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Conformance to Standardized Minutia Detection Requirements

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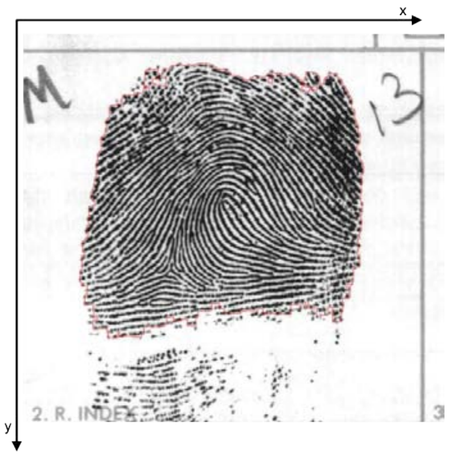
Conformance to Standardized Minutia Detection Requirements

MOTIVATION

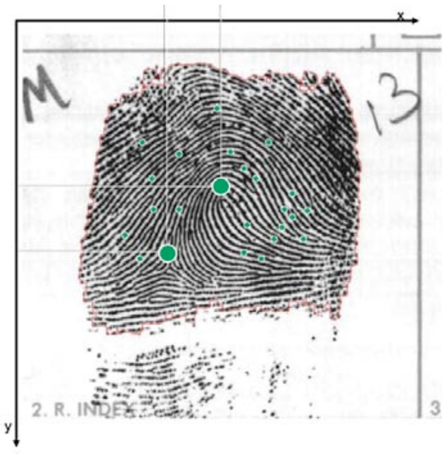
Motivation

Minutiae Templates

