JRC Workshop on Fingerprint Q in the context of SIS-II

On Multiple Q-metrics for SIS-II

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Agenda

- **Preliminaries:**
  Definitions, Types of Q-metrics, Factors affecting Q
  → Vector of Q-metrics
- **Combination of Q-metrics**
- **Interoperability and Calibration of Q-metrics**
- **Q-metrics in SIS-II**
- **Final Discussion**

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Preliminaries

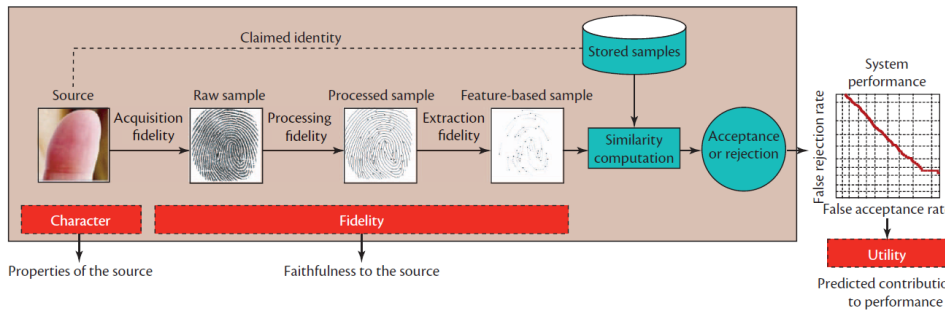
FORMAL DEFINITIONS (From ISO/IEC 29794-1)

Quality: *"The degree to which a biometric sample fulfils specified requirements for a targeted application"*

Quality Score: *"A quantitative expression of quality"*

TYPES OF BIOMETRIC SAMPLE QUALITY

- **Character** indicates the source's inherent discriminative capability.
- **Fidelity** is the degree of similarity between the sample and its source, attributable to each step through which the sample is processed.



- **Utility** is a sample's impact on the biometric system's overall performance, where the concept of sample quality is a scalar quantity that is related monotonically to the performance of the system.

→ **Q**: Q-metrics related to Character/Fidelity/Utility?

TYPES OF BIOMETRIC SAMPLE QUALITY:

About Q-metrics based on **Utility**

- Dependent on two/more matching samples!

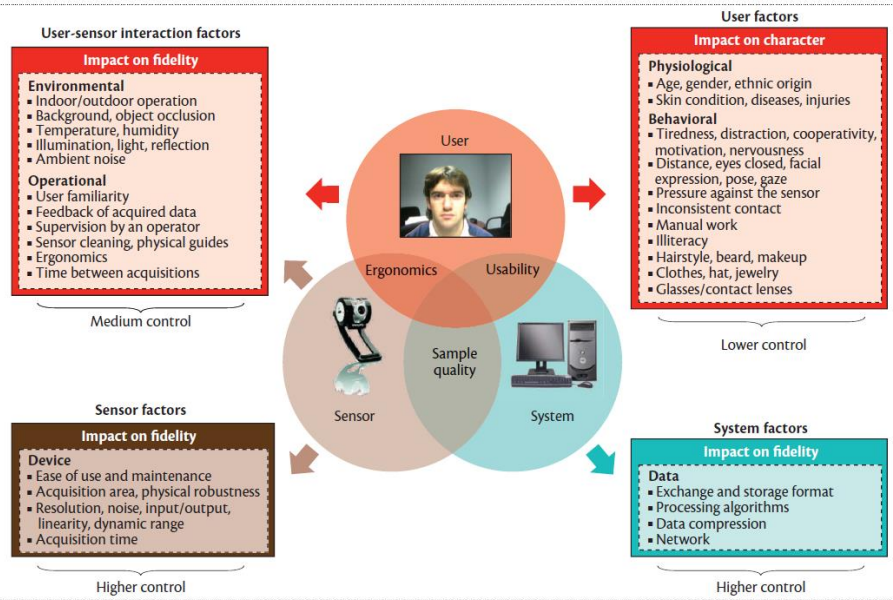
Authentication Score, S = F(Sample1, Sample2)
Quality value, Q1 = Q(Sample1)
Quality value, Q2 = Q(Sample2)
Score Estimate, E = P(Q1, Q2)

→ **Q**: Utility Q-metrics specific for SIS-II application, more general (matcher-agnostic)?

