Biometric Identification: A Holistic Perspective

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Biometric Technology for Human Identification IV

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Evolution of Biometric Applications

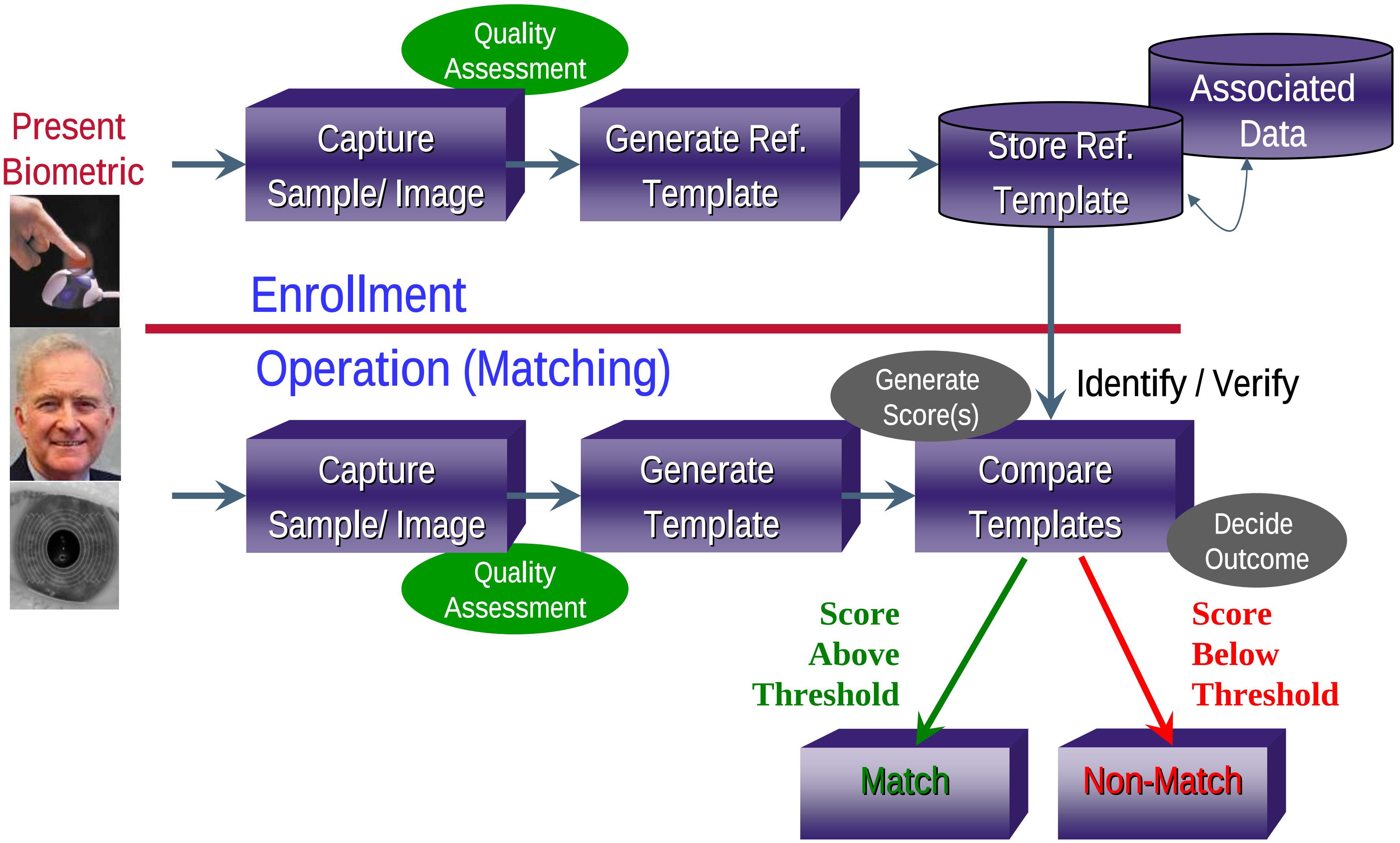
Characteristic	Prior to 9/11 and Globalization	Post 9/11 and Globalization
Location	Centralized – local, national	Distributed – local, national, international
Database Size	100's – 100K's	1M's – 100M's
Operational Environment	Well-defined and predictable	Variable and unpredictable
Population Characteristics	Homogeneous	Diverse
Interoperability	Stand-alone	Cooperative