1. Fingerprint image (biometric sample) after acquisition as generated by capture device.

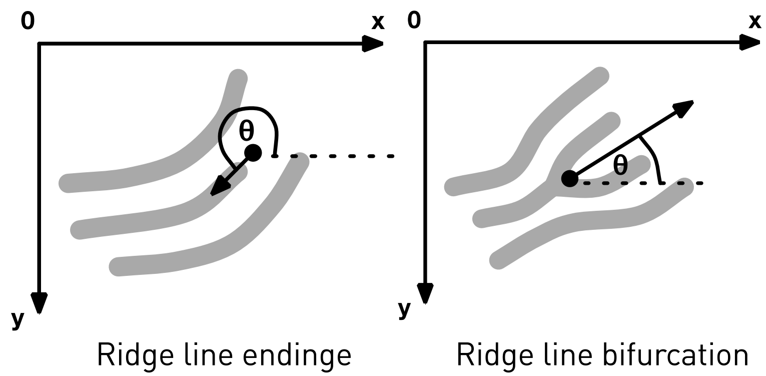


2. Features (minutiae) as identified during feature extraction process.



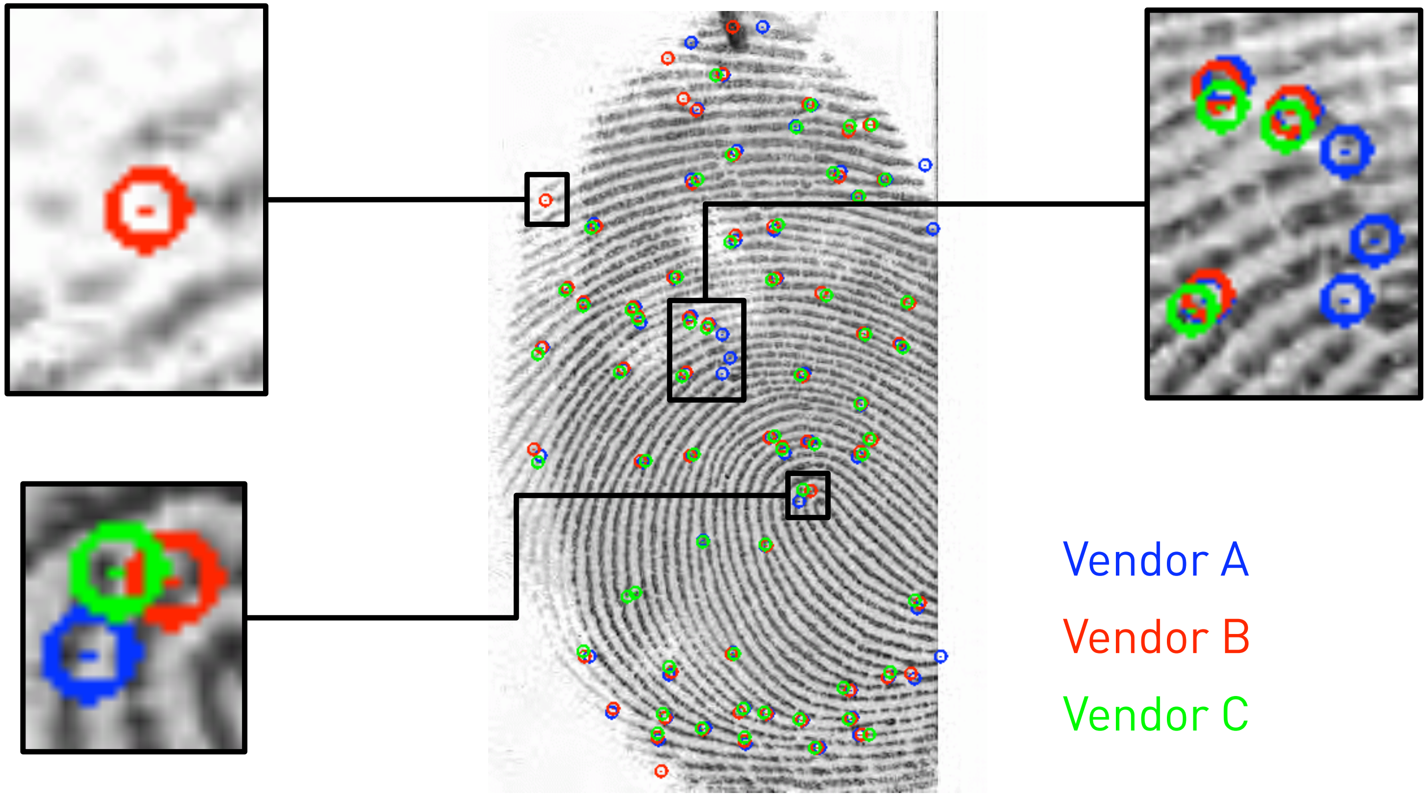
3. Biometric template encoding. According to ISO/IEC 19794-2:
   1. Minutia x-coordinate
   2. Minutia y-coordinate
   3. Minutia angle θ
   4. Minutia type t
   5. Minutia quality q

