Multi-Modal Combination using the Biometric Gain Concept

Nigel Sedgwick

Cambridge Algorithmica Limited
9 Oakdene
Beaconsfield
Buckinghamshire
United Kingdom HP9 2BZ

Tel: +44 (0)1494 678989
URL: http://www.camalg.co.uk
Fax: +44 (0)1494 678990
Email: ncs@camalg.co.uk

Overview of Presentation

1. What is Multi-Modal Combination?
2. Benefits
3. Example of Need: Detection of Multiple Applications (DMA)
4. Costs and Problems
5. Biometric Gain: the Concept
6. Score Normalisation: What it Does
7. Example Performance: Face with Hand Geometry
8. Status of Standardisation of Multi-Modal Combination
9. Claims of Which to be Wary
10. What should We be Doing: Just Now and Soon?
11. Conclusions

What is Multi-Modal Combination?

Using 2 or more different biometric modalities, together, in deciding whether the subject is genuine or an impostor.

Examples are: iris combined with fingerprint; face combined with hand geometry.

*Other **Multi-Biometric** vocabulary terms include:*

multi-instance: combining more than one separate instance of the same biometric modality; eg fingerprints from 2 or more different fingers

multi-algorithmic: processing the same biometric sample with 2 or more pattern-matching algorithms, and combining the results

repeated instance: capturing the same biometric instance (eg a single fingerprint) more than once, to reduce image capture errors, and combining the results

Benefits of Multi-Modal Combination

Improved Technical Performance, in terms of a better trade-off between False Match Rate (FMR) and False Non-Match Rate (FNMR).

Greater Universality. A greater proportion of the population of subjects will be able (and willing) to present examples of at least one of the biometric modalities. For example, those with poor quality fingerprints, amputated body parts, etc could still offer one or more alternative biometric modalities.

Greater Resistance to Biometric Avoidance Techniques. Impostors need to spoof more than one biometric device at the same time; eg gelatine false fingertips.

Other multi-biometric techniques, eg multi-instance and multi-algorithmic, also provide some of the above advantages.

Example of Need: Detection of Multiple Applications (DMA)

Consider the proposed UK National Identity Scheme and associated issue of passports.

There is a desire to prevent multiple applications passing undetected, even after 40 million people have already enrolled.

Each false match needs to be checked by non-biometric means. For extra checks on only every 10th applicant, the FMR needs to be around 0.00000025% ($2.5x10^{-7}$%).

What proportion of undetected duplicate applications is acceptable? Do we need 95% detection, or 99%, to be a good enough deterrent. Or even better against terrorist commanders. This determines the tolerable FNMR.

An operating point with 1% FNMR and 0.00000025% FMR is about equivalent to an Equal Error Rate (EER) of 0.0005%.

Costs and Problems

Capture requires multiple biometric devices, with associated procurement and maintenance costs.

Enrollment is likely to take longer, for subjects.

Longer enrollment increases costs of any supervising staff.

Multi-modal verification, if done, has similar cost issues and response time issues.

Multi-modal combination needs extra processing. Device characterisation requires pre-operational work; the computational load is much less problematic.

Templates have to be stored for each biometric modality.

Biometric Gain: the Concept (1)

It's rather like hi-fi amplifier gain; one just considers the ratio of the output to the input, of each biometric subsystem.

For verification, we use the Biometric Gain against Impostors (BGI).

$$\text{BGI} = \frac{\text{Probability of being an impostor, given the biometric evidence too}}{\text{Probability of being an impostor, given only prior knowledge}}$$

Most of the time, a very good approximation to the BGI is the Likelihood Ratio of Genuine to Impostor (LRGI). **This is used in many good pattern-matching algorithms in existing biometric subsystems.**

$$\text{BGI} \simeq \text{LRGI} = \frac{\text{Probability of seeing the evidence from an impostor}}{\text{Probability of seeing it from the expected genuine subject}}$$

Biometric Gain: the Concept (2)