Large-scale identity governance requirements need more robust, scalable, and interoperable systems — U.S. NSTC Subcommittee on Biometrics [1]

Current and Emerging Applications

- Border control (US-VISIT)
- Passports/visas (DoS)
- Federal and first responder identity credentials (PIV/HSPD-12)
- Transportation Worker Identification Credential (TWIC)
- REAL ID
- Intelligence in the field
- Next Generation Identification (NGI - FBI)
- Automatic Biometric Identification System (ABIS – DoD)
- E-commerce

Generalized Biometric System



Beyond Sensors and Algorithms . . .

- Performance and Scalability
  - Data quality
  - Multibiometric fusion
  - Operational environment
  - Human factors
  - Workflow
  - Dynamic thresholds and queuing models
- Interoperability / Data Sharing – Standards
- Cost Benefit
- Law, Ethics, and Privacy

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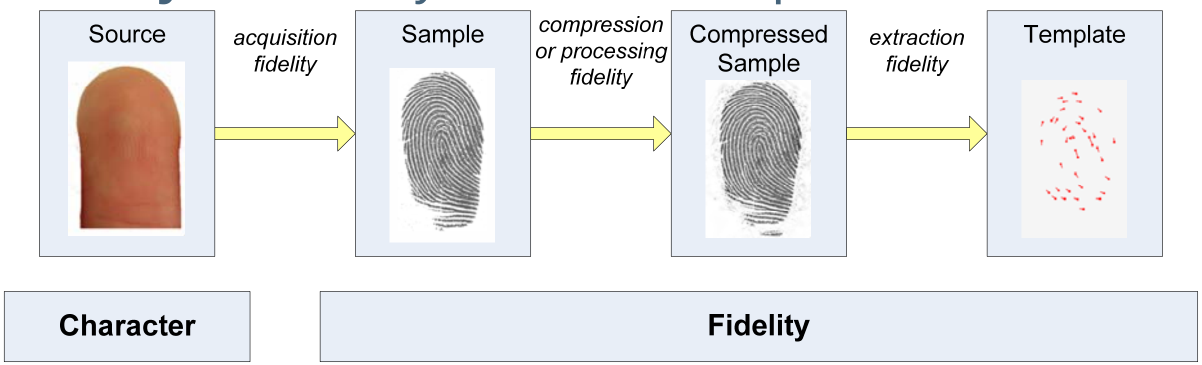
Data Quality

