NFIQ 2.0 – Features for fingerprint quality determination

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Outline

Introduction

- Starting point for features
  - NFIQ 1.0
  - ISO/IEC TR 29794-4:2010
  - Literature

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- Workshops central to development of features

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$$\mathbf{Q}_{\text{NFIQ 2.0}} = \Big(Q^{\mu}_{\text{FDA}}, Q^{\mu}_{\text{LCS}}, Q^{\mu}_{\text{OCL}}, Q^{\mu}_{\text{OFL}}, Q^{\mu}_{\text{RVU}},$$
$$Q^{\sigma}_{\text{FDA}}, Q^{\sigma}_{\text{LCS}}, Q^{\sigma}_{\text{OCL}}, Q^{\sigma}_{\text{OFL}}, Q^{\sigma}_{\text{RVU}},$$
$$\mathbf{Q}_{\text{FDA}}, \mathbf{Q}_{\text{LCS}}, \mathbf{Q}_{\text{OCL}}, \mathbf{Q}_{\text{OFL}}, \mathbf{Q}_{\text{RVU}},$$
$$Q_{\text{MU}}, Q_{\text{MMB}}, Q^{rel}_{\text{COH}}, Q^{sum}_{\text{COH}}, Q^{\mu}_{\text{AREA}},$$
$$Q^{cnt}_{\text{MIN}}, Q^{com}_{\text{MIN}}, Q^{mu}_{\text{MIN}}, Q^{ocl}_{\text{MIN}} \Big) .$$

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- Mean and standard deviation of local features
- Histogram of local features (boundaries determined from CDF)

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- Local quality at minutiae locations
- Mean and standard deviation of local features
- Histogram of local features (boundaries determined from CDF)
- Classifier
  - Random Forest trained for binary classification
  - Input: 69 dimensional feature vector
  - Output: probability of input being Class 1 (high utility) quantized $[1, 100]$

NFIQ 2.0 Quality features

Name	Capture mode	Type	Number of subjects	Fingers	Number of comparisons per finger	Used for
AZLA	Scanned ink	Operational	240,000	Index and Thumb	120,000 mated. 120,000 non-mated	training + testing
POEBVA	Live scan	Operational	180,000	Index	120,000 mated. 120,000 non-mated	training + testing
VISITIDF	Live scan	Operational	220,000	Index and Thumb	95,000 mated. 120,000 non-mated	training + testing
DHS2	Live scan	Operational	180,000	Index	120,000 mated. 120,000 non-mated	training + testing
IQMI	Scanned ink	Operational	250,000	10 fingers	250,000 mated. 250,000 non-mated	testing
BKA BKA	Live scan + Scanned ink	Operational	342,000 images	10 fingers	—	testing
SD 29	Scanned ink	Public	209	10 fingers	1912 mated. 35,791 non-mated	testing
FVC 2000 DB1	Live scan	Public	110	8 fingers	—	compliance testing
FVC 2000 DB3	Live scan	Public	110	8 fingers	—	compliance testing
FVC 2002 DB1	Live scan	Public	110	8 fingers	—	compliance testing

- Data from operational sources (Optical sensors)

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- Data from operational sources (Optical sensors)
- Training set 6629 images (3295 in Class 0 and 3334 in Class 1)
- Validation set 99797 randomly selected images
- External validation on BKA data and FBI data

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  - 1 NFIQ=1 ($S_{act} > 0.7$) and S_{gen} in 90th percentile
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Feature importance ranking