$$m = \langle x, y, \theta, t, q \rangle \in \mathcal{M}$$



Motivation

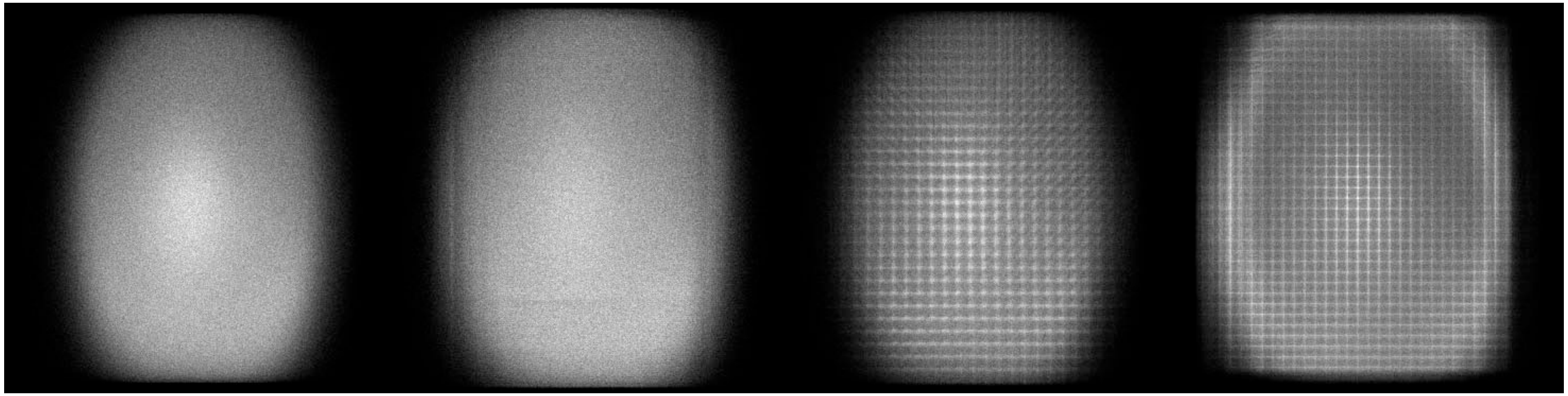
Minutiae Detection Deficiency



Motivation

Minutiae Misplacement

- MINEX results presented at BIOSIG 2009
  - 2D histogram of minutiae locations
  - Angle and type information ignored



(Source: Tabassi et al., BIOSIG2009)

Motivation

- ISO/IEC 29109-x: Conformance testing methodology for biometric data interchange formats defined in ISO/IEC 19794-x:
  - Level 1: Data format conformance
  - Level 2: Internal consistency checking
  - Level 3: Content checking

Motivation

Conformance Testing

- ISO/IEC 29109 - Part2: Finger minutiae data
- ISO/IEC 29109-2 AMD1: Semantic conformance testing - Part2: Finger minutiae data
  - Scope: tests of semantic assertions

    Type A Level 3 as defined in ISO/IEC 29109-1:2009

ISO IEC

ISO/IEC JTC 1/SC 37 **N 4834**

ISO/IEC JTC 1/SC 37
Biometrics
Secretariat: ANSI (USA)

Document type: Other document (Defined)

Title: Text for 29109 2 minutia level three amendment WD4

Motivation

- ISO/IEC 29109-2 AMD1:
- „The reason these tests are necessary is because in practice minutia detectors sometimes
  - fail to properly place a minutia
  - detect a false minutia within the ridge structure of a parent fingerprint;
  - detect a false minutia outside or at the periphery of an image of the parent fingerprint
  - fail to detect a minutia within the fingerprint data
  - fail to determine type correctly
  - fail to measure angle correctly „

Motivation

- ISO/IEC 29109-2 AMD1 (SC37N4834):
  - Clause 7.4 Minutiae conformance measure

$$\text{MINUTIA\_CONFORMITY}(r,t) = (1-p)H(W/4-d)$$

  - Clause 7.5 Out-of-area test

$$\text{OUTSIDE}(T) = \frac{1}{N}\sum_{i=1}^{N} \text{MPS}(t_i)$$

  - Clause 7.6 False minutia test

$$\text{TRUE\_MINUTIA\_FRACTION}(R,T) = 1 - \frac{\text{NI}_T}{\text{N}_T}$$

Conformance to Standardized Minutia Detection Requirements

REVISED PERSECTIVE ON SEMANTIC CONFORMANCE TESTING

Semantic Conformance Testing

- Level 3: Content checking
  - „to test that the BDIRs produced by an IUT are faithful representations of the original biometric data and that they satisfy those requirements of the base standard that are not simply a matter of syntax and format [...]“ (ISO/IEC 29109-1)

- Strict (loose) definition of ‚faithfulness‘
  - „A biometric template resulting from a noise-free and linear transformation applied to the input biometric characteristic‘s (sample‘s) traits.“
  - Faithfulness in strict sense desired
  - Faithfulness in loose sense measured, due to non-linear physical effects during data acquisition

