirements differ a lot for different applications (e.g. between one-to-one and one-to-many)
  - Quality is not sufficiently well-defined in the standard
- There‘s no common language to establish an interoperable definition of *fingerprint of sufficient quality* for a specific application scenario
  - When developing an application scenario, define a common understanding of the required image quality – at the very beginning!
  - A baseline tool (as common language) is needed for doing this

Joint effort towards NFIQ2.0

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NIST National Institute of Standards and Technology U.S. Department of Commerce

Federal Office for Information Security

Bundeskriminalamt

Fraunhofer IGD

CASED

secunet

Homeland Security Science and Technology

NFIQ history / milestones

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- 2004: Release of NFIQ-1 by NIST
  - Open source, accepted by the community
  - Only five different values as output (1 – 5)
- March 2010: 1st workshop at IBPC 2010
  - Wish list on NFIQ2.0
    - Open source, generalization, interoperability
  - NFIQ2.0 should follow a similar technical approach – but better, bigger, faster, etc.
- March 2012: 2nd workshop at IBPC 2012
  - Presentation of concepts and first components
- Sept. 2013: Biometric Consortium Conference (BCC 2013)
  - Presentation of the 1st NFIQ2.0 prototype

NFIQ2.0 design considerations

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- Modular approach for NFIQ2.0 development is desired
  - to be flexible regarding the implementation
  - to have a common basis of functionality needed for NFIQ2.0 development which might then be extended by exchange of certain modules
  - because project team is distributed and located all over the world
  - because only certain project partners have access to certain fingerprint databases
  - because work can be shared and re-used by others
  - to simplify the development process

NFIQ2.0 development process

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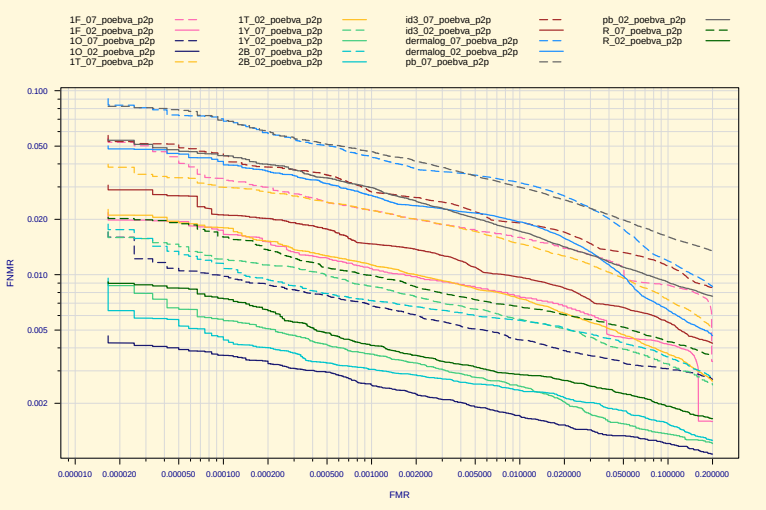
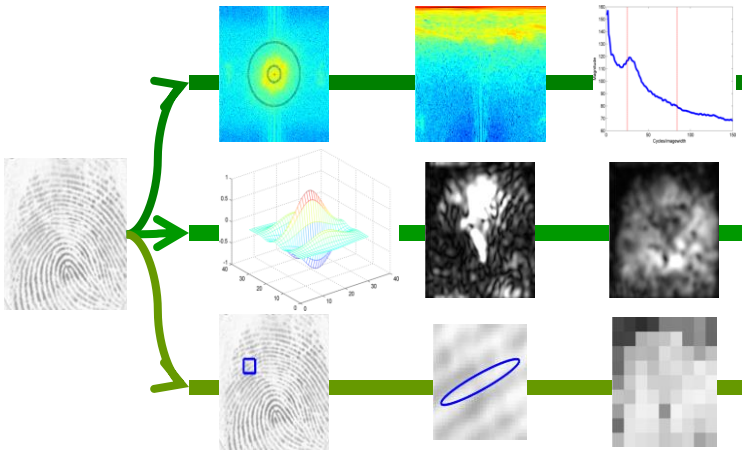
- **(1) Public call for participation** (9 comparison score providers)



- **(2) Feature implementation + evaluations** (100+ features)