	Name	MeanDreaseGini
Q^{σ}_{FDA}	Frequency Domain Analysis_Standard Deviation	140.760
Q^{com}_{MIN}	FingerJet FX OSE COM Minutiae Count	92.089
Q^{ocl}_{MIN}	FingerJet FX OSE OCL MinutiaeQuality	83.027
Q^{μ}_{RVU}	Ridge Valley Uniformity_Mean	69.517
Q^{μ}_{FDA}	Frequency Domain Analysis_Mean	62.229
Q^{cnt}_{MIN}	FingerJet FX OSE Total Minutiae Count	57.565
Q^{σ}_{RVU}	Ridge Valley Uniformity_Standard Deviation	50.946
Q^{7}_{LCS}	Local Clarity Score_Bin_7	50.688
Q^{8}_{LCS}	Local Clarity Score_Bin_8	50.100
Q^{9}_{FDA}	Frequency Domain Analysis_Bin_9	47.844
Q^{sum}_{COH}	ROI Orientation Map Coherence Sum	38.104
Q^{2}_{OFL}	Orientation Flow_Bin_2	37.172
Q^{μ}_{LCS}	Local Clarity Score_Mean	36.483
Q^{5}_{RVU}	Ridge Valley Uniformity_Bin_5	35.617
Q^{3}_{RVU}	Ridge Valley Uniformity_Bin_3	35.139
Q^{μ}_{AREA}	ROI Area Mean	34.932
Q^{1}_{OFL}	Orientation Flow_Bin_1	33.751
Q^{0}_{OFL}	Orientation Flow_Bin_0	33.513
Q_{MU}	MU	32.914

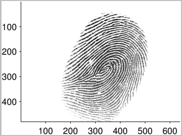
Quality feature example - frequency domain analysis

- Q_{FDA} local determination of ridge-valley signature

Algorithm 3: fda algorithm

Input: Fingerprint image **I**
Output: fda quality score Q_{FDA}
for *each block* **V** *in* **I** **do**
  pad **V** with 2 pixel around border
  rotate **V** with nearest neighbour interpolation such that dominant ridge flow is perpendicular to x-axis
  crop **V** such that no invalid regions are included
  with **V** obtain the ridge-valley signature **T** (eq. (11))
  compute the dft of **T** to obtain the magnitude representation **A**
  discard the first component of **A**
  determine F_{max} as the index of the largest magnitude in **A**
  compute Q_{FDA}^{local} of **V** using **A** and F_{max} (eq. (12))
end

Quality feature example - frequency domain analysis



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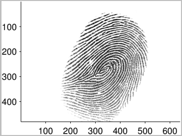

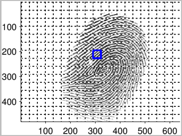

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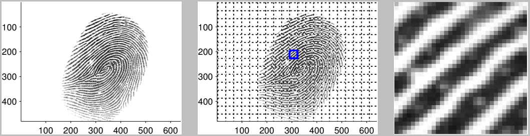

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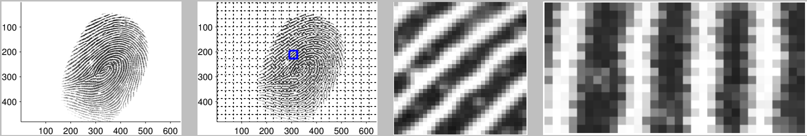

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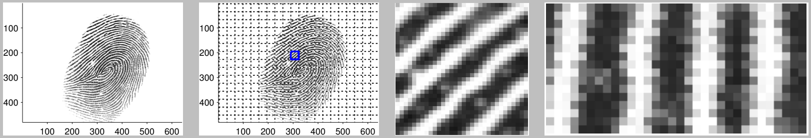

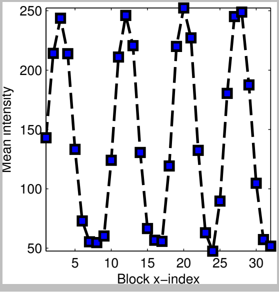

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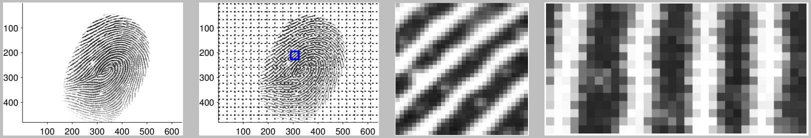

