Panel Discussion Questions

1. **What are the biggest road-blocks to progress in multi-modal biometrics?**

2. **To overcome the paucity of multi-modal data, the practice has developed of creating multi-modal data by "randomly" matching together uni-modal samples to form multi-modal samples. Is this valid?**

3. **What are the advantages and disadvantages of signal, score, and decision level fusion?**

4. **In current research, developing a multi-biometrics algorithm requires a researcher to develop an algorithm for each modality and a fusion algorithm. Is this good for the field?**

Panel Discussion Questions

5. **Is the decision to deploy mainly, 1) Performance, 2) Economics, 3) Scenario**

6. **Is multi-biometrics 1) science or 2) applied technology**

7. **Is now the appropriate time to develop a multi-biometric standard through international standards bodies?**

8. **Travel documents call for face, finger, and iris. Considering perceived accuracies of these modalities, what are the implications for multi-modal research?**

9. **How much data is needed?**

10. **How would you define a standard multi-modal data sample?**

Multi-biometrics, Déjà Vu?

Panelists

P. Jonathon Phillips, NIST

Kevin Bowyer, Notre Dame

Douglas Reynolds, MIT Lincoln Labs

Paul Griffin, Identix

Multi-biometrics, Déjà Vu?

P. Jonathon Phillips

12 Dec 2003

Multi-biometrics, Déjà vu?

- Evidence multi-biometrics improve performance

- Open questions:
  - Are some combinations “better” than others?
  - What is a good baseline to assess improvement?
  - How will we identify good combinations?