FACTORS AFFECTING QUALITY (1)

- **Character:**
  - Feature richness (e.g. number of minutiae)
  - Missing data / Outliers affecting algorithms / …
  - Ageing? (out of the scope here, but important!)
- **Fidelity: Imaging properties**
  - Optical: Focus / spatial resolution / contrast / sharpness / …
  - Digital: Format / compression / SNR / …
- **Fidelity: Presentation properties**
  - Partial fingerprint / non-fingerprint data …
  - Positioning / Sensor interaction / …
  - Spoof attempts? (out of the scope here, but important!)
- **Fidelity: Environment properties**
  - Illumination / background / reflections / …
  - Temperature / humidity / …

FACTORS AFFECTING QUALITY (2)



F. Alonso-Fernandez, J. Fierrez and J. Ortega-Garcia, "Quality Measures in Biometric Systems", *IEEE Security & Privacy*, Vol. 10, n. 9, pp. 52-62, December 2012.

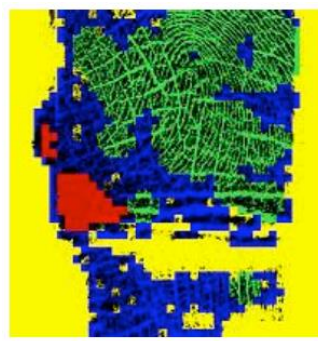
FACTORS AFFECTING QUALITY (3)

From ISO/IEC 29794-4:2016 (Annex B):

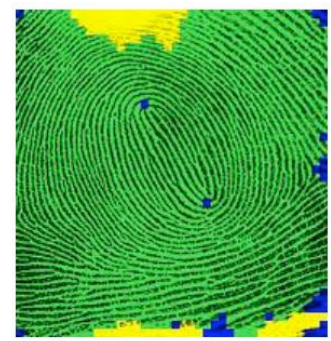
1. Defect caused by user character
   - A. Extreme skin conditions such as very wet, very dry, etc.
   - B. Scars
   - C. Wrinkles
   - D. Blisters
   - E. Eczema
   - F. Impurities such as dirt, latent print, etc.
2. Defect caused by imaging
   - A. Sampling error
   - B. Low contrast or signal-to-noise ratio
   - C. Distortion
   - D. Erroneous or streak lines
   - E. Uneven background
   - F. Insufficient dynamic range
   - G. Non-linear or non-uniform grayscale output
   - H. Pixels not available due to hardware failure
   - I. Aliasing problems
3. Defect caused by user behavior
   - A. Elastic deformation
   - B. Improper finger placement such as too low, rotated, etc.
   - C. Insufficient area of finger image
4. Defect caused by environment
   - A. Humidity
   - B. Light
   - C. Impurities on the scanner surface such as latent prints

→ **Q**: Q-metrics related to specific factors in SIS-II?
- Sensor and acquisition setup maintenance, system administration, actionable feedback ...

LOCAL VS GLOBAL Q-METRICS



Score = 14/100



Score = 81/100

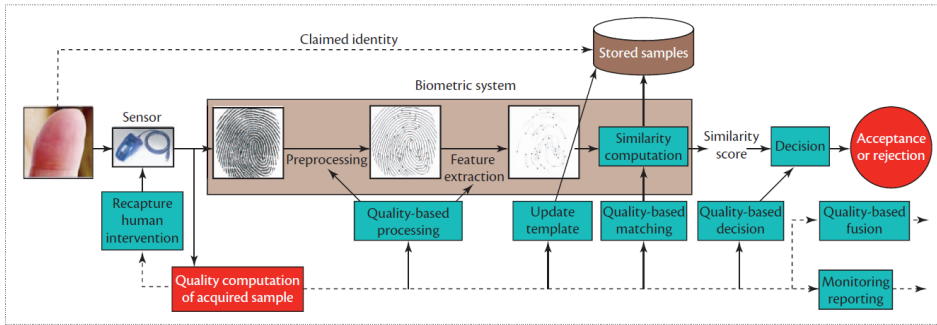
(Both defined in ISO/IEC 29794-4, and provided by default by some vendors)

