Reconciling Differing Concepts of Biometric Image Quality

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The Importance of Definitions

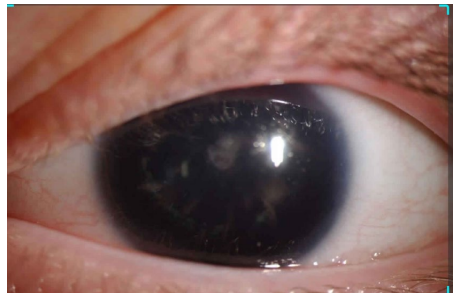
- No quantity can be measured with more accuracy or precision than that in which it is defined
  - Definitional accuracy and precision limits measurement accuracy and precision
- Different definitions will lead to different values and different applications for a measurement

Complexities in Defining “Biometric Quality”

- ISO/IEC 29794-1 “Information technology —Biometric sample quality Part 1: Framework” presents 3 **interrelated** conceptualizations of “quality”
- **Character**: set of attributes associated with a biometric characteristic that **cannot be controlled** during the biometric acquisition process
- **Biometric fidelity** degree to which a biometric sample is **representative** of its source biometric characteristic
- **Biometric utility** degree to which a biometric sample supports biometric **recognition performance**

“Character”

- “Biometric Recognition” is a human/machine technology
- “Character”, mentioned explicitly in all Parts of 29794, refers to human characteristics that “cannot be controlled” (by collector) but sometimes can be tested
  - Implies Plato’s idealized concept of “form”
  - Inherent demographic bias
- Assumed but not tested
  - Faces have 2 aligned eye sockets
  - Time invariant
- Explicitly tested:
  - Fingers have coherent friction ridges
  - Face not occluded beards
  - Iris boundaries concentric, iris/pupil/sclera gray scale difference



“Fidelity”

- Primarily technical characteristics of “representative” collection
  - Collection device characteristics defined in Annex D of relevant parts of ISO/IEC 39794 “Extensible Biometric Interchange Formats”
  - Limitations: Part 4 (Contact FP), Part 5 (Machine Readable Travel Docs)
- Concepts of “fidelity” differ across modes
  - Illumination specified for Part 5(Face) and Part 6(Iris) but not Part 4 (Contact FP)
  - No light reflection from finger, so skin albedo is not a factor
- Other collection device specs:
  - Modulation transfer function
  - Spatial Sampling
  - Optical distortion
  - Pixel aspect ratio
  - Signal to Noise ratio

“Utility Supports Recognition Performance”

- Two inter-dependent pillars of error rate performance
  - Stability: supports false non-match rate
  - Distinctiveness: supports false match rate
    - Influence of quality on false match rate not addressed in Parts 5 and 6
- DoD “Cotton Ball” problem established theoretical dependence of distinctiveness on stability

Performance and Conformance

BOLD added

ISO/IEC 29794-1:2024 “Part 1: Framework”

- 7.1.3 Quality measure (quality score or q”uality component) or error

  Quality scores enable discrimination between distinct levels of performance. **A quality score shall predict performance** metrics such as false match and false non-match rates when comparisons are made to references developed under stated collection policies.

ISO/IEC 29794-5:2025 “Part 5: Face image data”

- 1. Scope

  “This document establishes requirements on implementations that **quantify how a face image’s properties conform** to those of canonical face images, for example those specified in ISO/IEC 39794-5:2019, Clause D.1.”

The Complexity of “Quality”