- **(3) Training + Test set construction**

- **(4) Machine learning**

NFIQ2.0 framework

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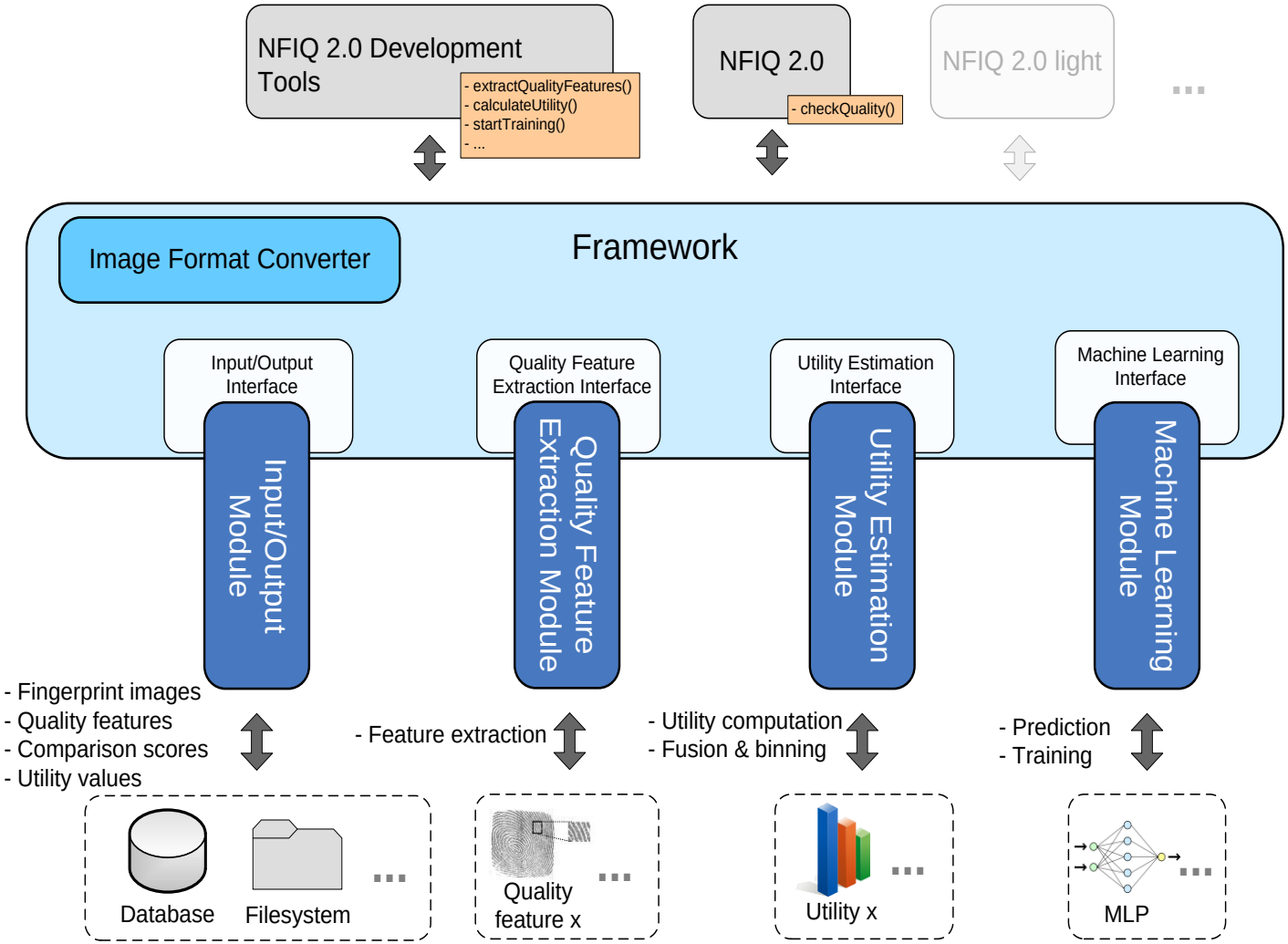

NFIQ2.0 features

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- **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
  - Total count of minutia
  - Count of minutia in region of interest
    - Various selection of ROI

Requirements

- Must be based on publicly available algorithms
- Standardized interface (inputs and outputs)