Multi-Biometrics

Multi-Modal

Face Algorithm

Finger Algorithm

Fusion

Multi-Samples

Face Fusion Algorithm

Multi-Algorithms

Face Algorithm 1

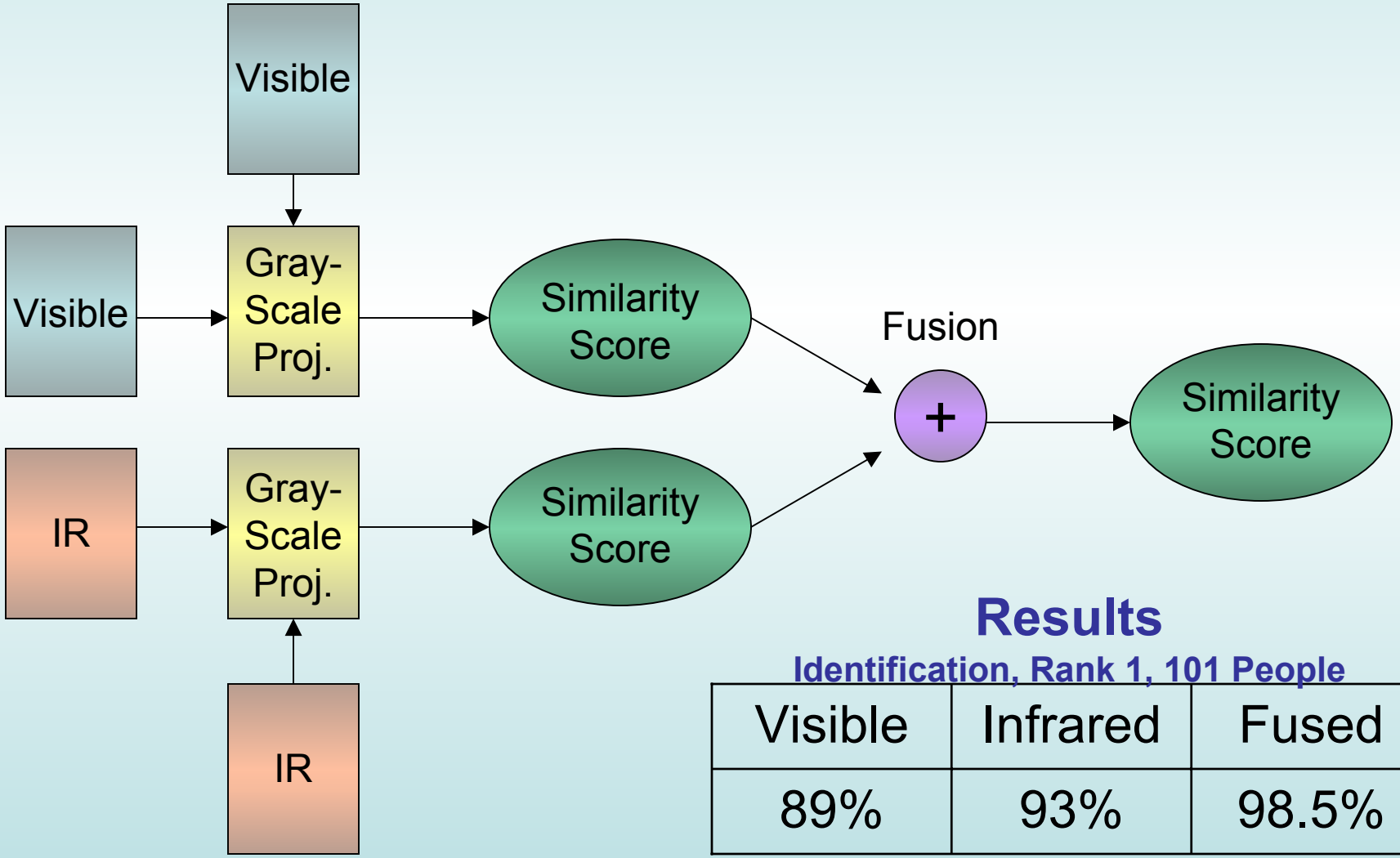
Face Algorithm 2

Face Algorithm 3

Fusion

Early multi-biometrics approach

From Wilder, Phillips, Jiang, Wiener, 1996

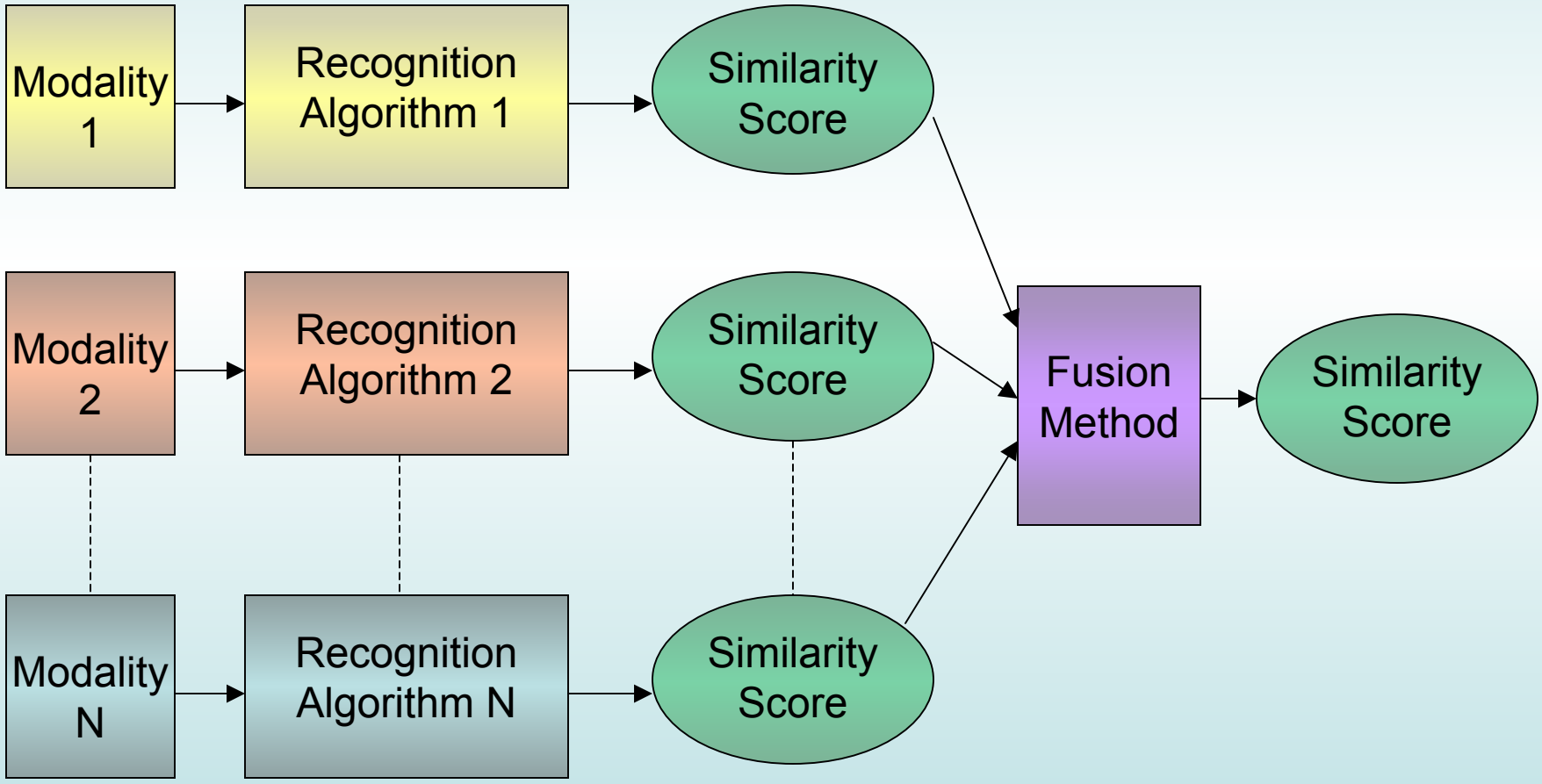


Results

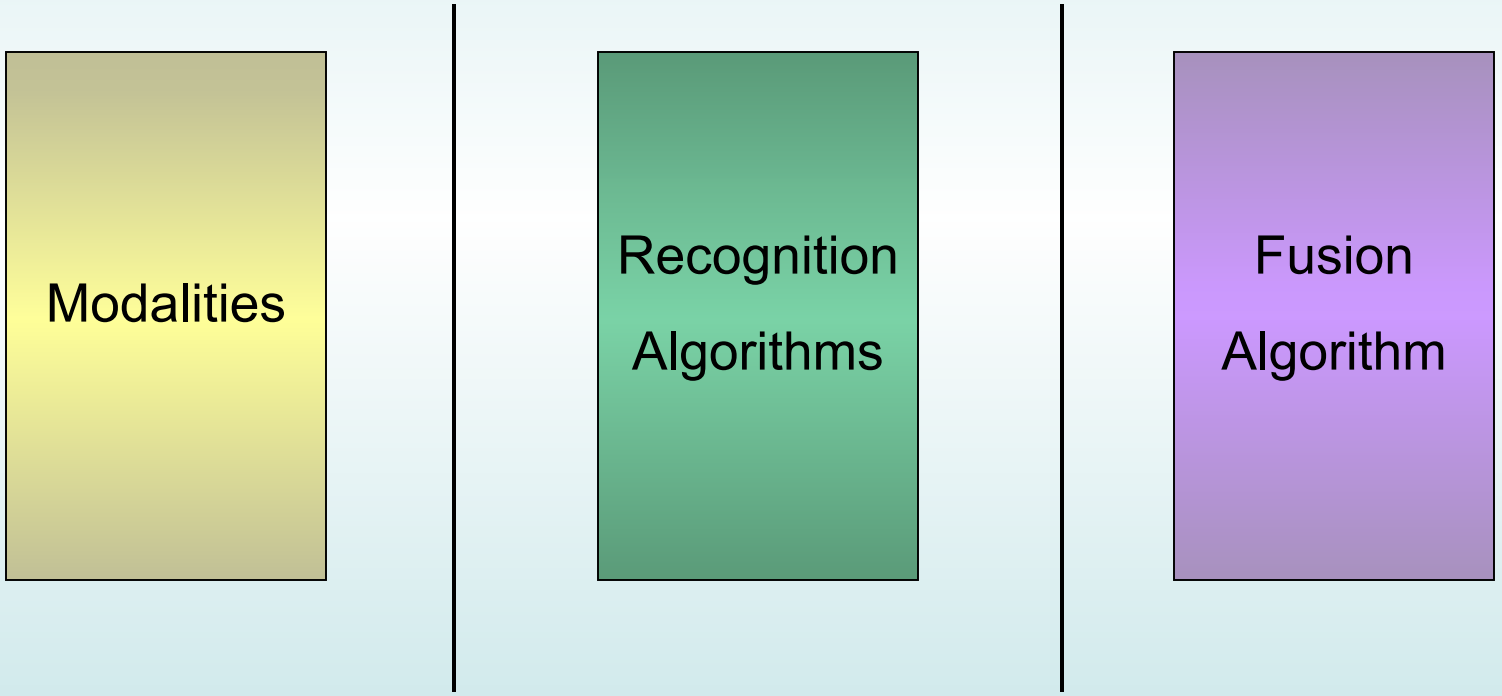
Identification, Rank 1, 101 People

Visible	Infrared	Fused
89%	93%	98.5%

Prototype Multi-biometrics Algorithm

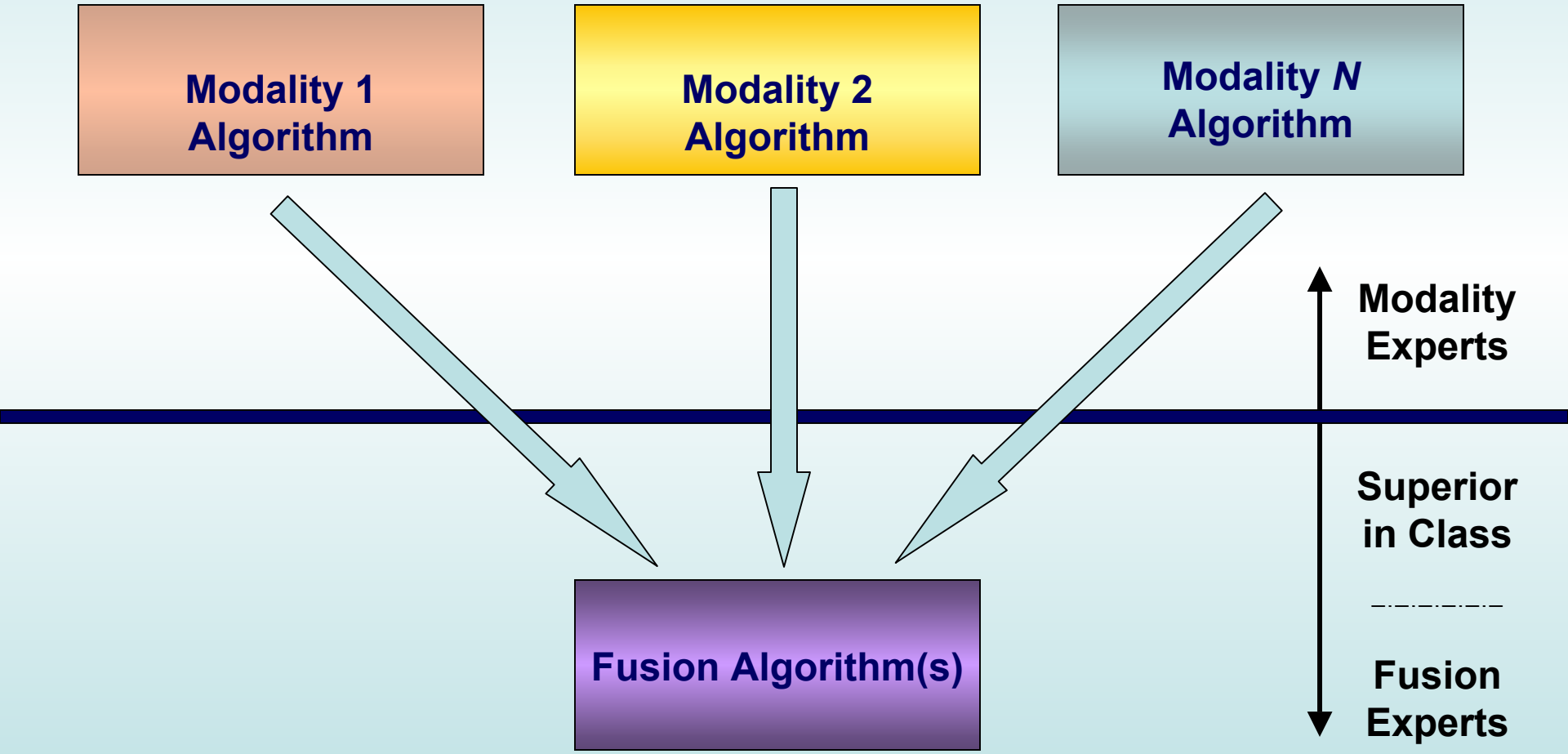


Factors Effecting Performance