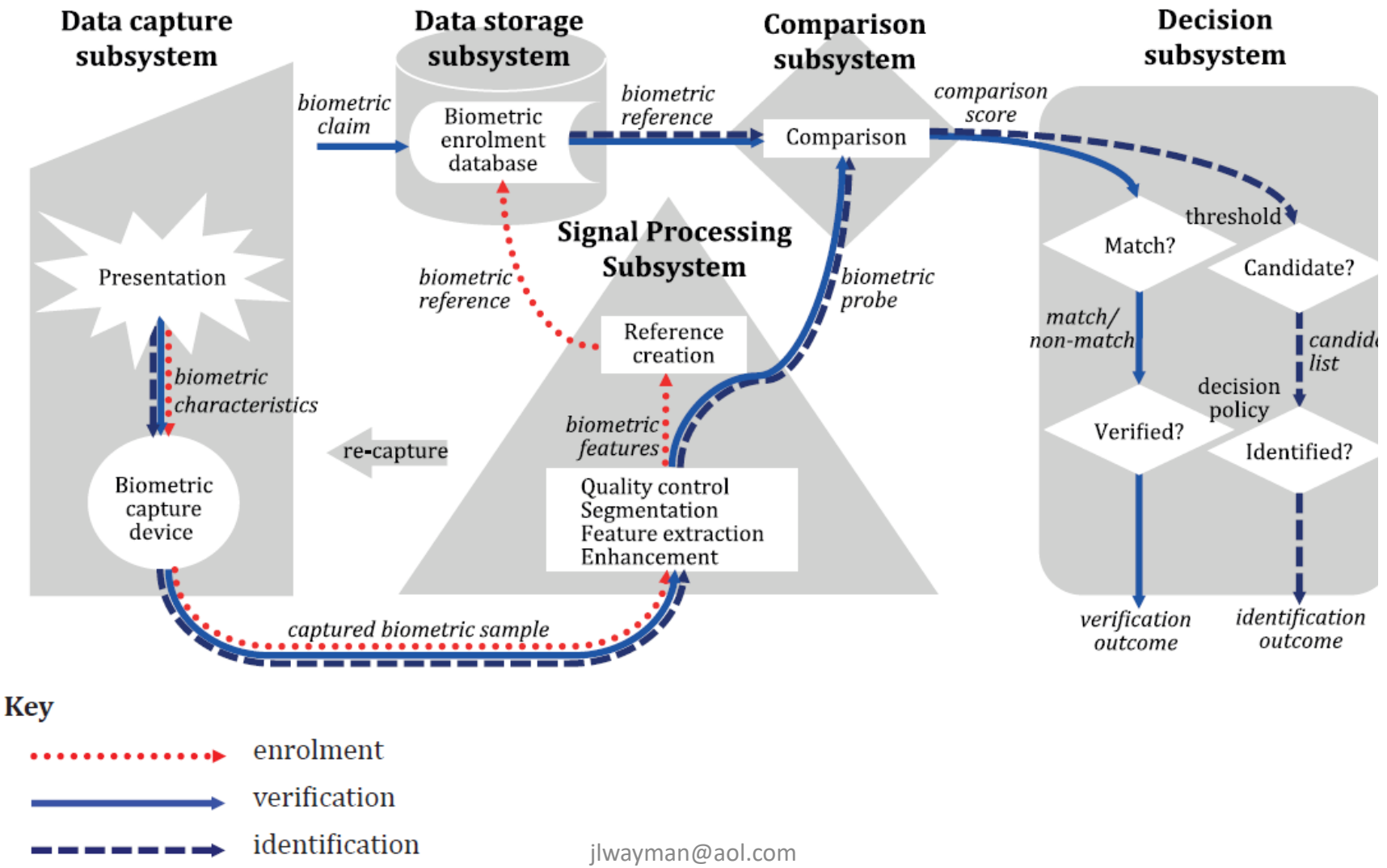
- Character, Fidelity and Utility are not separate and not independent
- Utility = performance= f(error rates, throughput)
- Error rates = f(stability, distinctiveness, mode/algorithm)
- Distinctiveness = f(stability, character, fidelity, algorithm)
- Stability= f(collection conformance, character consistency, mode/algorithm)
- So “Quality” as focused on “Utility” is a complicated function of character, fidelity, collection conformance, mode/algorithm

ISO/IEC 29794-1:2024 Examples of Use

- “real-time quality feedback (in) biometric capture process”
- “data fusion”
- “hardening systems against presentation attacks using or targeting low quality biometric samples”
- “correlating quality measures to other system metrics can be used to diagnose problems and highlight potential areas of performance improvement.”