Machine learning

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- **Two class prediction**
  - High vs. low performers
    - **Class 1:** High performers are images that result in high genuine scores
      - > $CDF^{-1}(0.95)$
    - **Class 0:** Low performers are images that result in false reject
      - Threshold at FMR=0.0001
    - Quality score is the probability that a given image belongs to class 1.
  - Map quality score to recognition rate
- **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
  - Training
    - About 5000 samples in each of the low and high performers classes
    - 1000 trees in forest

NFIQ2.0 prototype

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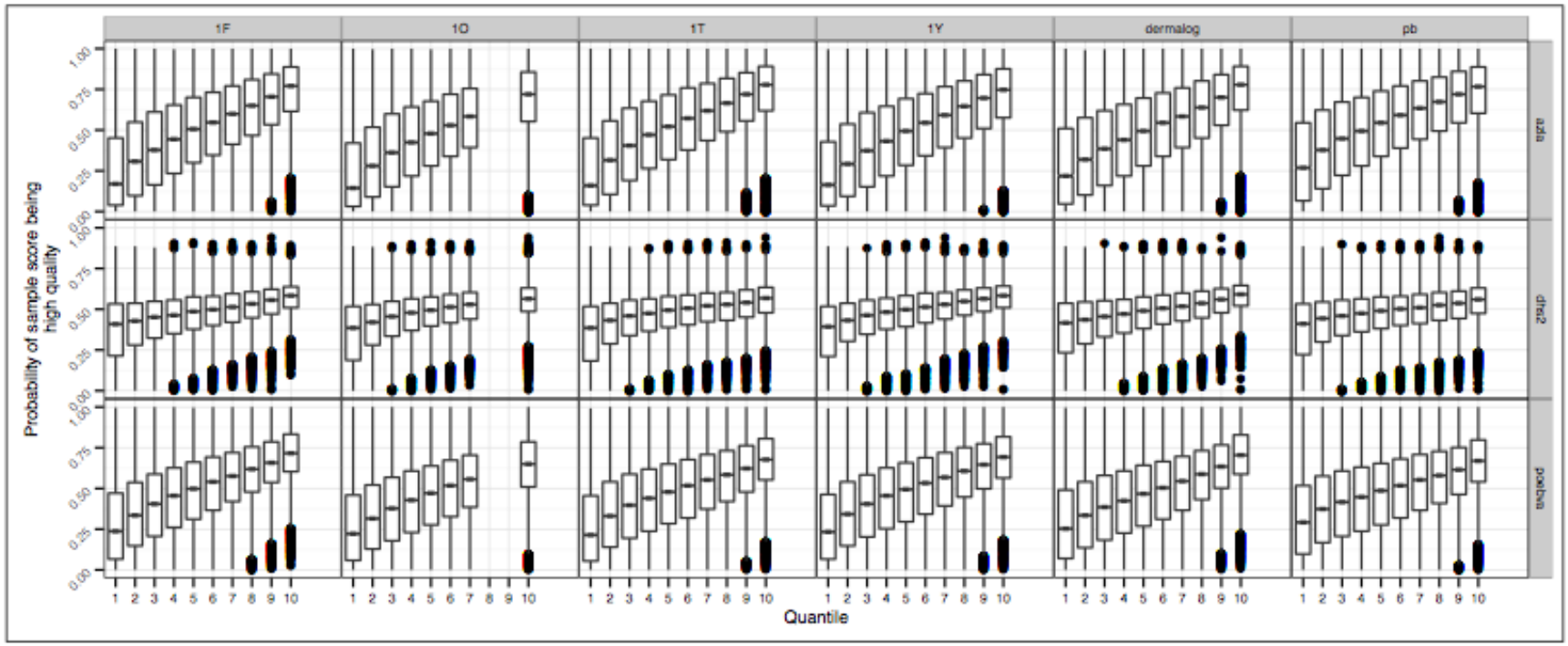
- Test result :: Boxplot of the output of random forest per quantized comparison score bin for test set