- good quality
- Poor ridge flow or poor minutiae
- too dark
- too light

→ **Q**: Local Q-metrics in SIS-II?

How are quality scores used?

- **Prediction of performance:**
  - At acquisition, enrolment, or recognition
- **Level of confidence in the result:**
  - Including other factors affecting confidence about the data?
- **To improve performance if quality is poor:**
  - Retake image (auto-capture)
  - Take additional image (quantity vs quality)
  - Remedial correction of specific problems (e.g. sensor maintenance)
  - Different algorithms or algorithm configurations



Preliminaries: Recap

- Q Types: Character/Fidelity/Utility
- Diverse **Factors affecting Q**
- **Local/Global Q**
- Diverse **usages of Q-metrics**

VECTOR OF Q-METRICS
(Possible in ISO 29794-4:2016)

→ **Q**: Who defines the Q-metrics?
- Industry / standard. bodies / SIS-II?

→ Q: Which Q-metrics?
- From industry / Application-driven

→ Q: How to define Q-metrics when Application driven?

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. 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 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_{Nist}): a vector of quality metrics is encoded in bytes 6-N. 255 (FF_{Nist}), 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_{Nist}).					
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.

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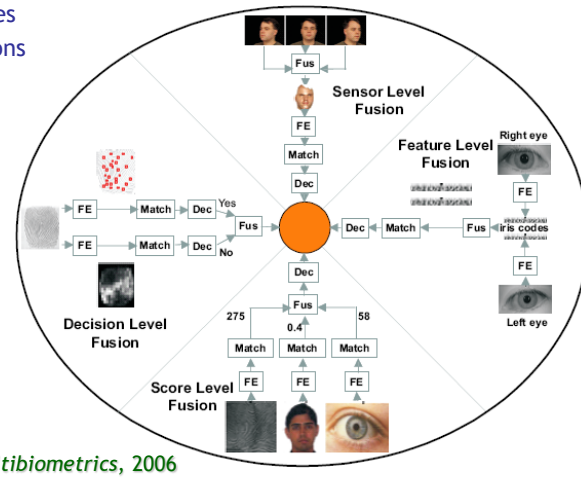
Combination of Q-metrics

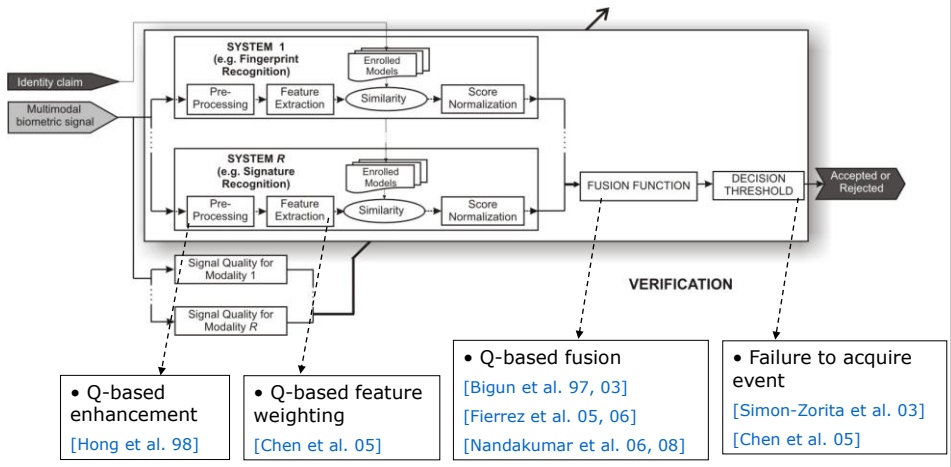
MULTIBIOMETRICS

- Multibiometrics*: use of multiple sensors, instances, realizations, algorithms and/or modalities for biometric person authentication
- Why?
  - Some subjects may experiment difficulties with a specific modality
  - Some modalities better adapted than others to specific applications
  - Exploit fusion capabilities
  - Overcome noisy conditions
  - Robutness to attacks



