NFIQ 2.0
Open Source Distribution

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Agenda

- Development kit
- Operational software
Distribution packages

- **Development kit**
  - Aimed for developers and researchers
  - Includes NFIQ 2.0 Framework
  - Plug and play of different combinations of quality features and machine learning techniques

- **Operational software**
  - Aimed for operational use
  - Includes command line tool
Development kit
Motivation for NFIQ 2.0 Framework

- Lessons learned from NFIQ re-training in 2009/2010
  - NBIS source code changes necessary for adaptation of
    - machine learning algorithm
    - quality features
- Modular approach for NFIQ 2.0 development is desired
  - to be flexible regarding the implementation
  - to have a common basis of functionality needed for NFIQ 2.0 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
  - to allow sharing and re-using of results
  - to simplify the development process
Development kit
Architecture of NFIQ 2.0 Framework

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

NFIQ 2.0
- checkQuality()

NFIQ 2.0 light
...

Image Format Converter

Framework

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

Machine Learning Module

Input/Output Module

Quality Feature Extraction Module

Utility Estimation Module

Database

Filesystem

Quality feature x

Utility x

MLP
Development kit
NFIQ 2.0 development tools and interchange file format

- Implemented on top of the NFIQ 2.0 Framework
  - ComputeQualityFeatureData, ComputeQualityVector
  - ComputeUtilityValues
  - StartTraining
  - ComputeQuality (final or intermediate NFIQ 2.0 algorithm)
  - XMLExportImport

- XML interchange file format defined
  - exchange of training and evaluation data among project partners
    - fingerprint comparison scores of several databases
    - utility values and quality scores
    - quality features
  - referenced by unique IDs
Development kit
Example: How to perform training with the NFIQ 2.0 Framework I

- Assume that necessary data for training is stored in database X
- Compute quality features
  \[\text{computeQualityFeatureData}(X, <\text{featureID}_1>, \ldots, <\text{featureID}_M>)\]
- Compute and fuse utility values
  \[\text{computeUtilityValues}(X, <\text{providerID}_1>, <\text{utility}_{ID}>)\]
  \[\ldots\]
  \[\text{computeUtilityValues}(X, <\text{providerID}_N>, <\text{utility}_{ID}>)\]
  \[\text{fuseUtilityValues}(X, <\text{providerID}_1>, \ldots, <\text{providerID}_N>, <\text{utility}_{ID}>)\]
- Select images for training
  \[\text{defineImagesForTraining}(X, <\text{trainingSet}_X>, <\text{testSet}_X>)\]
  \[\text{and/or}\]
  \[\text{partitionDataForTraining}(X, <\text{seed}>, <N_{\text{train}}_X>, <N_{\text{test}}_X>)\]
- Start training
  \[\text{train}(<\text{providerID}_1>, \ldots, <\text{providerID}_N>, <\text{utility}_{ID}>, <\text{featureID}_1>, \ldots, <\text{featureID}_M>, \text{useWeights})\]
Development kit
Example: How to perform training with the NFIQ 2.0 Framework II

- Select images for evaluation
  
  ```
  defineImagesForEvaluation(X, <evaluationSet_X>)
  and/or
  partitionDataForEvaluation(X, <seed>, <N_eval_X>)
  ```

- Start evaluation
  
  ```
  evaluate(<providerID_1>, ..., <providerID_N>, <utility_ID>,
  <featureID_1>, ..., <featureID_M>)
  ```
Development kit
Open source libraries

- NFIQ 2.0 Framework will be open source

- External library dependencies
  - OpenCV for image processing
  - FingerJetFX minutiae extraction
  - RapidXML for XML parsing
  - NIST Biometric Data Interchange (BIOMDI)
Development kit
Input / output modules

- Modules for
  - PostgreSQL DB
  - NIST Record-Store format
  - File system

- Everyone can add new modules to adapt the NFIQ 2.0 Framework to their existing infrastructure!
Development kit
Quality feature modules

- More than 100 features integrated
  - NFIQ 1 features
  - FJFX minutiae count and minutiae quality features
  - Orientation Certainty Level, Ridge Valley Uniformity, Radial Power Spectrum, Local Clarity Score, …
  - ROI area features
  - Contrast features (Mu, Mu Mu Block, Sigma, …)
  - Quality map features
  - Gabor features

- Adding new features is easy!
Development kit
Machine learning modules

- Random Forest implemented
- Self Organizing Maps to be added for NFIQ 2.0 lite
Operational software
Why two different software distributions?