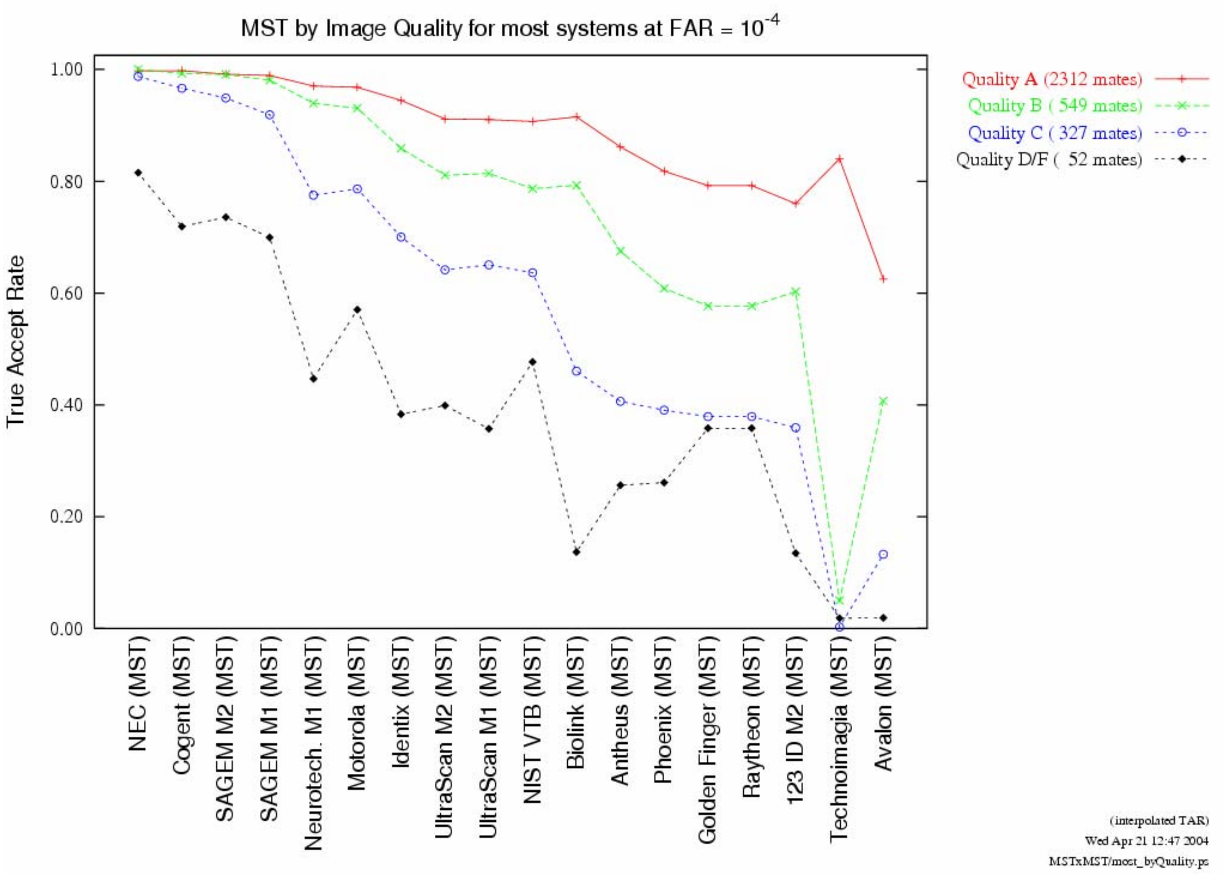
- Quality of both biometric and textual data is critical
- Biometric sample quality
  - **Character -** inherent characteristics of source
  - **Fidelity -** similarity between sample and source



REF: Hicklin and Khanna [4]

  - **Utility -** contribution to matching process
- Quality **metrics** are matcher dependent and do not necessarily coincide with human perception
- Accuracy and throughput are dependent on quality of both the probe and gallery samples

Data Quality Impact on Performance
(ref. NIST FpVTE 2003)



Highest Quality

Lowest Quality

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Quality Driven Data Capture

- Capture up to “n” samples until the specified quality threshold achieved, otherwise
  - Retain highest quality sample
  - Invoke an alternative process or biometric
- Capture series of samples (e.g., video stream)
  - Retain highest quality sample (image frame)
  - Fuse samples to obtain higher quality sample
  - Retain and search/enroll multiple samples
- Monitor quality trends to determine if equipment or operator performance is degrading

Quality Driven Processing

- Higher quality replaces lower quality reference sample once they are deemed mates
- A "local" quality metric can disqualify features or limit their contribution to matching decision
- Probe and/or reference sample quality can determine
  - Weight of a sample's match score in a score-level fusion approach
  - Which of several matchers to use
  - Matcher threshold

Human Factors for System End-Users and Operators

- Human factors impact data quality and consistency, system accuracy and throughput, personal satisfaction, and willingness to cooperate. Relevant aspects include the following:

<u>System End-Users</u>

- Anthropometrics
- Age / Aging
- Language / Culture
- Disability
- Instruction
- Habituation
- Affordance

<u>System Operators</u>

- Training
- Ergonomics
- System cues
- Fatigue/monotony
- Stress
- Performance feedback

Human Factors Impact Assessment

- **Usability** – “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use” [ref. ISO 92241-11]
  - **Effectiveness** – sample quality
  - **Efficiency** – time on task
  - **Satisfaction** – subject perceived comfort level
- To measure usability, must establish and specify
  - User population characteristics
  - Tasks to be performed
  - Operational context

NIST Counter Height Study for 10-print Slap Capture (ref: Theofanos and Orandi [5])