* Arun Ross et al., *Handbook of Multibiometrics*, 2006

SYSTEM MODEL OF MULTIBIOMETRICS INCLUDING MULTIPLE Q-METRICS



- Q-based enhancement [Hong et al. 98]
- Q-based feature weighting [Chen et al. 05]
- Q-based fusion [Bigun et al. 97, 03] [Fierrez et al. 05, 06] [Nandakumar et al. 06, 08]
- Failure to acquire event [Simon-Zorita et al. 03] [Chen et al. 05]

H. Fronthaler, K. Kollreider, J. Bigun, J. Fierrez, F. Alonso-Fernandez, J. Ortega-Garcia and J. Gonzalez-Rodriguez, "Fingerprint Image Quality Estimation and its Application to Multi-Algorithm Verification", *IEEE Trans. on Information Forensics and Security*, Vol. 3, n. 2, pp. 331-338, June 2008.

HOW TO COMBINE Q-METRICS?

- **Multiple Q-metrics representing the same objective (e.g., matching performance Utility)**
  - Calibration → Quality Score Fusion
- **Multiple Q-metrics representing different factors**
  - **→ Strongly application-dependent:**
    E.g. Utility U1 + image sensor fidelity F1 + improper finger placement F2
    - May not be worth combining (but anyway good to keep/process separately!)
    - May be worth combining: U1 + F1 + F2 → Improved Utility Q-metric U2

→ Q: Who defines the fusion methods?
- Industry / standardization bodies / SIS-II / researchers?

→ Q: Which fusion methods for SIS-II?

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Interoperability and Calibration of Q-metrics

INTEROPERABILITY through STANDARDS

- Quality scores (Utility-based) should aim to be predictive of sample behavior in a matching environment
- Quality scores should be interchangeable between systems
  - Transportable via biometric data interchange formats
- Quality scores should be meaningful, interpretable and useful

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- M1 and ISO/IEC biometric data interchange format standards already provide a Quality Score field, but do not define its use
  - When I get a score, I don't know what it means
- BioAPI defines a 0-100 quality score range and bins
  - 0-25: unacceptable
  - 26-50: marginal
  - 51-75: acceptable
  - 76-100: excellent
- ISO/IEC 29794-1/4/5: 0 lowest, 100 highest

CALIBRATION OF QUALITY SCORES

(Also studied as Score Normalization in the research literature)

- Calibration of methods to measure the known quality factors (Character, Fidelity, ...)
  - Can use reference data exhibiting the range of factors

- Calibration of a performance predictor (for matching /segmentation / ...) considering given system(s)
  - Reference data should be typical of applications in mind (given system and population data)

D. Ramos and J. Gonzalez-Rodriguez, "Reliable Support: Measuring Calibration of Likelihood Ratios", *Forensic Science International*, Vol. 230, pp. 156-169, May 2013.

NFIQ 2.0 and Q CALIBRATION

(Extracted from E. Tabassi et al. IBPC 2016, May 4, 2016)

General: based on large scale operational data	**On-demand: based on application-specific data**
» Calibration: – general calibration curves or tables for NFIQ 1.0 → NFIQ 2.0.	» Calibration – We will provide software tools and technical guidance on how to compute calibration curves.
» Decision Table – For enrollment and verification quality threshold setting – Tabulation of estimated rejection rate and improvement in FNMR for each value of NFIQ 2.0 (i.e., [0,100]).	» Decision Table – Ditto above.
	» This allows for optimal calibration and decision making considering data properties.