- Operational software package is what will be used in applications
- NFIQ 2.0 has overhead that is not needed in applications
  - Input/output modules
  - Utility modules
  - Features that were not selected for the NFIQ 2.0
- Operational software provides optimized code (not features itself but the usage of them)
- Command line tool will be provided
  - Input: Fingerprint image
  - Output:
    - Quality score
    - Actionable quality feedback
    - Quality feature values (optional)
    - Performance numbers (optional)
Operational software
NFIQ 2.0 command line tool

NFIQ2 <fingerprintImage> <imageFormat> <outputFeatureData> <outputSpeed>

- <fingerprintImage>: path and filename to a fingerprint image
- <imageFormat>: one of following values describing the fingerprint image format: BMP, WSQ
- <outputFeatureData>: if to print computed quality feature values (true|false)
- <outputSpeed>: if to print speed of quality feature computation (true|false)

- Command line tool calls internal library that can be used to easily integrate NFIQ2 algorithm into applications
Operational software
NFIQ 2.0 examples

- Development version with 29 quality features

NFIQ2: Achieved quality score: 97
Time needed for quality score computation: 213.000 ms
Actionable quality (EmptyImageOrContrastTooLow):
165.580 -> HIGH actionable quality
Operational software
NFIQ 2.0 examples

- Development version with 29 quality features

NFIQ2: Achieved quality score: 7
Time needed for quality score computation: 128.364 ms
Actionable quality (EmptyImageOrContrastTooLow):
199.397 -> HIGH actionable quality
Operational software
NFIQ 2.0 examples

- Development version with 29 quality features

NFIQ2: Achieved quality score: 0
Time needed for quality score computation: 0.515 ms
Actionable quality (EmptyImageOrContrastTooLow):
  253.108 -> LOW actionable quality
Operational software
NFIQ 2.0 examples

- Output with feature values

  - FingerJetFX_MinutiaeCount: 57.000
  - FingerJetFX_MinCount.COM.MinRect300x200: 39.000
  - FingerJetFX_MinCount.COM.MinCircle200: 24.000
  - FingerJetFX_ROI.Block.Area: 0.280
  - FFX.Min.Fields.MinutiaeQuality_0: 0.000
  - FFX.Min.Fields.MinutiaeQuality_1: 0.088
  - FFX.Min.Fields.MinutiaeQuality_2: 0.421
  - FFX.Min.Fields.MinutiaeQuality_3: 0.491
  - FFX.Min.Fields.COM.Min.MMB_224: 127.428
  - FFX.Min.Fields.OCL.MinutiaeQuality_0: 0.000
  - FFX.Min.Fields.OCL.MinutiaeQuality_20: 0.018
  - FFX.Min.Fields.OCL.MinutiaeQuality_40: 0.053
  - FFX.Min.Fields.OCL.MinutiaeQuality_60: 0.421
  - FFX.Min.Fields.OCL.MinutiaeQuality_80: 0.509
  - Mu: 165.580
  - MMB: 165.580
  - OCL: 0.803
  - OCL_CD: 0.821
  - ImgProcROI.PIXEL.Abs: 105166.000
  - ImgProcROI.Pixel.Area: 0.685
  - ImgProcROI.Area.Mean: 127.076
  - OrientationMap_ROIFilter_CoherenceSum: 308.950
  - OrientationMap_ROIFilter_CoherenceRel: 0.687
  - LowFlowMap16_ROIArea.HighFlowBlocks: 443.000
  - RVU_P: 0.485
  - RVU_NP: 0.494
  - RPS_ROIArea: 5189.663
  - LCS: 0.825
  - OF: 0.864
Operational software
NFIQ 2.0 examples

- Output with feature speed
  - Contrast features (Mu, MMB): 0.454 ms
  - FJFX features (FingerJetFX_MinutiaeCount, FingerJetFX_MinCount_COMMInRect300x200, FingerJetFX_MinCount_COMMInCircle200, FingerJetFX_ROIBlockArea): 25.113 ms
  - FJFX minutiae quality features (FJFXPos_Mu_MinutiaeQuality_*): 0.381 ms
  - FJFX minutiae quality features (FJFXPos_COMMIn_MMB_224): 0.090 ms
  - FJFX minutiae quality features (FJFXPos_OCL_MinutiaeQuality_*): 0.597 ms
  - OCL features (OCL): 1.568 ms
  - OCL features (OCL_CD): 10.233 ms
  - ROI features (ImgProcROIPixelAbs, ImgProcROIPixelArea, ImgProcROIArea_Mean): 12.259 ms
  - Quality map features (OrientationMap_ROIFilter_CoherenceSum, OrientationMap_ROIFilter_CoherenceRel): 2.737 ms
  - Quality map features (LowFlowMap16_ROIArea_HighFlowBlocks): 26.711 ms
  - RVU features (RVU_P): 12.518 ms
  - RVU features (RVU_NP): 12.247 ms
  - RPS features (RPS_ROIArea): 86.592 ms
  - LCS features (LCS): 16.166 ms
  - OF features (OF): 13.611 ms
Summary

- Development kit
  - Provides flexible integration and development for future versions and improvements
  - Design of dedicated versions possible (e.g. NFIQ 2.0 lite)
  - Large collection of quality features

- Operational software
  - Optimization done for use in applications
  - Unnecessary data and code removed

- Both will be distributed as open source!
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