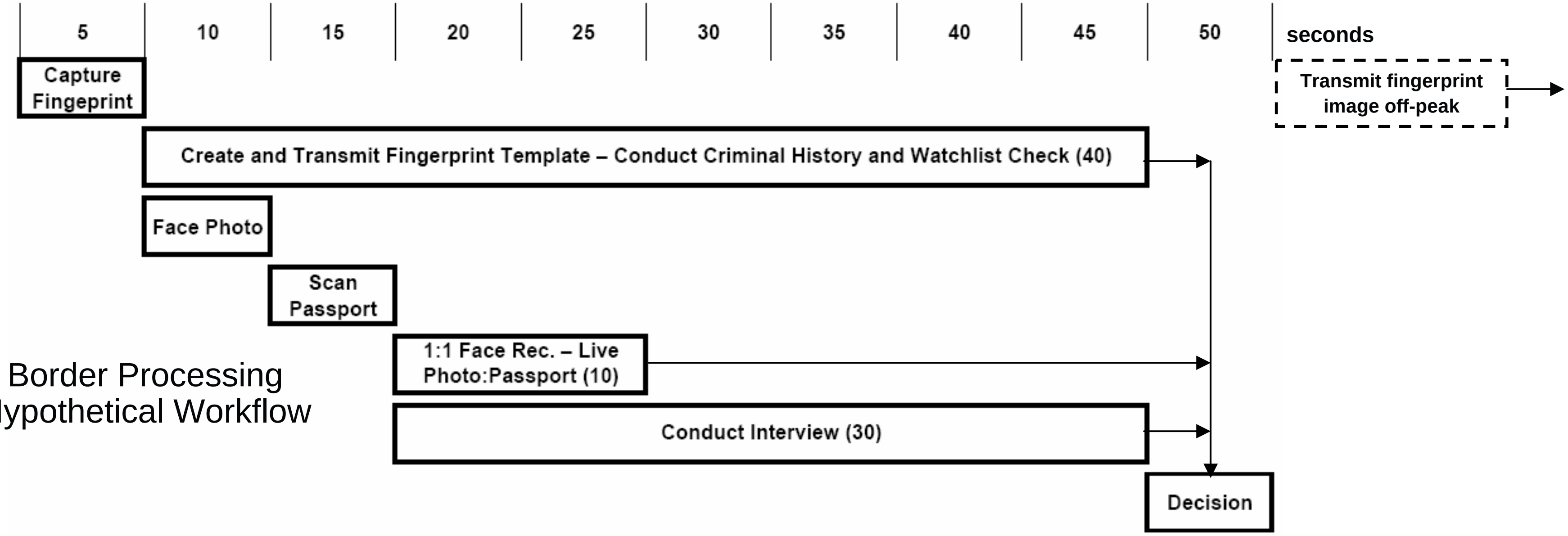
- Studied usability of 6” high slap capture device on counter heights of 26”, 32”, 36”, and 42”
- Findings
  - 36” most efficient when right slap is part of the sequence; end-users preferred to start with right hand
  - 26” most effective for sequence with simultaneous thumbs and left slap
    - Quality (NFIQ metric) decreased with height
    - Thumb quality most sensitive to height
    - Sequential thumbs better than simultaneous
  - Satisfaction greatest for 32” and 36”

Controlling and/or Adapting to the Operational Environment

- Modality/technology selected should be compatible with the application environment
- Key factors
  - Illumination - intensity, frequency, angle
  - Background content
  - Temperature
  - Humidity
  - Vibration
  - Noise
  - Workspace dimensions
- Adaptive approaches – judicious sensor placement; environmental sensing and adaptation; signal/image processing to compensate for, remove, or discount artifacts

Workflow Engineering

- Organize workflow to minimize end-to-end processing time and resource utilization
- Example – create FP template at client, transmit small template file for processing during peak workload and transmit larger image file for archiving off-peak; this also distributes processing across client workstations and reduces processing demand on matcher server