Need to disentangle factors

Multi-Biometric Algorithm Development



Why Adopt Multi-biometric

- Performance (classical)
  - How much increase?
  - Economics?
- Robustness
  - Scenario?
  - Economics?

Multi-Modal Versus Uni-Modal Performance In Biometrics

Professor Kevin W. Bowyer
Computer Science & Engineering
University of Notre Dame

Biometrics Conference – Washington DC – September 20, 2004

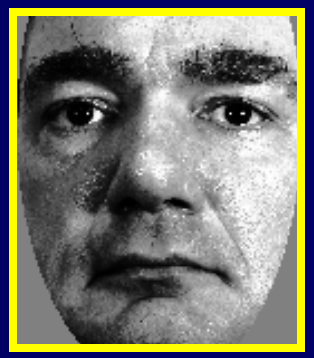
Evaluating Multi-Modal Results

You have seen N results such as those on the next three slides.

Such results are asserted to show that some multi-modal biometric results in improved performance.

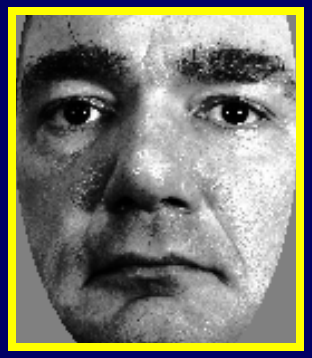
Infra-Red and Visible Face

= 73%



= 73%

+

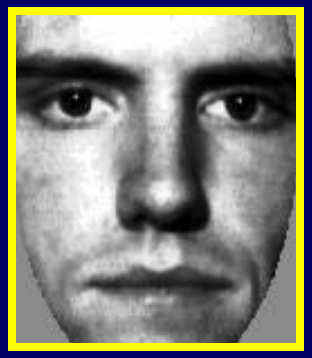


= 90%
stat. significant

2-D and 3-D Face

= 89%

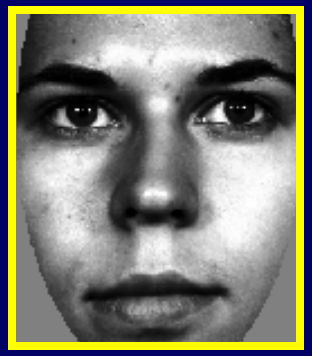
= 94.5%



+

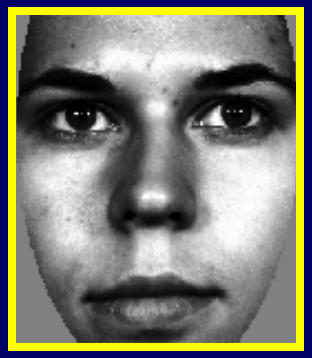
= 98.5%
stat. significant

2-D Ear and 2-D Face



= 83.3%

= 86.5%



+

= 98.7%
stat. significant

Evaluating Multi-Modal Results

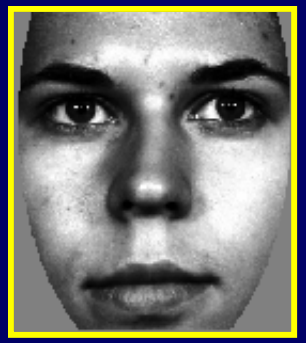
Do such results prove that a multi-biometric performs better?