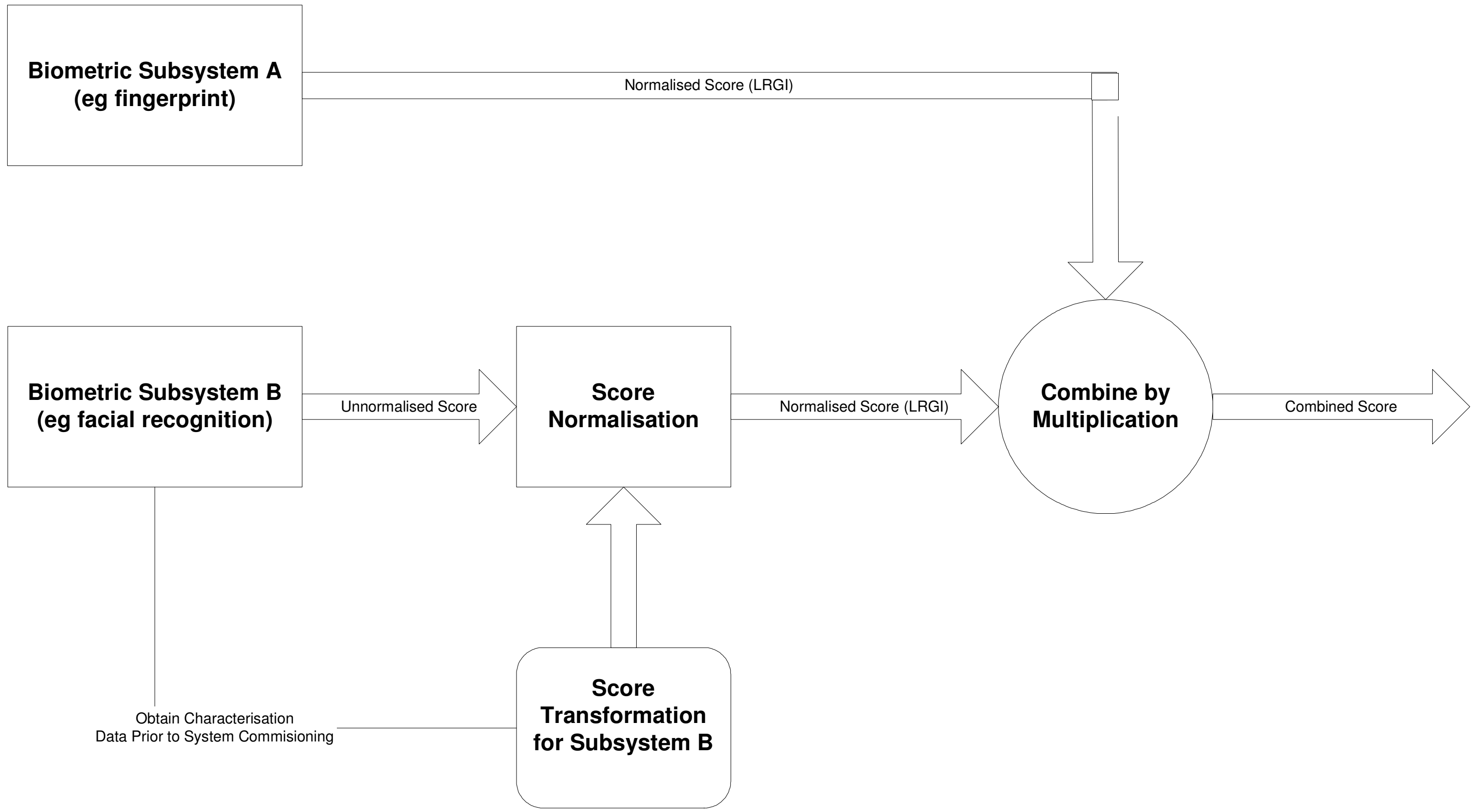
Every score that comes out of the biometric devices is transformed to the LRGI scale. This is a score normalisation process. It can be done within each biometric subsystem, or by a special multi-modal combination subsystem.