Border Processing Hypothetical Workflow

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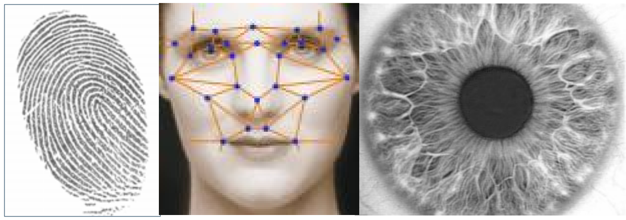
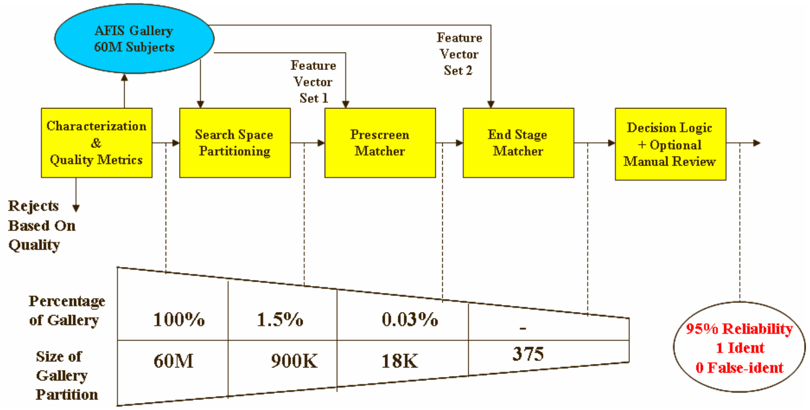
Multibiometric Systems and Fusion

- Multibiometric approaches offer the potential to improve
  - Accuracy
  - System robustness and fault tolerance
  - Resistance to fraud
  - Efficiency and reduce cost
- Greatest benefits derived when integrating uncorrelated biometric characteristics

Categories of Fusion

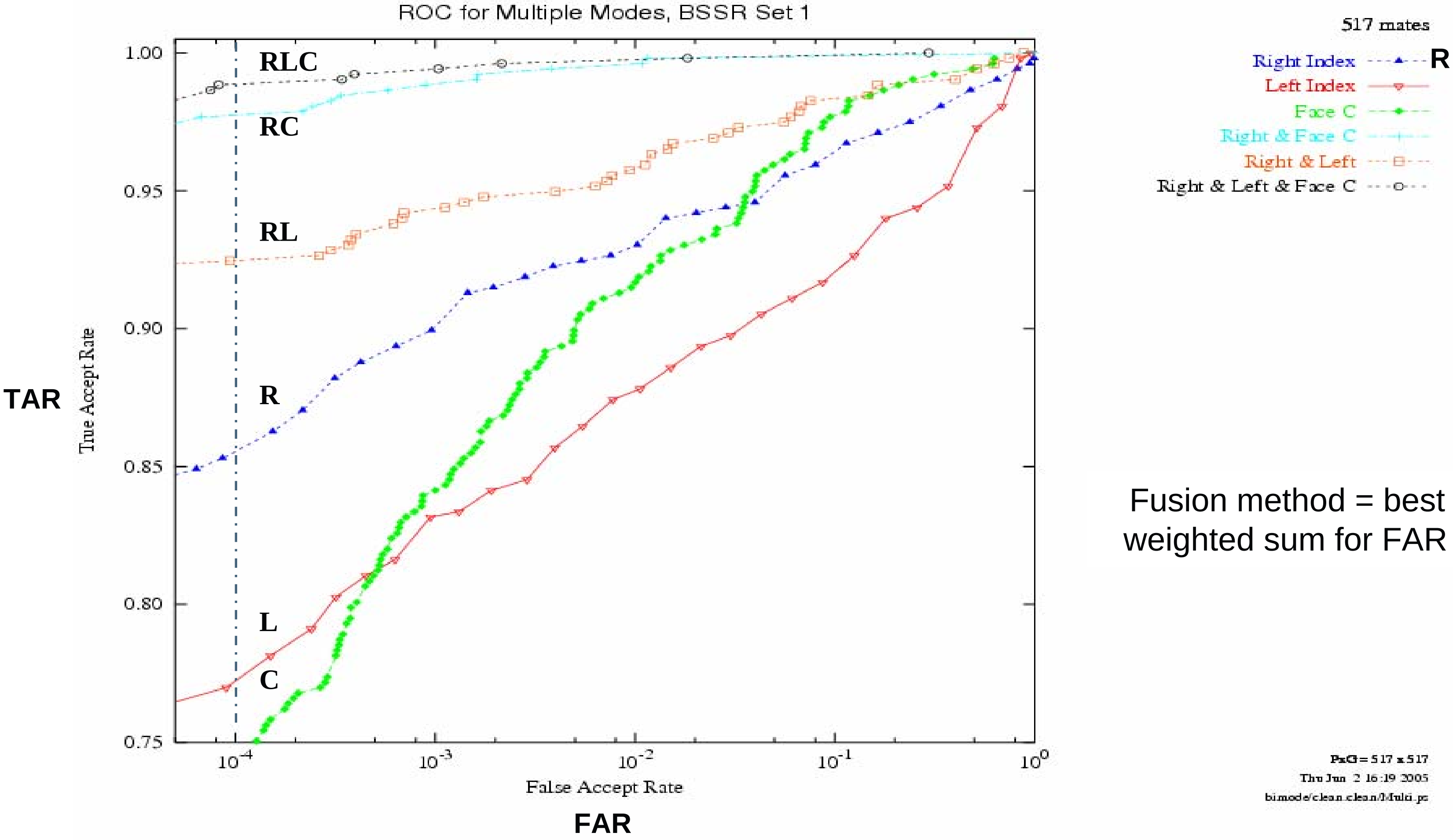
- Multi-presentation
  - e.g., Multiple images of the same finger
- Multi-instance
  - e.g., Images from multiple fingerprints; two irises
- Multi-modal
  - e.g., Face + Finger + Iris
- Multi-sensor
  - e.g., Capacitive and optical fingerprint sensors; multi-spectral iris capture
- Multi-algorithm
  - Multiple matchers