NFIQ2.0 prototype features

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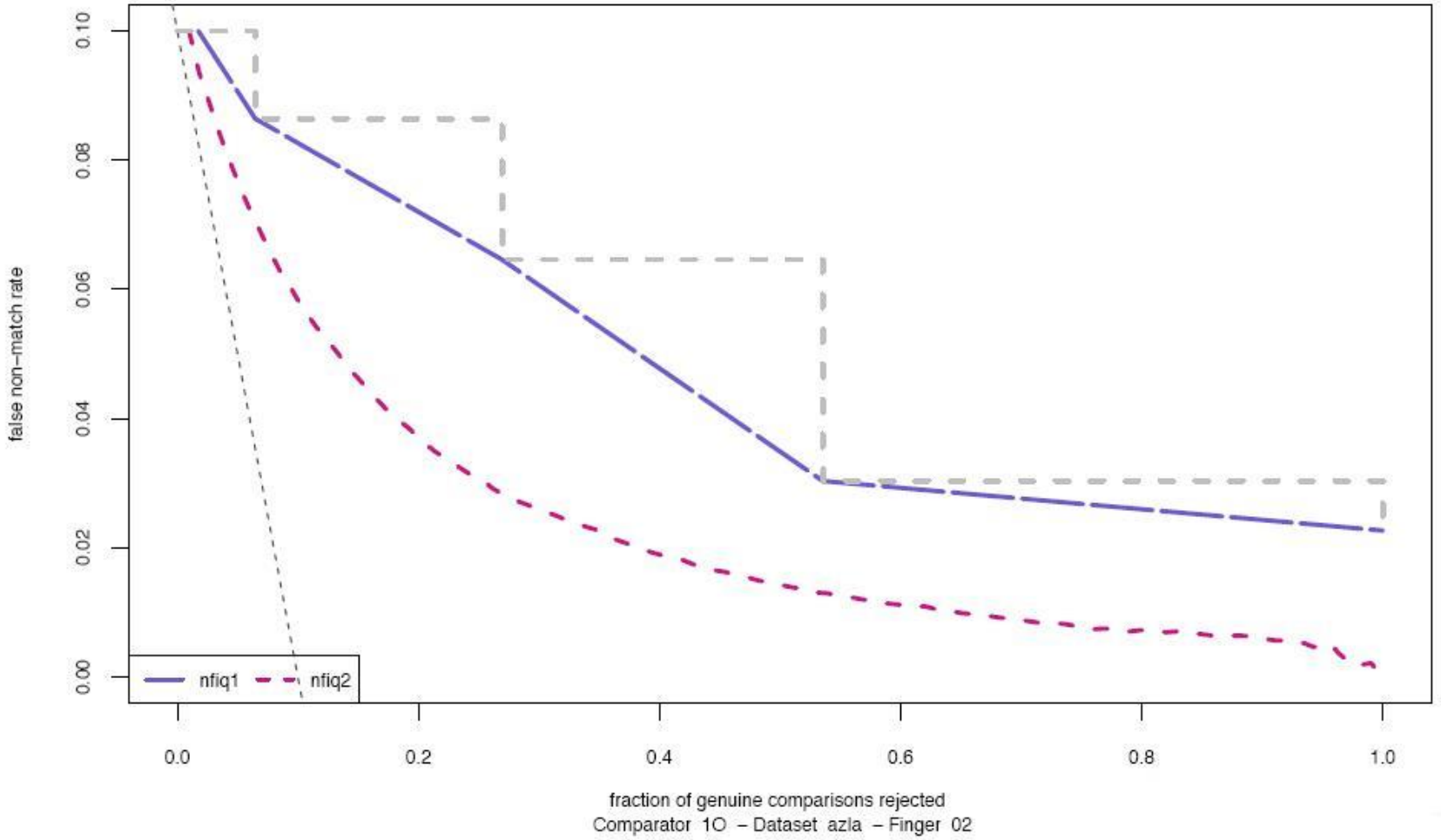
- Preliminary feature list
  - Size of fingerprint
  - Ridge valley uniformity
  - Orientation certainty
  - Orientation flow maps
  - Gabor features
  - Minutiae count and quality
  - Simple contrast features
  - Radial power spectrum