Semantic Conformance Testing

Formalisation

- Faithfulness
  - Modeled as continuous function $\mathcal{F} : \mathcal{M} \times \mathcal{M} \rightarrow \mathbb{R}, \mathcal{F}(R_i, T_{k,i})$
  - With reference set R_i and test set
  - Measured at minutiae-level $m \in R_i, m' \in T_{k,i}$
    - Per attribute equality $\forall \psi \in \{x, y, \theta, t\} : \psi =_{\mathcal{R}} \psi'$
    - No addition of spurious minutiae $|R_i| = |T_{k,i}|$

- Computation Model $\mathcal{SCM} = (\mathcal{A}, GTM, \mathcal{F}, CR_{max})$
  - For a set of feature extractors $\forall A_k \in \mathcal{A}$:
  - compute conformance rates $CR(A_k) =$
  - based on a reference data set $\frac{1}{N_{GTM}} \sum_{i=1}^{N_{GTM}} (\omega_i \cdot$
  - and on definition of faithfulness $\mathcal{F}(R_i, T_{k,i}))$

Semantic Conformance Testing

Reference Data Set

- Ground-Truth Minutiae $GTM, N_{GTM} = |GTM|$
- Consists of triplets (P_i, R_i, ω_i)
  - Biometric sample P_i
  - Reference template R_i
  - Weight ω_i
- Based on biometric samples of NIST special databases SD14 and SD29
- Samples manually analyzed by dactyloscopic experts of BKA

➥ Results in a scattered set of ground truth minutiae per biometric sample

➥ Sample fusion?

Semantic Conformance Testing

Testing Methodologies

- Explicit Fusion Methodology
  - Requires explicit data fusion process
  - Computes harmonized samples from scattered expert data - see
    a) presentation at IBPC 2010:
    http://biometrics.nist.gov/cs_links/ibpc2010/pdfs/Busch_Christoph_IBPC2010-gtm-100224.pdf
    b) presentation by Sebastian Abt at BIOSIG 2010:
    http://www.christoph-busch.de/files/Abt-FingerMinutiaeClustering-BIOSIG-2010.pdf
- Implicit Fusion Methodology
  - Implicit fusion during conformance rate computation

    where references R_{kd} are generated by d=1,...,D dactyloscopic experts
  - Requires adjusted weights
  - Uses scattered samples as-is
- Known-Truth Methodology
  - Utilizes synthetically generated data

Semantic Conformance Testing

A Quality-score Honoring Approach

- Minutiae quality scores
  - Valued 0 ≤ q ≤ 100 according to ISO/IEC 19794-2
  - Can be interpreted as confidence value
  - Usage of minutiae quality is controversially discussed in SC37 as no standardized method for determination exists
  - However, standardization of minutiae quality not required

- Quality-score honoring instance
- Function to measure faithfulness
  - Addresses minutiae misplacement and
  - spurious minutiae placement problems
  - Honores minutiae quality values

$$\mathcal{SCM}_{QBL} = (\mathcal{A}, GTM, \mathcal{F}_{QBL}, 1)$$

$$\mathcal{F}_{QBL}(R_i, T_{k,i}) = \lambda_1\gamma_1(R_i, T_{k,i}) + \lambda_2\gamma_2(R_i, T_{k,i})$$

Semantic Conformance Testing

Minutiae Misplacement Problem

- Quantifies degree to which automatically generated minutiae deviate from ground-truth minutiae
- Equally penalizes location, angle and type differences
- Penalty weighted according to minutiae reliability

$$\gamma_1(R_i, T_{k,i}) = \frac{1}{|R_i|}\sum_{j=1}^{|R_i|}(1-(1-faith(m_j, m'_j))e^{-(1-\frac{q'_j}{100})})^2$$