Answer – Maybe / maybe not.

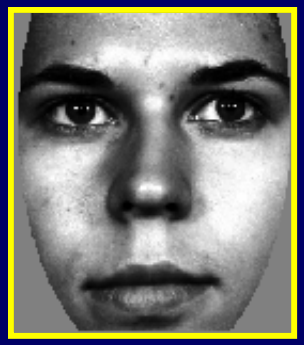
The multi-biometric uses two images.

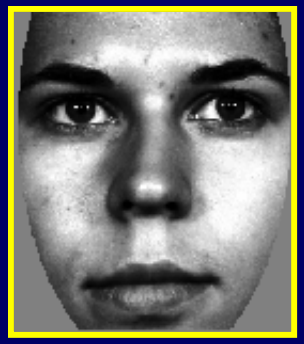
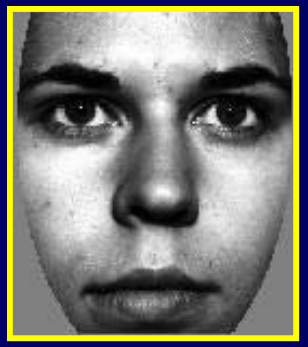
What if two 2-D face images are used?

Face + Ear Recognition



= 83.3%

and  +  = 98.7%

but  +  = 91.6%

Evaluating Multi-Modal Results

In general, we find about 1/2 the apparent multi-biometric gain goes away when you control for the number of image samples.

Q. – Will "enough" 2-D face samples beat the multi-biometric approach?

Other Performance Aspects

Multi-modal may still be able to be acquired in a more "fail soft" manner, etc.

(Roli, 1-st BioSec Workshop, Barcelona, June 2004.)

"Bowyer's Conjecture"

One infra-red image is *less powerful* for face recognition than one 2-D image.

"Bowyer's Conjecture"

One 3-D image is *more powerful* for face recognition than one 2-D image.

"Bowyer's Conjecture"

One 2-D ear image is about *as powerful* for recognition as one 2-D face image.

"Bowyer's Conjecture"

Combining one image from each of two different modes is *more powerful* than either one alone.

"Bowyer's Conjecture"

Using 4 or 5 well-chosen 2-D face images is *more powerful* for recognition than one 3-D face image or multi-modal 3D+2D face.

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Multi-Modal Biometrics

Douglas Reynolds
Senior Member of Technical Staff
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Outline

- When does fusion make sense?
- Why face and voice?
- What is needed to for further multi-modal R&D?

When does fusion make sense?

- For improved performance
  - More inputs for better decision making
- For improved robustness
  - Fall back systems when one mode degrades
- When an application allows it at low “cost”
  - Scenario can easily accommodate more sensors
  - Benefits outweigh cost of additional sensors

Why face and voice?

- Most natural way we recognize each other
  - Unobtrusive, standoff sensors
- Low cost sensors
  - Cheap audio and video recording devices and storage
- Complementary information
  - Studies have shown accuracy improvement with both
  - Relatively disjoint channels provide robustness
  - Two different inputs make spoofing more difficult
- Both convey static and dynamic information to exploit
  - Face: Facial structure + lip dynamics and visemes
  - Voice: Vocal apparatus + prosodics, accents, and idiolect
  - Potential gains for tighter integration and early fusion
- Lip-reading can help supply better spoken text to aid voice recognizer
  - Text-independent→ text-dependent

What is needed to for R&D?
Infrastructure

- Data
  - Synthetic multi-modal corpora OK for initial work
  - Some multi-modal corpora exist
    XM2VTS , VidTIMIT
  - Future corpora need to better reflect realistic conditions (acoustic noise and lighting conditions)
- Evaluation measures – MoP vs. MoE
  - Should distinguish between technology-focused vs. application focused evaluation measure
  - Is multi-modal combination an application of technologies or a technology itself?
- Common recognition algorithms
  - To minimize barrier to entry
  - Perhaps some notion of standardized scores
  - Not ideal since it tends to focus on late fusion