NFIQ2.0 prototype performance

E. Tabassi: „Development of NFIQ 2.0 “,
Biometric Consortium Conference, (2013)



NFIQ2.0 Light

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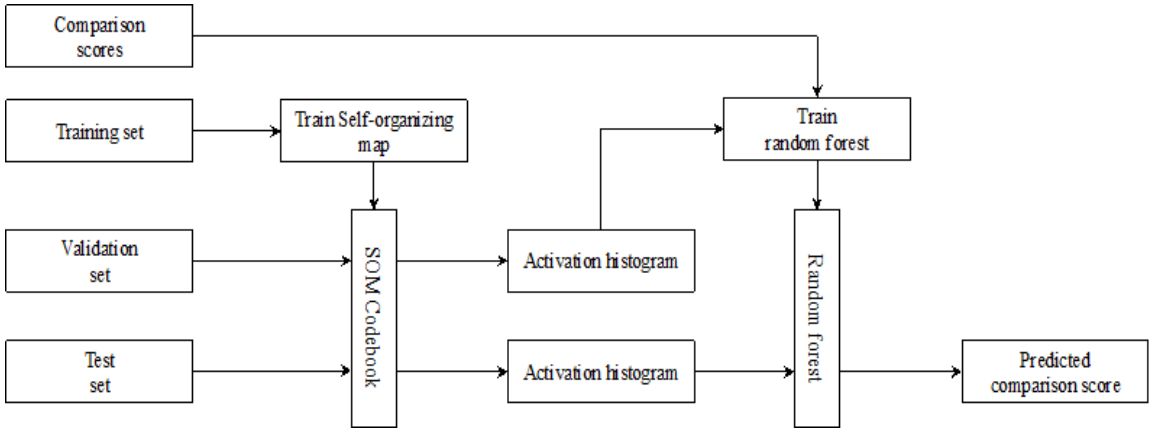
- Motivation
  - Computation complexity of feature extraction is high
  - Therefore, feature computation not feasible in mobile devices/sensors
- Suggested solution
  - Pre-compute a lookup table to speed up the computation
- Two stage process
  - Clustering using Self-Organizing Map
  - Prediction using Random Forest



Self Organizing Maps (SOM) for NFIQ2.0 Light

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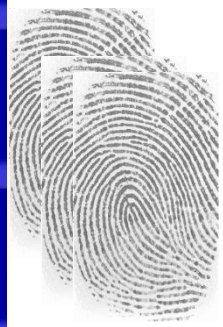
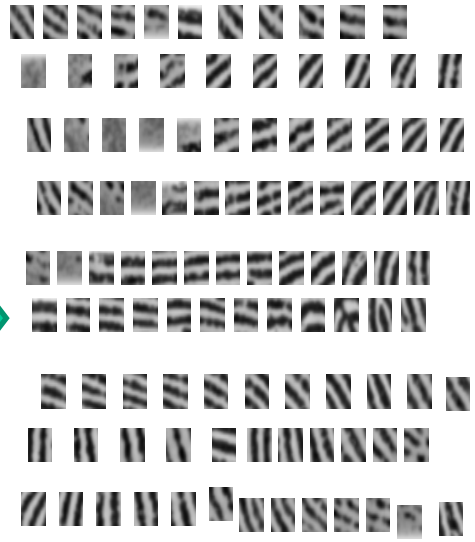
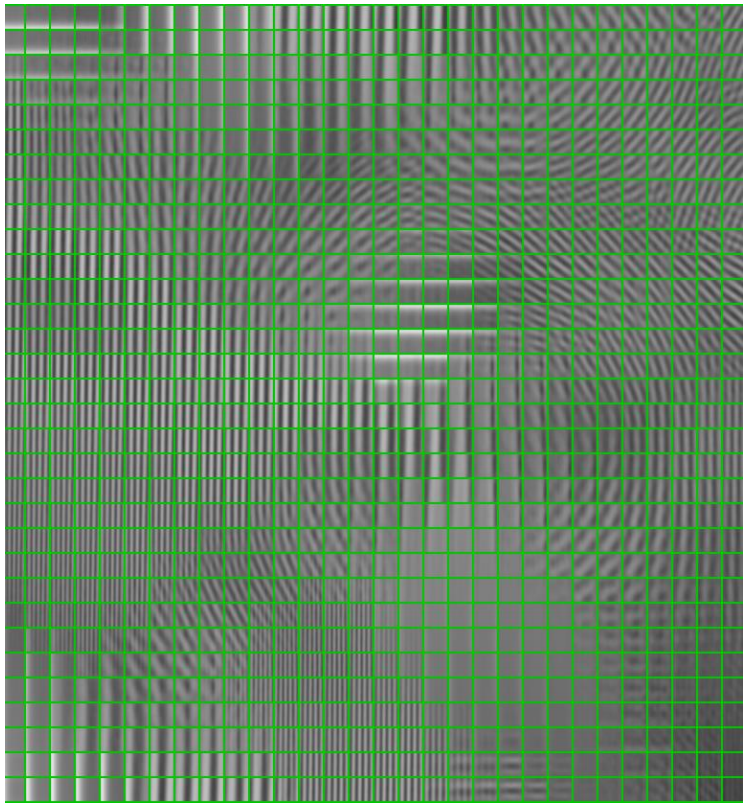
M. Olsen, E. Tabassi, A. Makarov, C. Busch: „Self-Organizing Maps for Fingerprint Image Quality Assessment“, in Proceedings of the 26th Conference on Computer Vision and Pattern Recognition (CVPR 2013), June 23-28, Portland, Oregon, (2013)