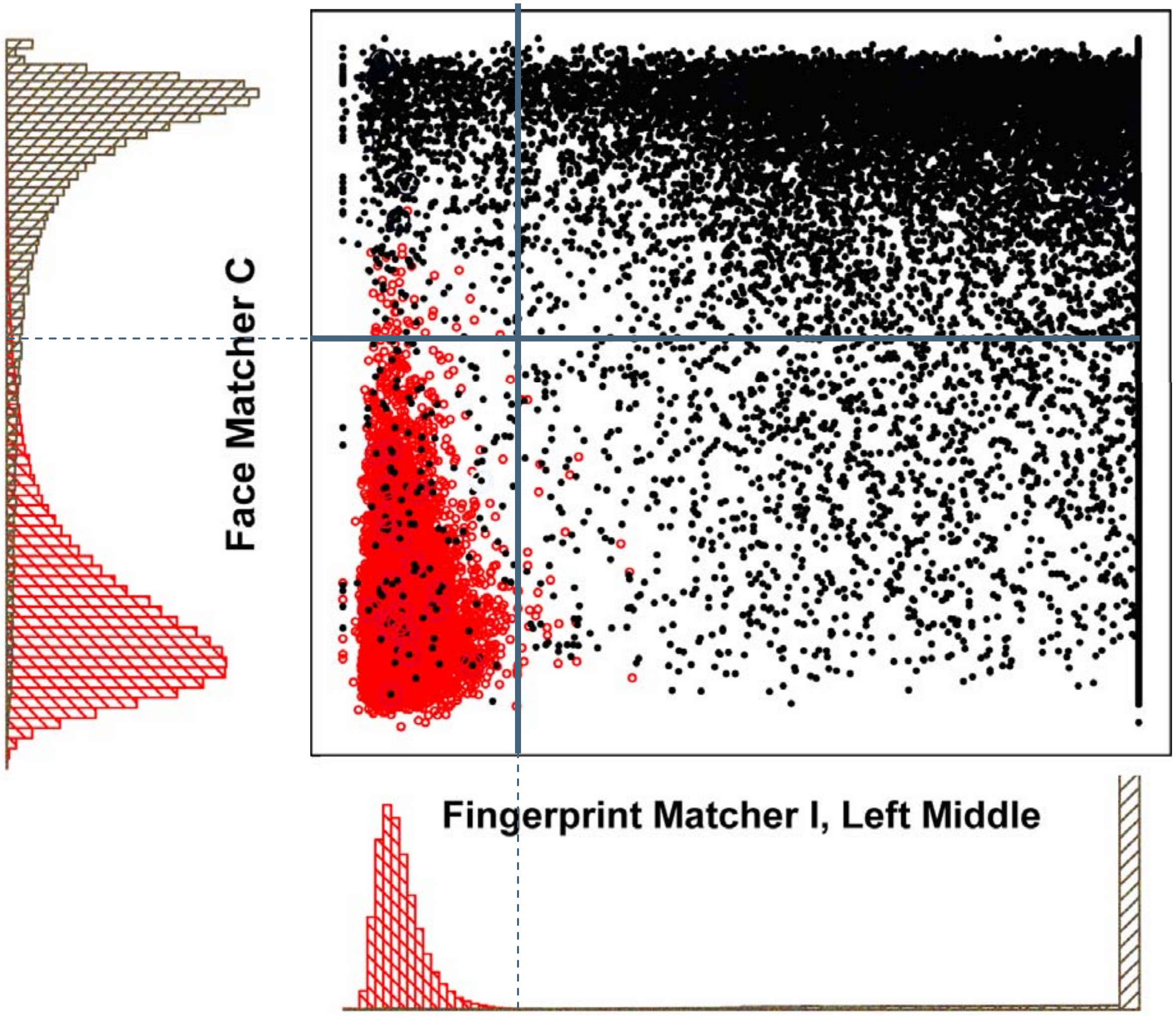
Comparison of Multibiometric Fusion

(NIST BSSR1 Face and Finger Data)



