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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 learining techniques

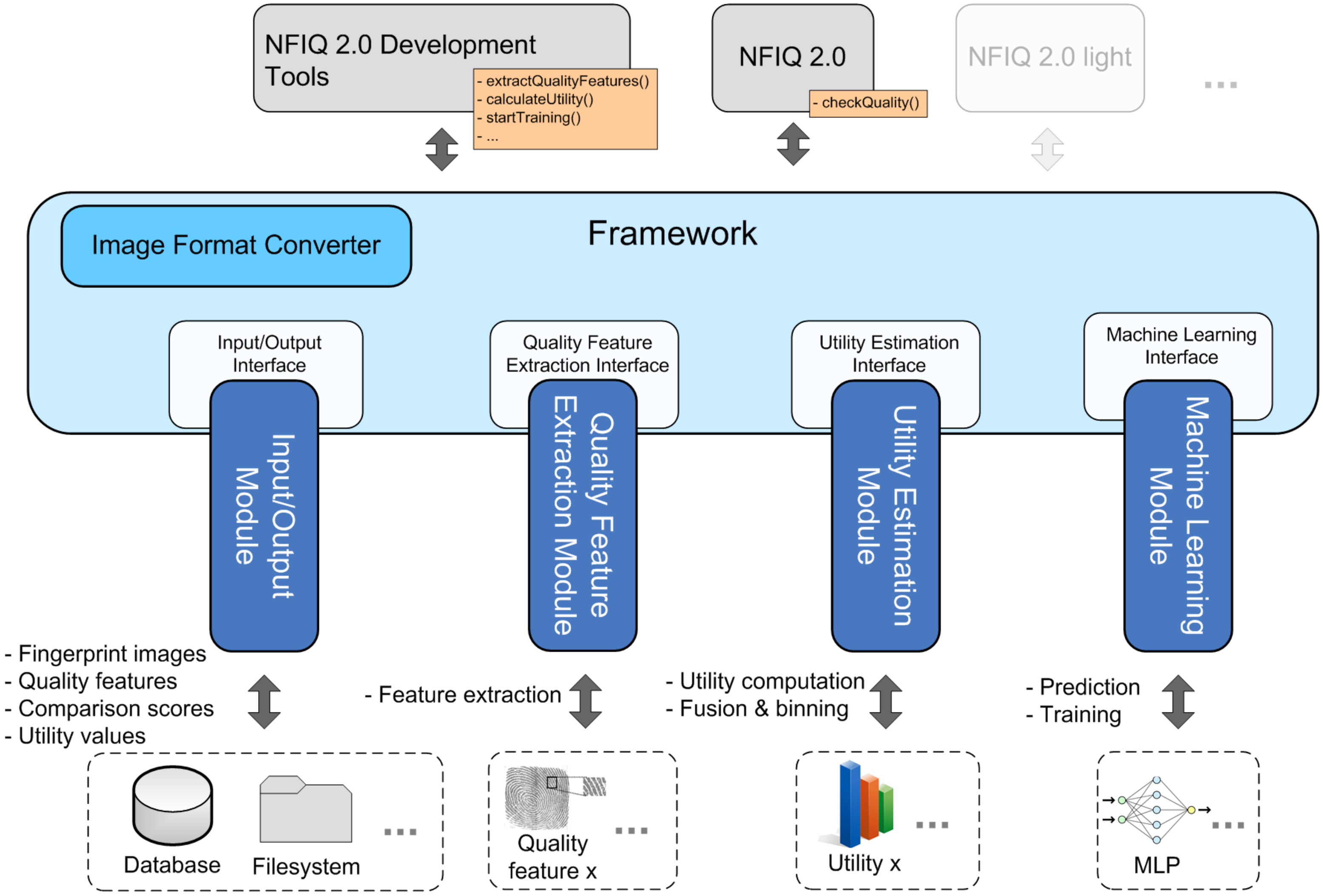
- Operational software
  - Aimed for operational use
  - Includes command line tool

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

...