Images divided into blocks



SOM code book



NFIQ2.0 Light process flow

E. Tabassi: „Development of NFIQ 2.0 “,
Biometric Consortium Conference, (2013)

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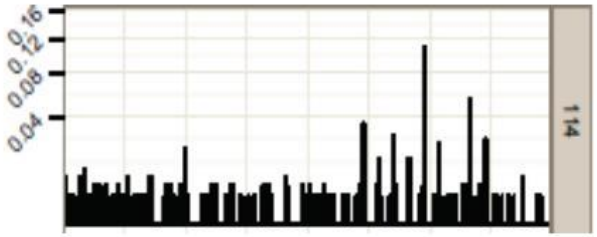
Divide fingerprint image into blocks and look up nearest cluster to get a label

A	A	A	A	A
A	B	C	D	A
A	E	C	D	A
A	E	C	C	A

Finger image is transformed into cluster histogram



Random Forest

Quality Score

NFIQ2.0 Light prototype performance

M. Olsen, E. Tabassi, A. Makarov, C. Busch: „Self-Organizing Maps for Fingerprint Image Quality Assessment“, in Proceedings of the 26th Conference on Computer Vision and Pattern Recognition (CVPR 2013), June 23-28, Portland, Oregon, (2013)

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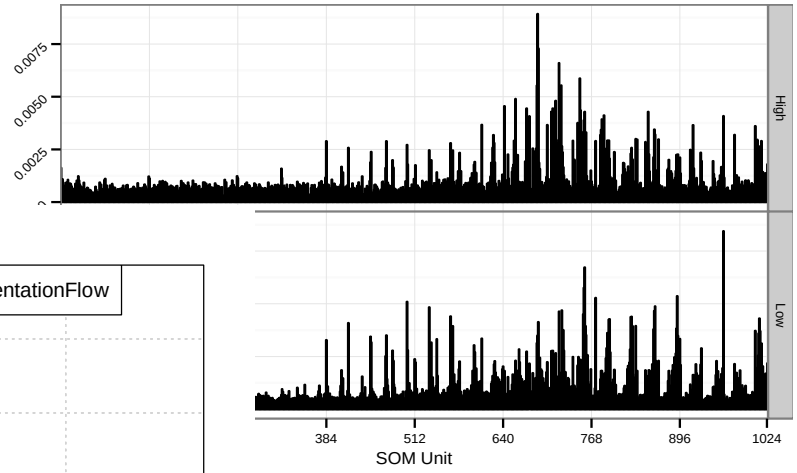
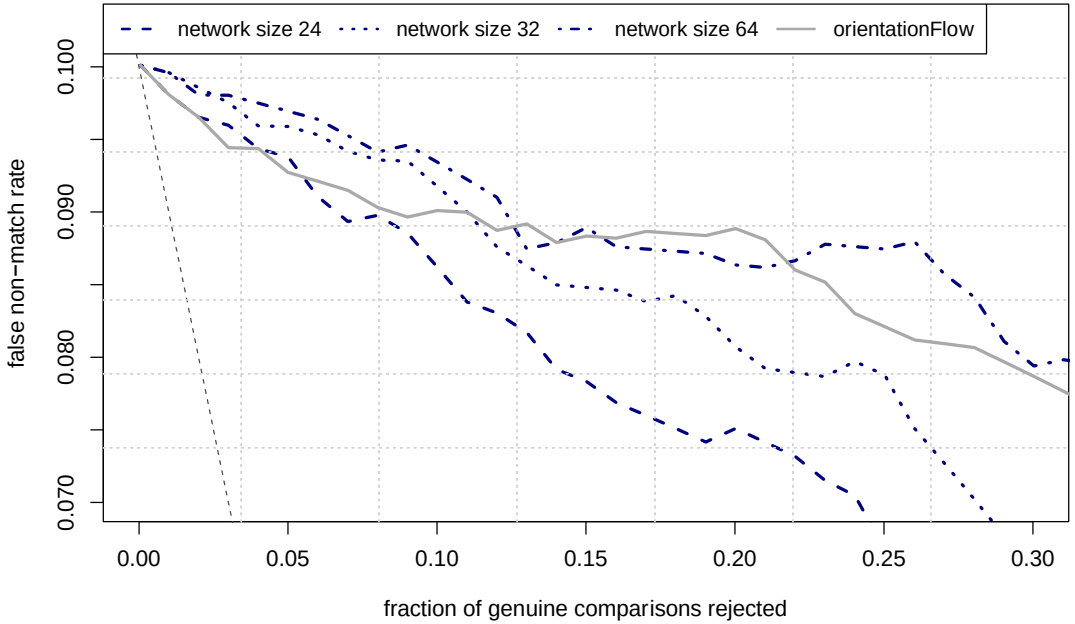
Features