What is needed to for R&D?
Fusion Research

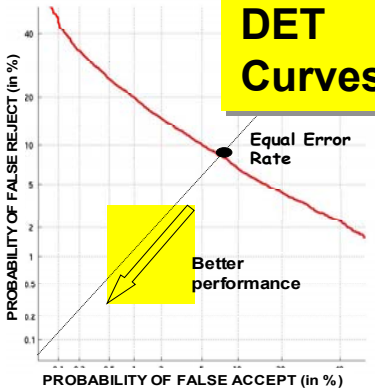
- Better theoretical framework
  - Statistical combination (learned parameters)
  - Rule-based
  - Event-based
- Early vs. late
  - Late: focused on fusion of separate system scores
  - Early: requires internals and probably new classifiers
- Use of external knowledge
  - Measures of channel quality and conditions to know when to discount mode
  - Modification of priors
  - When/how to adapt or update fusion
- Fusion or combination
  - Primary and secondary testing
  - Fast, more errorful first pass providing short-list for slow, more accurate second pass

Evaluation
MoPs to MoEs

- **MoP**: Technology-focused Measures of Performance
  - Represents quantitative measure of core technology
- **MoE**: Application-focused Measures of Effectiveness
  - Represents quantitative/qualitative measure of how technology helped final application

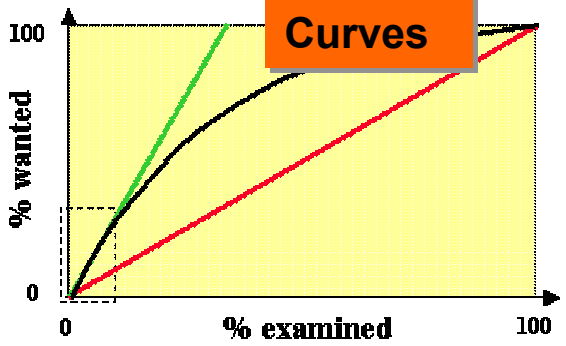
MoPs ⟵ ⟶ MoEs

DET Curves



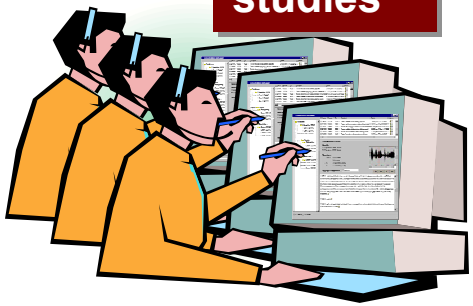
Easy to repeat
Defined objective
Cheap
Suited to machine consumer

Lift Curves



Repeatable, given priors
Estimate benefit
Cheap
Intermediate

Usability studies



Hard to repeat
Fuzzy objective
Expensive
Suited to human consumer

Topics for Multi-Biometric Research

Paul Griffin

Chief Technology Officer, Identix Corporation
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September 20, 2004

Problem #1: Border Security

- Multi-biometric systems are too expensive for most IT and PAC applications.
- However, many countries are likely to adopt multi-biometric systems for border security where high throughput makes MB systems cost effective.

United States	Finger (1+1)	Face
European Un.	Finger (1+1)	Face
Japan	Iris?	Face
United Kingdom	Finger	Face
Korea	Finger	Face
Canada	Finger	Face
Israel	Hand or None	Face
Australia	None	Face