Points of Application in Biometric System

ISO/IEC SC27 Standing Document 11



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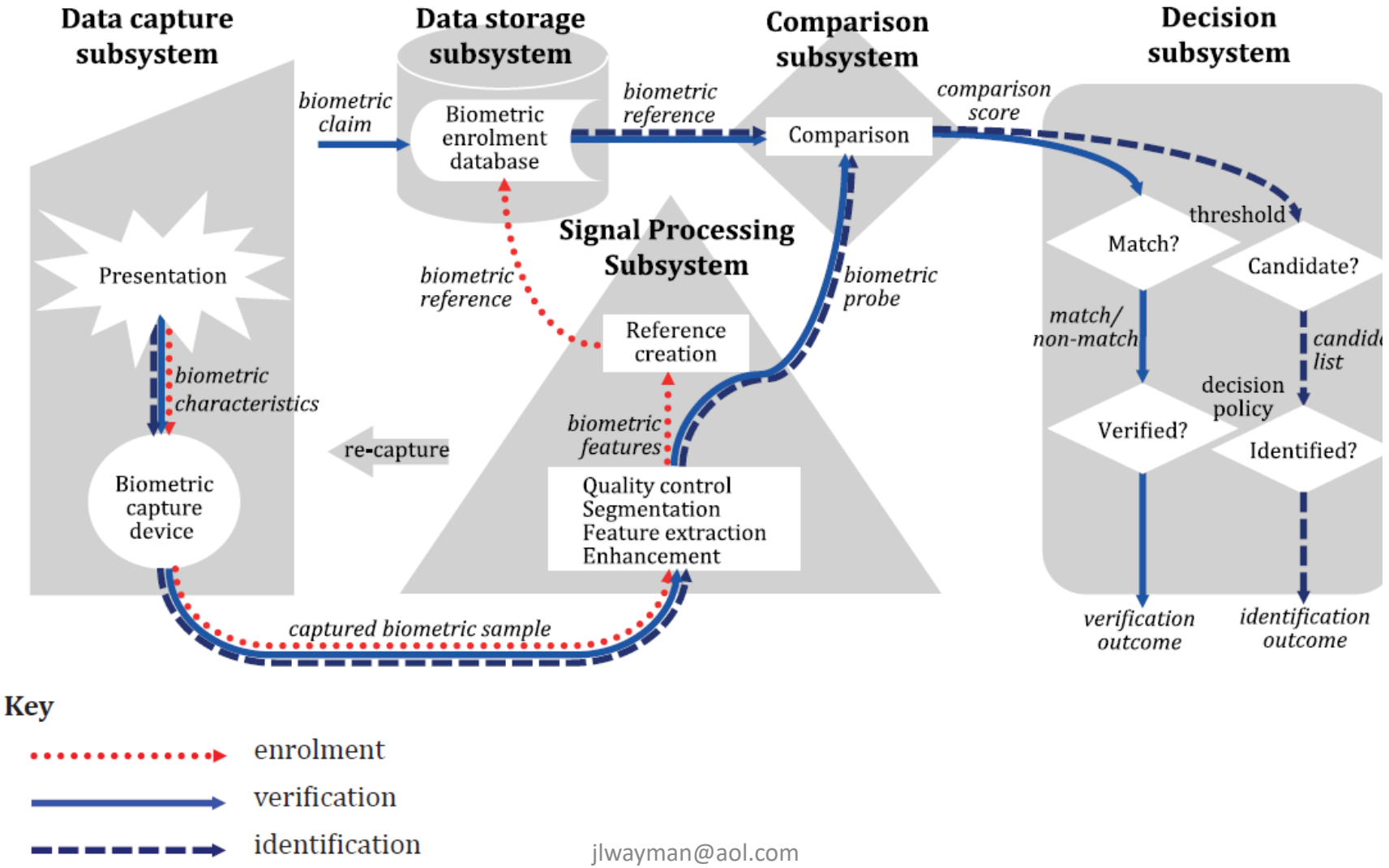
Front End



Back End

Enhancing Performance on Front End

- Front-end application
  - Data capture subsystem
    - “Failure to Capture”
  - Signal processing subsystem
    - “Failure to Acquire”
    - Reference creation
- Enhancement through “Discard Rates”
  - Only a concept in Parts 1 and 5
  - No mention in Parts 4 and 6

Enhancing Performance on Back End

- "Pairwise" comparison of quality components
  - "Quality comes in pairs" – P. Jonathon Phillips
  - Part 1: 10. Pairwise quality
    - "In some applications, there are no assumptions regarding the conformance of either the probe or the reference to any collection best practices or requirements".
  - Part 6: 6.4 Iris image quality metrics computed from two images
  - Part 5: Annex B.1
    - "Q = $F(X_1)$, … predicts (*Score)* because it implicitly assumes the comparison $V(X_1, X_{PORTRAIT})$. Quality scores are evaluated as predictors of mated comparison scores;"
- Use of quality score in comparison algorithm choice
- Quality support for data fusion
  - Nandakumar, et al (2006)
  - Poh, Kittler, and Bourlai (2010)

PART	CONFORMANC METRIC	CHARACTER (BIOLOGY)	FALSE NON-MATCH RATE	FALSE MATCH RATE	DISCARD (FRONTEND)	PAIRWISE (BACKEND)
1		✓	✓	✓	✓	✓
4		✓	✓	✓	✓	
5	✓	✓	✓		✓	
6		✓	✓		✓	✓

Recommendations

All parts of ISO/IEC 29794 should be harmonized to:

1. Acknowledge both “performance” and “conformance” as reasonable approaches to quality
2. Include “pairwise” mutual quality comparison for backend applications
3. Acknowledge impact of quality on false match rate
4. Inform use of quality metrics in data fusion