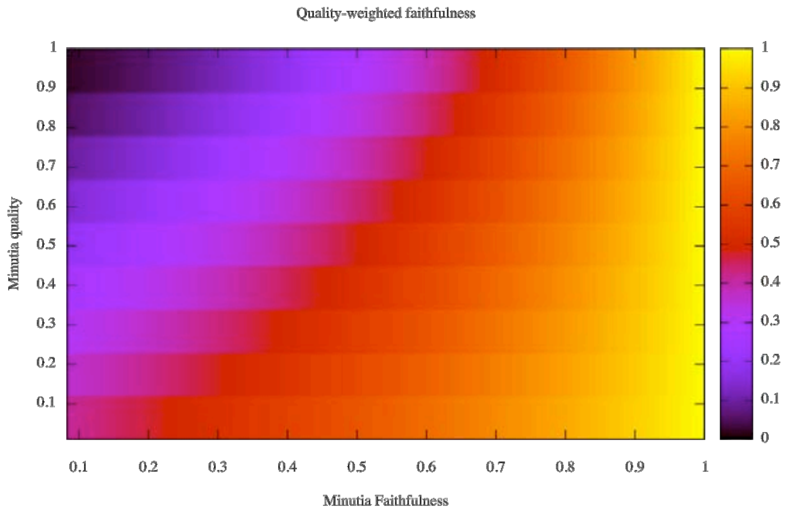
$$faith(m_j, m'_j) = \begin{cases} 0, & \text{if } d_2(m_j, m'_j) > tol_d \\ f_j, & \text{otherwise} \end{cases}$$

$$f_j = \frac{s_j^{\Delta d} + s_j^{\Delta \theta} + s_j^{\Delta t}}{3}$$

$$s_j^{\Delta d} = \frac{tol_d - d_2(m_j, m'_j)}{tol_d}$$

$$s_j^{\Delta \theta} = \frac{\pi - min\{2\pi - |\theta_j - \theta'_j|, |\theta_j - \theta'_j|\}}{\pi}$$

$$s_j^{\Delta t} = \begin{cases} 1, & \text{if } t_j = t'_j \\ 0,25, & \text{if } t_j \neq t'_j \text{ and } t_j \text{ is unknown} \\ 0, & \text{otherwise} \end{cases}$$



Semantic Conformance Testing

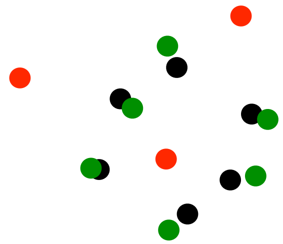
Spurious Minutiae Problem

- Compute ratio of spurious minutiae
  - no distinction between „out of fingerprint area“ and „inside“
- Weighted according to minutiae reliabilities

$$\gamma_2(R_i, T_{k,i}) = 1 - \frac{1}{|T_{k,i}|} \sum_{j=1}^{|S_{k,i}|} \frac{q'_j}{100}$$

$$S_{k,i} = \{m' \in T_{k,i} | \nexists m \in R_i : d_2(m, m') \leq tol_d\}$$

reference minutiae
spurious minutiae
mated minutiae



Assessing Semantic Conformance of Minutiae-based Feature Extractors

EVALUATION AND RESULTS

Evaluation and Results

Environment

- Development of feature extractors and comparators using 3 SDKs

- Computation of 162 DET curves
- Analysis of 3294 biometric samples
- Creation of 12661 biometric templates
- Computation of 34,6M comparison scores

Evaluation and Results

Real World Correlation

- Comparison of CRs and avg. non-native equal error rates (nnEER)
- nnEER estimate of real-world inter-vendor performance:
  - Average of equal error rates in non-native case,
  - i.e. using probe templates from V_x and reference templates from V_y

$$nnEER_\phi = \frac{1}{2(|\mathcal{V}|-1)} \sum_{\psi \in \mathcal{V} \setminus \{\phi\}} (EER_{\phi,\psi} + EER_{\psi,\phi})$$

$$\mathcal{V} = \{A_{V_A}, A_{V_B}, A_{V_C}\}$$

avg. EER	A_{V_A}	A_{V_B}	A_{V_C}
A_{V_A}	0.0415	0.0459	0.0493
A_{V_B}	0.0455	0.0428	0.0519
A_{V_C}	0.0495	0.0516	0.0376

(a)