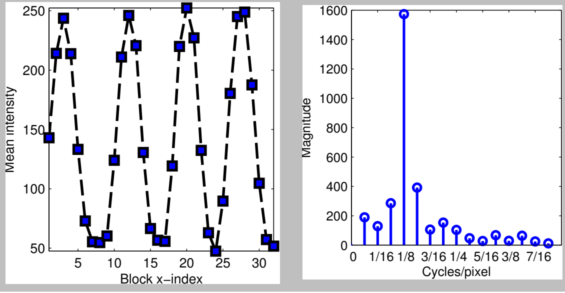

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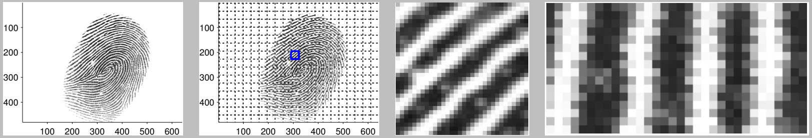

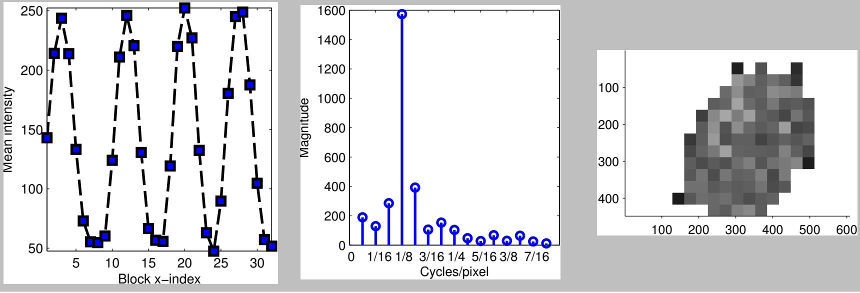

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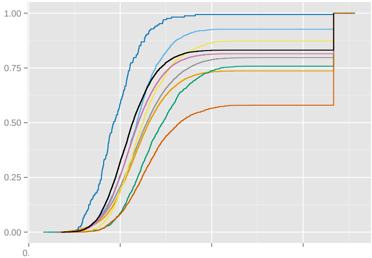

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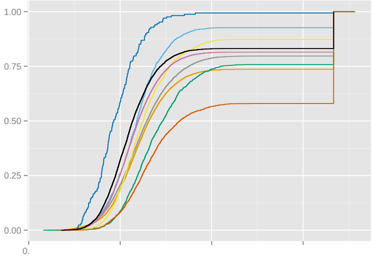

$$B_{\mathsf{FDA}} = \{-\infty, 0.26800, 0.30400, 0.33000, 0.35500, 0.38000, 0.40700, 0.44000, 0.50000, 1.00000, \infty\}.$$

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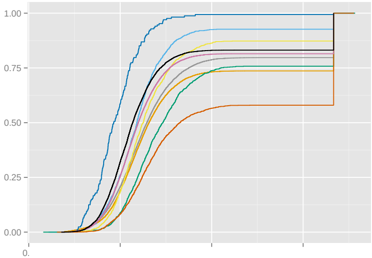

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- Mean, std.dev., 10 bin histogram ⇒12-dimension feature vector

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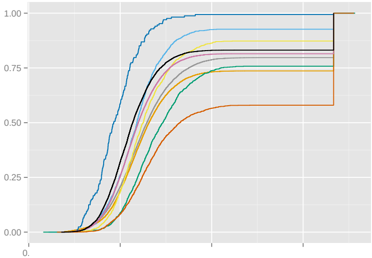

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$$Q_{\mathsf{FDA}}: \quad Q^{\mu}_{\mathsf{FDA}}, Q^{\sigma}_{\mathsf{FDA}}, Q^{1}_{\mathsf{FDA}}, \ldots, Q^{10}_{\mathsf{FDA}}$$