Fusion method = best linear weighted sum for FAR = 10^{-4}

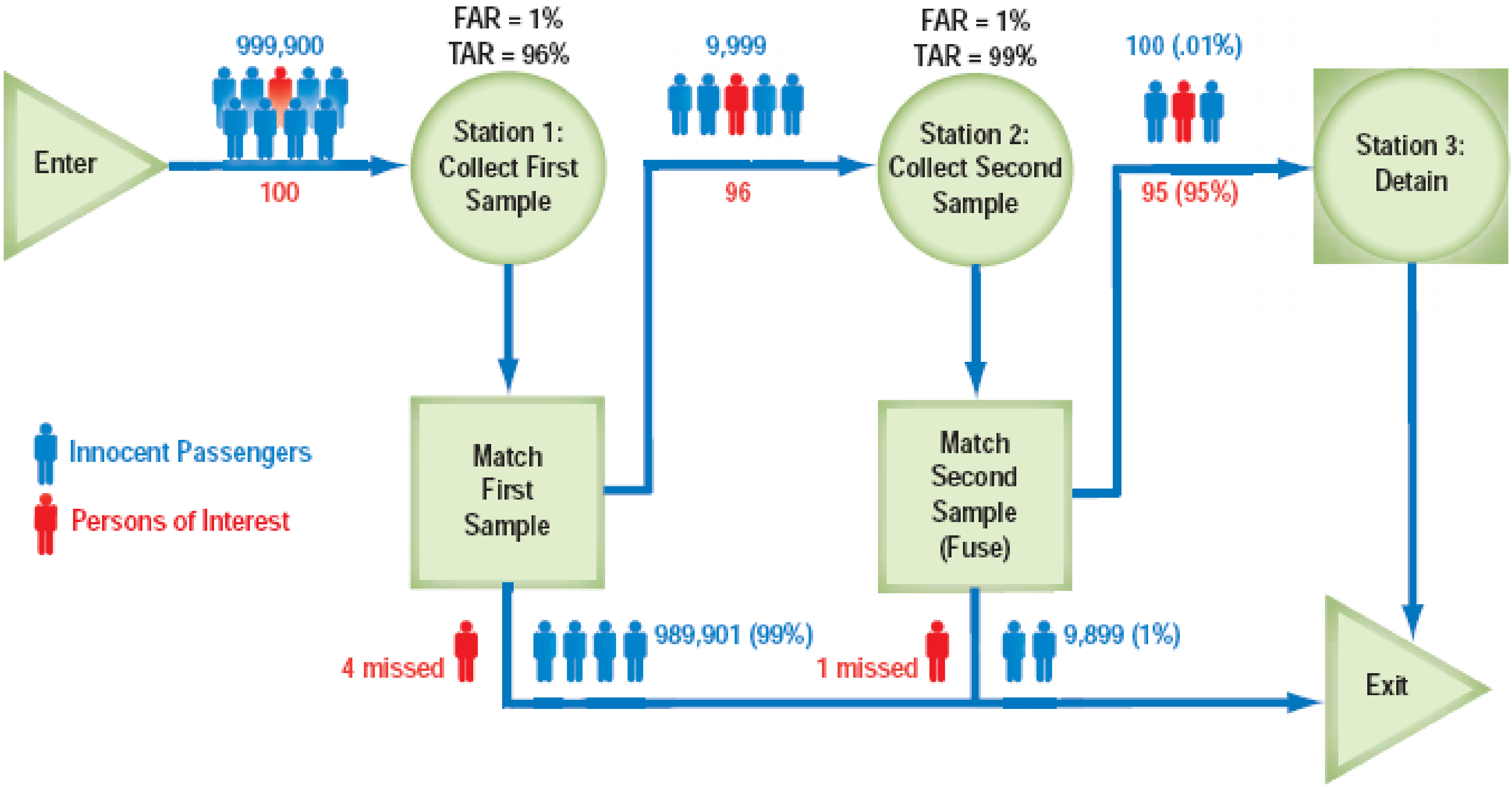
Why Fusion Works



Dynamic Matcher Thresholds and Queuing Models

- A combined biometric system accuracy and queuing model can be used to analyze and quantify the impact of accuracy on
  - Identifying persons-of-interest
  - Individual processing time
  - Utilization of resources
  - Required personnel costs
- Model's "cost function" must account for operational conditions, policy, and minimum performance requirements
- Model can be used both to design a system for baseline operations and as an operational tool to adjust system parameters (i.e., accuracy vs. throughput) in response to off nominal workload

Illustrative Model
(Ref: Ulery, Masi, Korves, and McCabe [9])



Interoperability and Standards

- Standardized file and data formats facilitate data sharing and system interoperability
- Standards-based hardware and software permit component-level technology refreshment
  - Increases system longevity and flexibility
  - Promotes industry competition leading to increased quality at decreased cost
- Standardized performance testing and reporting practices support system designer and end-user understanding and expectations
- Key biometric standards organizations
  - U.S.: ANSI/INCITS M1, ANSI/NIST
  - International: ISO JTC 1/SC 37
- Standardized test data supports product development and performance comparison (note: security and privacy requirements)

Standards — Some Challenges

- NIST demonstrated in MINEX04 that use of a standardized fingerprint minutiae template (INCITS 378) resulted in decreased matcher performance when compared with proprietary template formats.
- Standardized data quality metrics may not accurately and fairly reflect matcher performance due to algorithm and sensor variety.