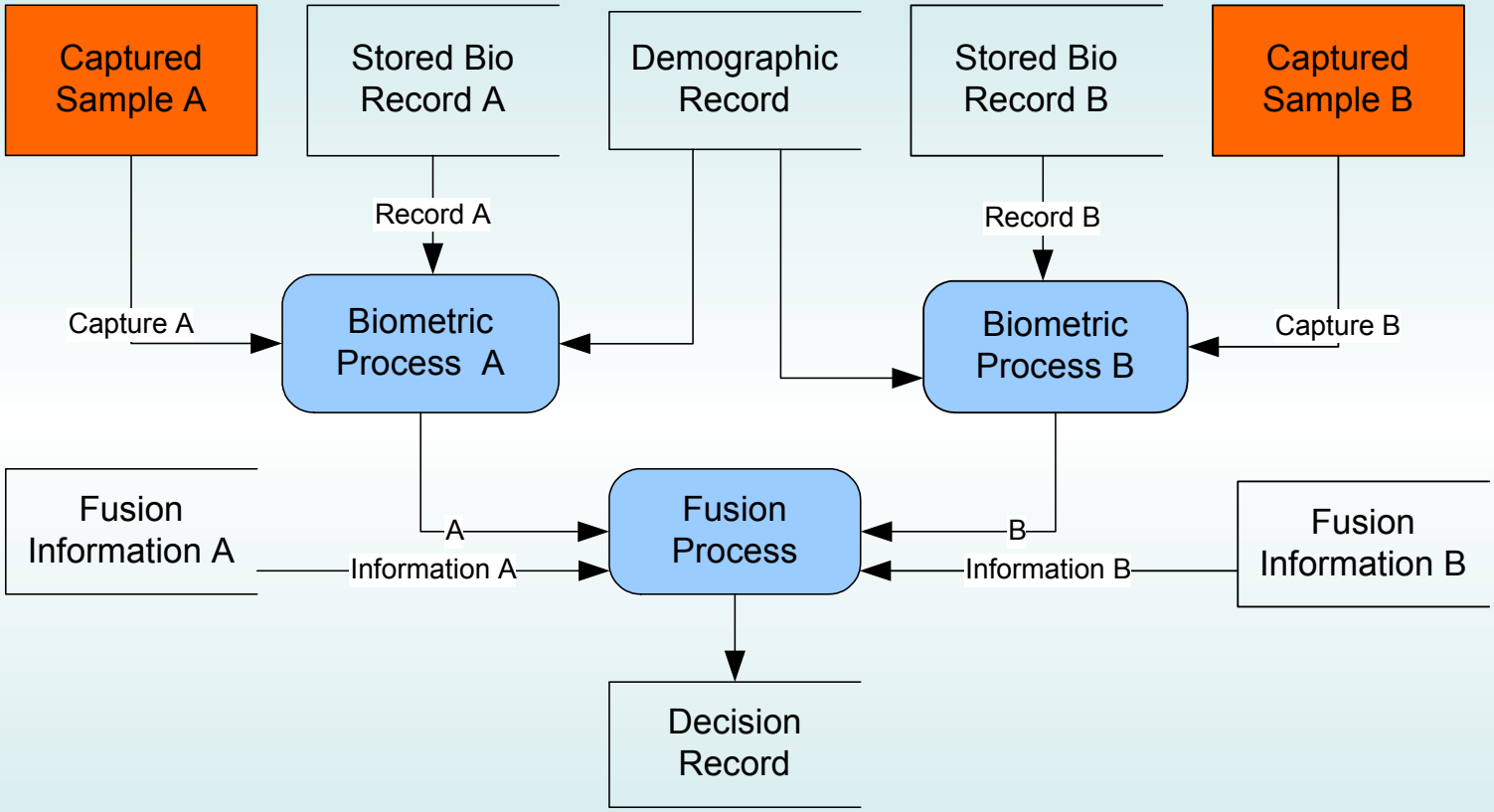
Problem #2: Sensitive Information

- There is a limited market for biometric systems for access to sensitive information.
- A typical requirement is FAR<.01% and FRR<.1%.
- No single “known” biometric can achieve this.
- For these markets, high cost ($1000) can be justified for “C2” certified biometric systems.
- Certification would consider fraud prevention, overall system performance as well as raw biometric performance.

Topic 1. Risk Analysis

- Generating an ROC or CMC curve is only half the solution. One also has to determine the operating point on that curve!
- Risk analysis is a well defined topic in statistics. The field of biometric statistical analysis would address the problem of reducing risk using biometric systems, and determining systems which minimize risk problem statements.
- This topic would be a collaborative effort between experts in biometrics, sociology, statistics, and government.
- Relevant to multi-biometric systems because performance is a driving factor in system development. Performance reduces risk/cost.
- The problem should drive the choice of biometric in a well-defined way. How is this quantified?
- Expertise in pattern matching and MatLab is not required.

Topic 2. Fusion



A fusion process must be determined for every use modality - verification, closed set identification, open set watch-list, etc.

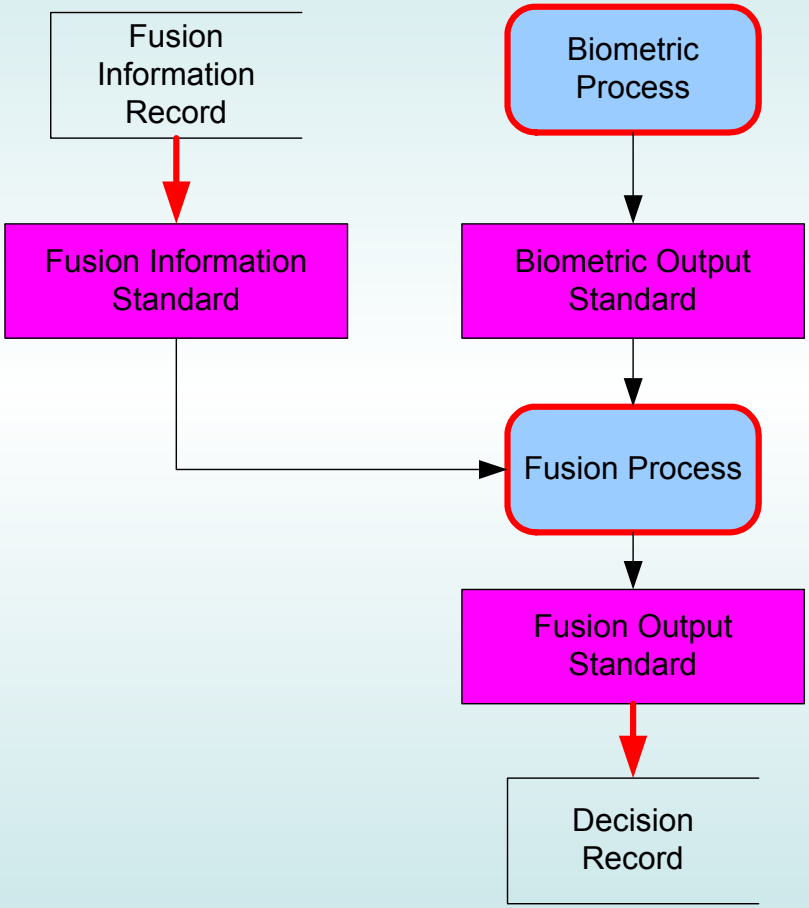
Fusion (continued)