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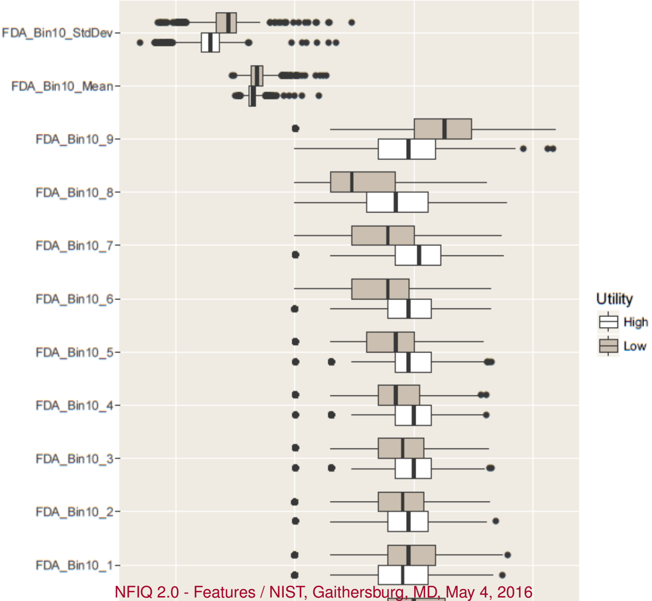

Speeding up NFIQ 2.0

- Request ⇒near frame rate quality assessment (10 Hz)

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800×750 pixel sensor output reproduced at 25% scale

Speeding up NFIQ 2.0

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- Removal of near constant area
- No processing of background area blocks

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Speeding up NFIQ 2.0

- Request $\Rightarrow$near frame rate quality assessment (10 Hz)
- Slap sensors provide large finger images
- Removal of near constant area
- No processing of background area blocks
- Avoid removing low quality fingerprint areas

800×750 pixel sensor output reproduced at 25% scale

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$330 \times 286 = 94380$
(15.7%)

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$330 \times 286 - (10 \times (32 \times 32)) = 84140$
(13.9%)

Actionable feedback

- Demand for actionable feedback from quality algorithm
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- Provide information $\Rightarrow$improve quality at recapture

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  - empty image ($\mu > 250$)
  - uniform image pixel intensity ($\sigma = 1.0$)
  - no or few minutiae detected ($N_{min} < 5$)
  - small foreground area ($N_{fgrnd} < 50000$)

Actionable feedback

empty image	$\mu > 250$	uniform image intensity	$\sigma = 1.0$
few minutiae	$N_{min} < 5$	small foreground	$N_{fgrnd} < 50000$

NFIQ 2.0 = 89

$\mu = 177$

$\sigma = 99$

$N_{min} = 60$

$N_{fgrnd} = 117337$

Actionable feedback

empty image	$\mu > 250$	uniform image intensity	$\sigma = 1.0$
few minutiae	$N_{min} < 5$	small foreground	$N_{fgrnd} < 50000$

NFIQ 2.0 = 21

$\mu = 220$

$\sigma = 64$

$N_{min} = 40$

$N_{fgrnd} = 36887$

Actionable feedback

empty image	$\mu > 250$	uniform image intensity	$\sigma = 1.0$
few minutiae	$N_{min} < 5$	small foreground	$N_{fgrnd} < 50000$