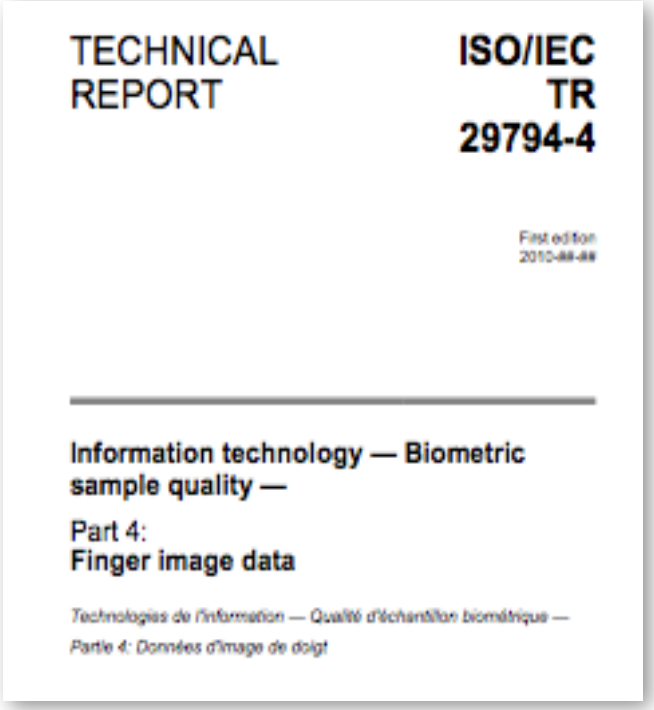


Performance



Dissemination as International Standard

- Results from development will be included in ISO/IEC 29794-4:201x "Information technology – Biometrics sample quality Part 4: Finger image data"
- Quality feature classes
  - Global features
  - Local features (blockwise)
- Expected return of research investment
  - Revision of ISO/IEC 29794-4:201x
    - Currently at 2nd working draft
  - Upgrade from Technical Report (TR) to an International Standard (IS)
- NFIQ2.0 complementing the standard as reference implementation


TECHNICAL REPORT

ISO/IEC TR 29794-4

First edition

Information technology — Biometric sample quality —

Part 4:
Finger image data

Technologies de l'information — Qualité d'échantillon biométrique —
Partie 4: Données d'image de doigt

State of play and expectations for the future

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- NFIQ2.0 prototype has been presented at the Biometric Consortium Conference (BCC) in September 2013
- Validation of the prototype is currently ongoing
  - Feature selection and validation on large databases
- NFIQ2.0 is expected to be used
  - as baseline tool for defining “fingerprint of sufficient quality”
  - by all major fingerprint-based biometrics systems
  - as calibration base for vendor QA tools
    - Vendor QA tools will not disappear, but – at least – for large scale applications must be comparable (statistically, not on a by-image-basis) to NFIQ2.0
- NFIQ2.0 Light is expected to be implemented in embedded systems and mobile devices (e.g. auto-capture loop of fingerprint sensors)

Thank you!

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  - http://www.bsi.bund.de
- NFIQ2.0: http://www.nist.gov/itl/iad/ig/development_nfiq_2.cfm