- While the Bayes and Neyman Pearson theorems provide roadmaps for decision making in Verification, the useful instantiation of optimal fusion for each biometric modality is incomplete or non-existent.

Process	Correlation	Deterministic Optimal Fusion Methodologies Proposed?
Verification	None,Weak,Strong	Yes, No, No
Identification	None, Weak, Strong	No, No, No
Watchlist	None, Weak, Strong	No, No, No

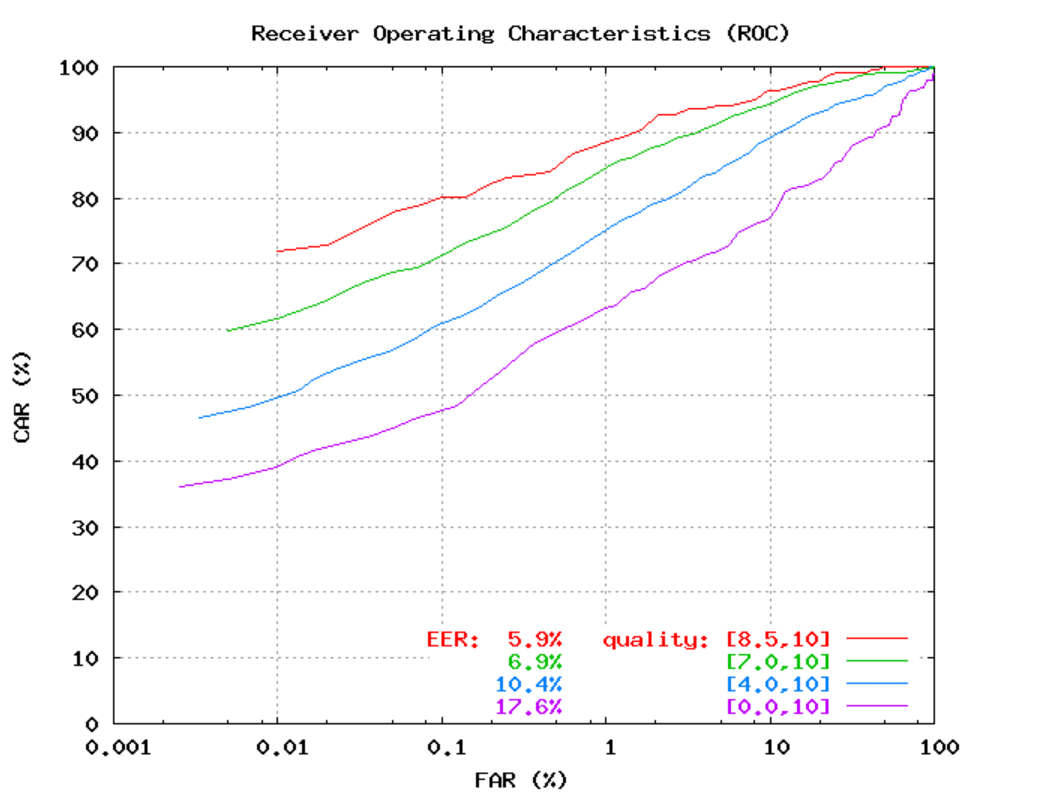
- While many ad-hoc experiments have been performed, the real theoretical framework of fusion remains mostly unaddressed.
- The field may be suffering from an over reliance on computers and “canned algorithms” to solve problems via brute force.
- Significant mathematically groundbreaking work remains to be performed.

Topic 3. Mix and Match



- Because performance is expected to be so good, it may be cost prohibitive to retest a good system whenever a biometric subunit is upgraded!
- For Verification, Identification, or any other biometric modality,
  - How does one define a universal score (Biometric Output)?
  - What information is truly required to “plug in” a biometric? (Fusion Info)?
  - What is the correct biometric independent score (Fusion Output)?

Topic 4. Fusion and Quality



- Most fusion approaches developed in the laboratory assume reproducible measurements of the True Acceptance Rate.
- However, the TAR is notoriously sensitive to sensor/capture quality

How does one properly couple Fusion with Quality?

–Use “Quality Invariant” Fusion Parameters, such as the FAR?

–Predetermine the Fusion models as a function of reproducible Quality Factors?