NFIQ 2.0 = 1

$\mu = 196$

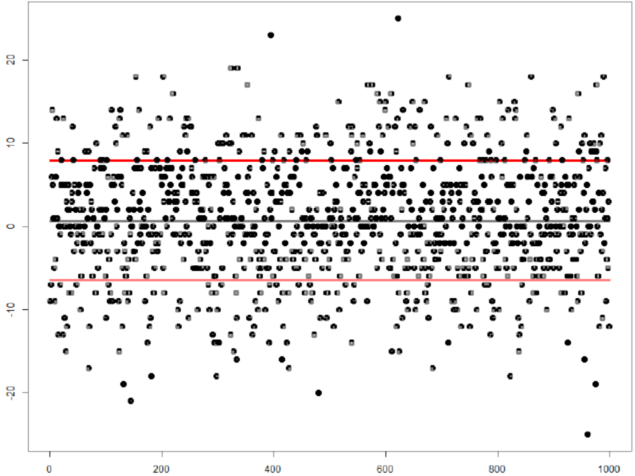
$\sigma = 79$

$N_{min} = 0$

$N_{fgrnd} = 16262$

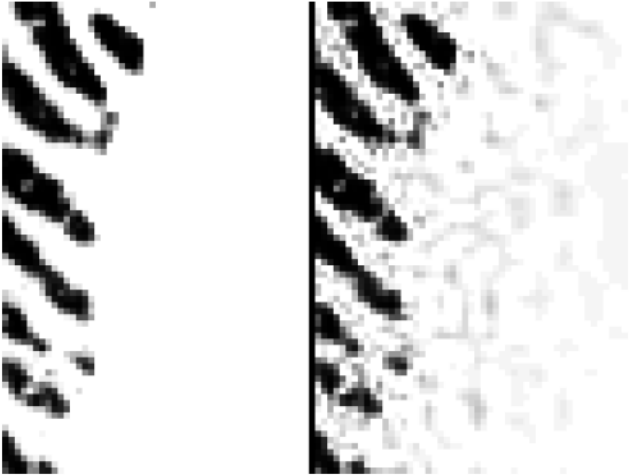
NFIQ 2.0 and WSQ compression

- Deviation between uncompressed and WSQ compressed (factor 8). 1000 images, MCYT 330 DP.



NFIQ 2.0 and WSQ compression

- Fingerprint boundary artifact at WSQ compression (factor 8). Gamma adjusted.



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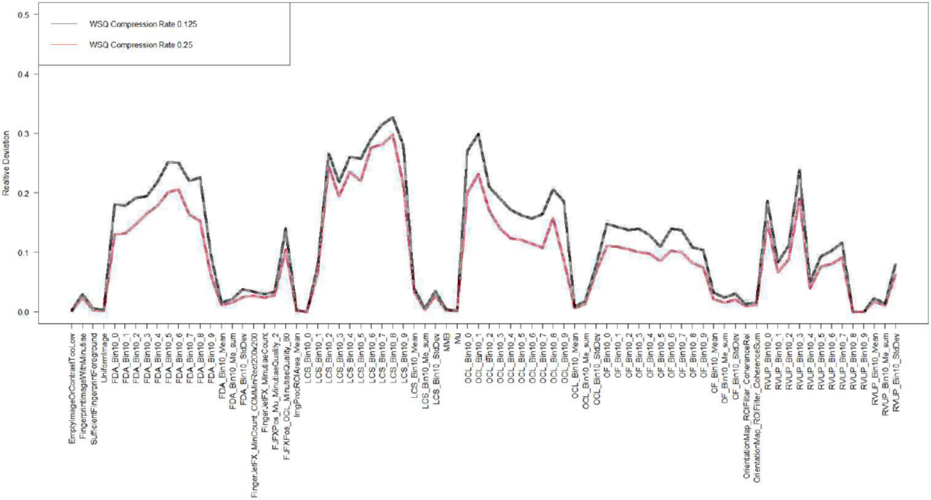

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  - progression to Draft International Standard in May 2016
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  - current status is 3rd Committee Draft
  - progression to Draft International Standard in May 2016
  - projected release as International Standard in 2017
- NFIQ 2.0 effectively a reference implementation of 29794-4 at this point
  - Open source, publicly available

Thanks for your attention

Martin A. Olsen
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NFIQ 2.0 `nist.gov/itl/iad/ig/development_nfiq_2.cfm`

Prototype quality features `share.nbl.nislab.no/public`