Framework

Image Format Converter

Input/Output Interface

Input/Output Module

Quality Feature Extraction Interface

Quality Feature Extraction Module

Utility Estimation Interface

Utility Estimation Module

Machine Learning Interface

Machine Learning Module

- Fingerprint images
- Quality features
- Comparison scores
- Utility values

- Feature extraction

- Utility computation
- Fusion & binning

- Prediction
- Training

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
  ```
  computeQualityFeatureData(X, <featureID_1>, …, <featureID_M>)
  ```
- Compute and fuse utility values
  ```
  computeUtilityValues(X, <providerID_1>, <utility_ID>)
  …
  computeUtilityValues(X, <providerID_N>, <utility_ID>)

  fuseUtilityValues(X, <providerID_1>, …, <providerID_N>, <utility_ID>)
  ```
- Select images for training
  ```
  defineImagesForTraining(X, <trainingSet_X>, <testSet_X>)
  ```
  and/or
  ```
  partitionDataForTraining(X, <seed>, <N_train_X>, <N_test_X>)
  ```
- Start training
  ```
  train(<providerID_1>, …, <providerID_N>, <utility_ID>, <featureID_1>, …,
   <featureID_M>, 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

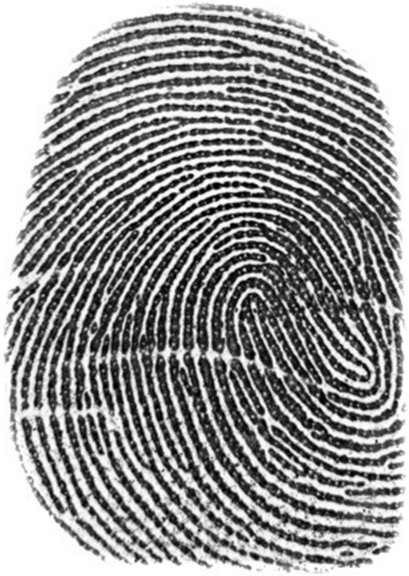
NFIQ 2.0 command line tool

```
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

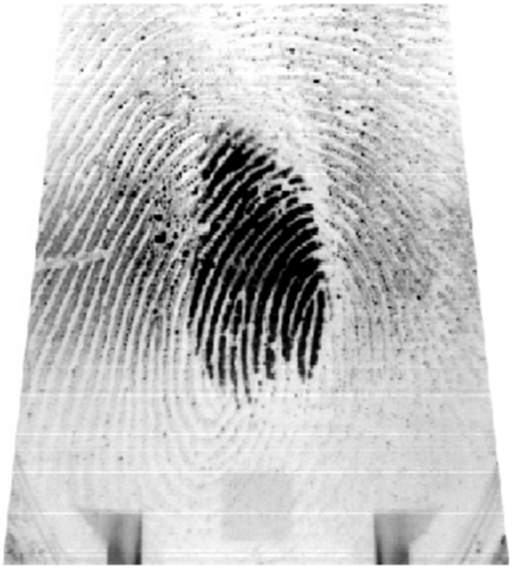
- Development version with 29 quality features



```
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_COMMinRect300x200: 39.000
FingerJetFX_MinCount_COMMinCircle200: 24.000
FingerJetFX_ROIBlockArea: 0.280
FJFXPos_Mu_MinutiaeQuality_0: 0.000
FJFXPos_Mu_MinutiaeQuality_1: 0.088
FJFXPos_Mu_MinutiaeQuality_2: 0.421
FJFXPos_Mu_MinutiaeQuality_3: 0.491
FJFXPos_COMMin_MMB_224: 127.428
FJFXPos_OCL_MinutiaeQuality_0: 0.000
FJFXPos_OCL_MinutiaeQuality_20: 0.018
FJFXPos_OCL_MinutiaeQuality_40: 0.053
FJFXPos_OCL_MinutiaeQuality_60: 0.421
FJFXPos_OCL_MinutiaeQuality_80: 0.509
Mu: 165.580
MMB: 165.580
OCL: 0.803
OCL_CD: 0.821
ImgProcROIPixelAbs: 105166.000
ImgProcROIPixelArea: 0.685
ImgProcROIArea_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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