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

→ **Q**: Who defines the calibration / score normalization methods?
- Industry / standard. bodies / SIS-II / researchers?

→ Q: Which calibration methods for SIS-II?

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Q-metrics in SIS-II Architecture

Q-METRICS IN SIS-II (1)

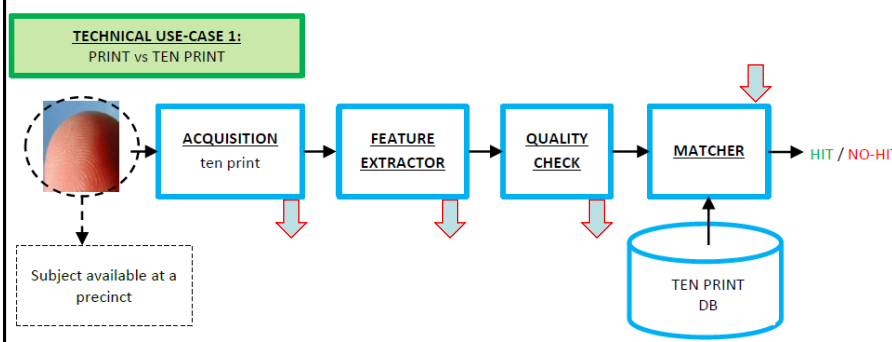

Figure 2. Flow-chart corresponding to the technical use-case 1 (i.e. ten print vs ten print) identified in the visits to the national AFIS

→ **Q**: Which Q-metrics are available by default (provided by vendor)?

→ **Q**: Which additional Q-metrics are worth considering?

Q-METRICS IN SIS-II (2) - *idem*

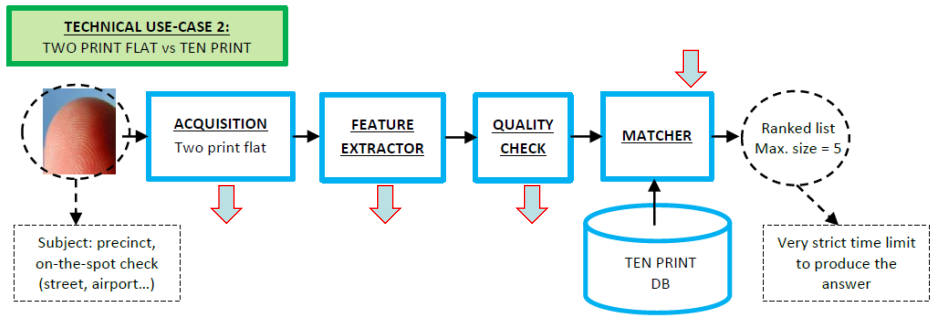

Figure 3. Flow-chart corresponding to the technical use-case 2 (i.e. fast identification or two print vs ten print) identified in the visits to the national AFIS

→ **Q**: Which Q-metrics are available by default (provided by vendor)?

→ **Q**: Which additional Q-metrics are worth considering?

Q-METRICS IN SIS-II (3)

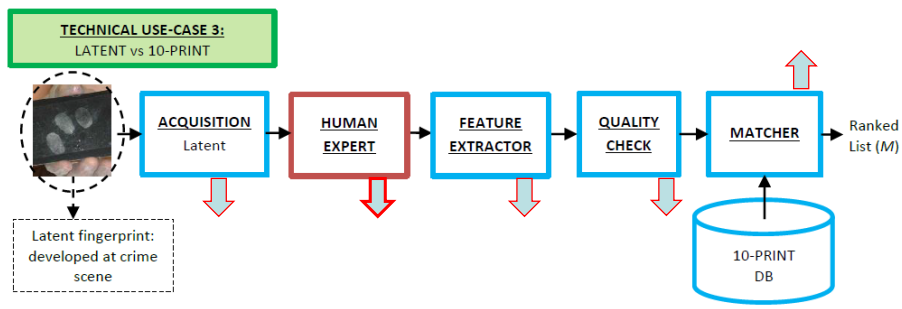

Figure 4. Flow-chart corresponding to the technical use-case 3 (i.e. latent vs ten print) identified in the visits to the national AFIS

→ **Q**: Which Q-metrics are available by default (provided by vendor or human intervention)?