- Application profiles are needed to standardize the use of a standard for given applications to achieve interoperability.

Assessing Cost Benefit and Return on Investment (ROI)

- Importance
  - To justify investment in biometric-based applications
  - To help tune system operating points
- Challenges
  - Many benefits are intangible
  - Difficult to associate $$$ with certain benefits (financial and ethical considerations)
  - Benefits may accrue to those who aren’t paying the bill
  - Determining realistic performance requirements – *How good is good enough?*

Cost Benefit Model Components

Cost Element	System Life Cycle Phase			
	Acquisition	Operation	Maintenance	Improvement
Hardware	X		X	X
Software	X		X	X
Design & Development	X		X	X
Facilities	X	X	X	X
Labor	X	X		X
End-user Instruction	X	X		X
Operator Training	X	X		X

- Model must also integrate performance requirements and metrics, policy considerations, and threat and workload dynamics
- Improvements may increase or decrease operation and maintenance costs

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Some Potential Benefit Components Include Costs Associated with . . .

- Loss of life
- Personal injury
- Fraud
- Theft
- Property damage
- Business financial loss
- Loss of business
- Loss of reputation
- Loss of security
- Loss of information
- Loss of privacy

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Summary

- Significant advances continue to be made in the individual biometric modalities
- There is a societal need for global, large-scale, interoperable biometric systems that challenge current capabilities
- Creative and integrated implementation of the approaches described in this presentation can help meet these needs with today's technologies
- Adoption of appropriate standards will facilitate both interoperability and future performance improvements via technology refreshment

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