IUT	nnEER	$CR_{QBL}(\cdot)$
A_{V_A}	0.0476	0.6214
A_{V_B}	0.0488	0.5133
A_{V_C}	0.0506	0.4039

(b)

Evaluation and Results

Real World Correlation

- Comparison of CRs and avg. non-native equal error rates (nnEER)
- nnEER estimate of real-world inter-vendor performance:
  - Average of equal error rates in non-native case,
  - i.e. using probe templates from V_x and reference templates from V_y

$$nnEER_\phi = \frac{1}{2(|\mathcal{V}|-1)} \sum_{\psi \in \mathcal{V} \setminus \{\phi\}} (EER_{\phi,\psi} + EER_{\psi,\phi})$$

$$\mathcal{V} = \{A_{V_A}, A_{V_B}, A_{V_C}\}$$

- Benchmarked using non quality honoring approach (SCM_{BL}) described in
  - Lodrova, Busch, Tabassi, Krodel, Drahansky. „Semantic Conformance Testing Methodology for Finger Minutiae Data“. In Proceedings of BIOSIG, 2009.

avg. EER	A_{V_A}	A_{V_B}	A_{V_C}
A_{V_A}	0.0415	0.0459	0.0493
A_{V_B}	0.0455	0.0428	0.0519
A_{V_C}	0.0495	0.0516	0.0376

(a)

IUT	nnEER	$CR_{QBL}(\cdot)$	$CR_{BL}(\cdot)$
A_{V_A}	0.0476	0.6214	0.6285
A_{V_B}	0.0488	0.5133	0.6295
A_{V_C}	0.0506	0.4039	0.6192

(b)

Evaluation and Results

Testing Methodologies

- Evaluation of implicit vs. explicit fusion methodologies
- Evaluation shows that both methodologies lead to comparable results

➥ Explicit clustering not necessary!

	Implicit fusion			Explicit fusion		
	$\gamma_1(R_i, T_{k,i})$	$\gamma_2(R_i, T_{k,i})$	$CR(\cdot)$	$\gamma_1(R_i, T_{k,i})$	$\gamma_2(R_i, T_{k,i})$	$CR(\cdot)$
A_{V_A}	0.483	0.795	0.639	0.409	0.834	0.621
A_{V_B}	0.414	0.614	0.514	0.352	0.674	0.513
A_{V_C}	0.345	0.444	0.394	0.289	0.518	0.403

Assessing Semantic Conformance of Minutiae-based Feature Extractors

CONCLUSION AND FUTURE WORK

Conclusion and Future Work

Conclusion and Contribution

- Semantic conformance computation based on formal definition of faithfulness
- Plausibility testing yields reasonable results
- Conformance rates of quality honoring approach correlate with real-world inter-vendor performance estimates
- Explicit clustering not necessary

- Contribution
  - Integration of ideas into ISO/IEC 29109-2 AMD1
  - Abt, Busch, Baier. „A quality-score honoring approach to semantic conformance assessment of minutiae-based feature extractors“. In Proceedings of BIOSIG 2011, pp. 21-32, 2011.
    A copy is available at:
    http://www.christoph-busch.de/standards-gtd.html

Conclusion and Future Work

- ISO/IEC 29109-2 AMD1 requires further contributions
- What is a common definition of a markup?

  a) an automated SDK generated minutia?

  b) a minutia generated by an individual
  (i.e. a dactyloscopic expert)

  c) any minutiae either a) or b)
- Need for Semantic Conformance Computation Challenge (SC3)

  - Stronger evaluation (more templates and algorithms)
  - in cooperation with NIST

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Thank you!

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