→ **Q**: Which additional Q-metrics are worth considering?

Q-METRICS IN SIS-II (4) - *idem*

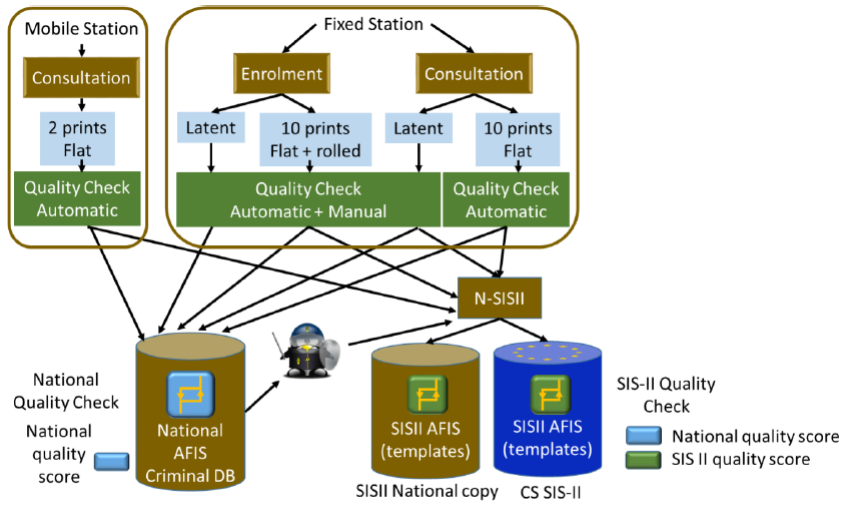

Figure 10. Law enforcement

Q-METRICS IN SIS-II (5) - *idem*

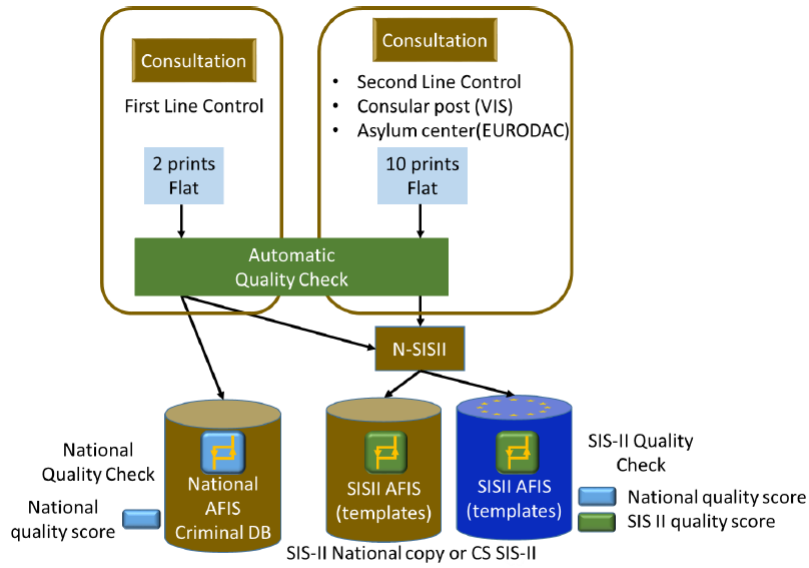

Figure 11. Border checks

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Final Discussion

- → Q: For vendors: description and availability of Q-metrics (not only overall utility-based Q-metrics)?
- → Q: For vendors: ready to implement additional Q-metrics?
- → Q: For researchers: ready to research/implement adequate calibration and fusion of Q-metrics for SIS-II?
- → Q: For SIS-II management: ready to share realistic population data for research/development?