This score normalisation takes into account the intrinsic FMR/FNMR performance of each biometric device. In addition, it takes into account the quality of the particular match.

LRGIs from different biometric subsystems are implicitly normalised to the same measurement scale. They can be combined by multiplication (or by addition of the log likelihood ratios, which has dynamic range advantages).

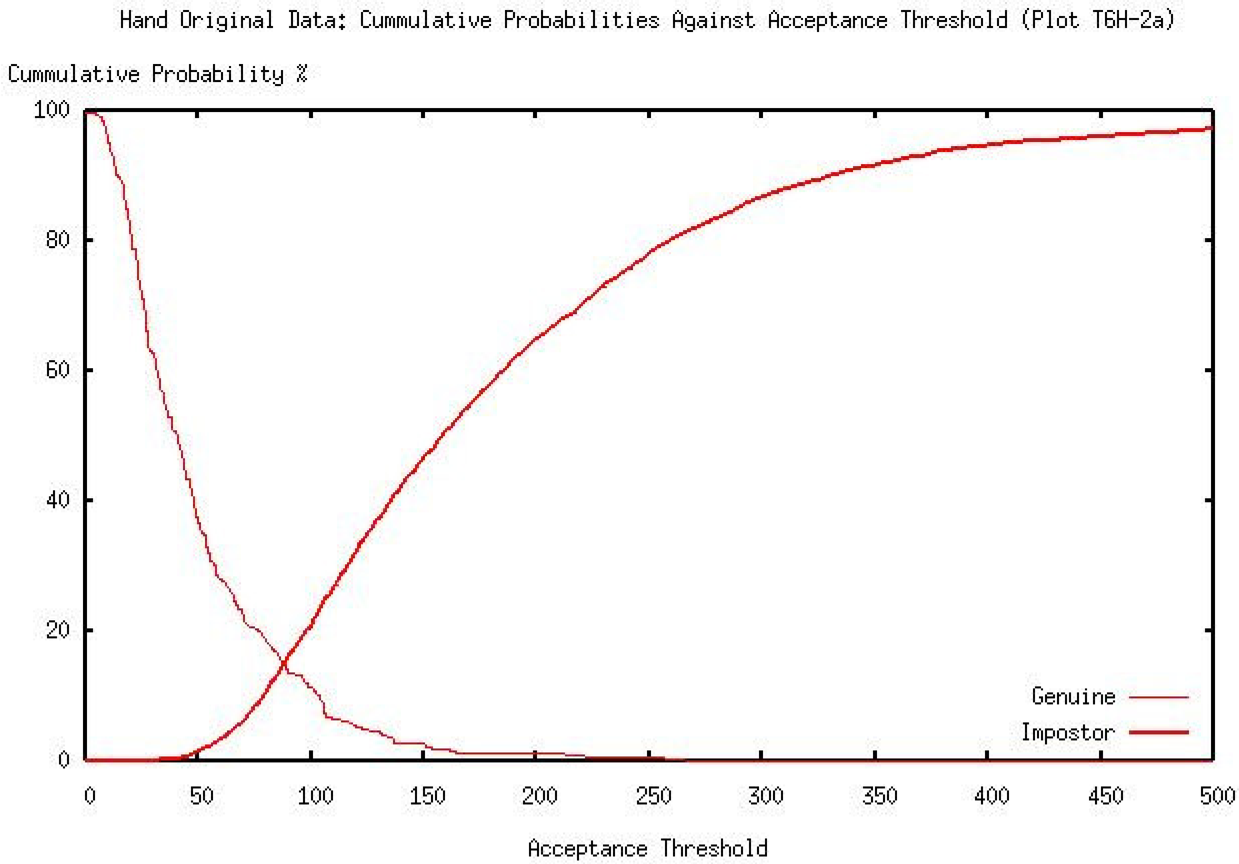
The approximation applies where the (*a priori*) probability of seeing an impostor is very small (which is usually the case). In this case, we do not need to know the *a priori* probability. This is extremely useful, as *a priori* probabilities are usually not known with any degree of confidence.

Biometric Gain: the Concept (3)



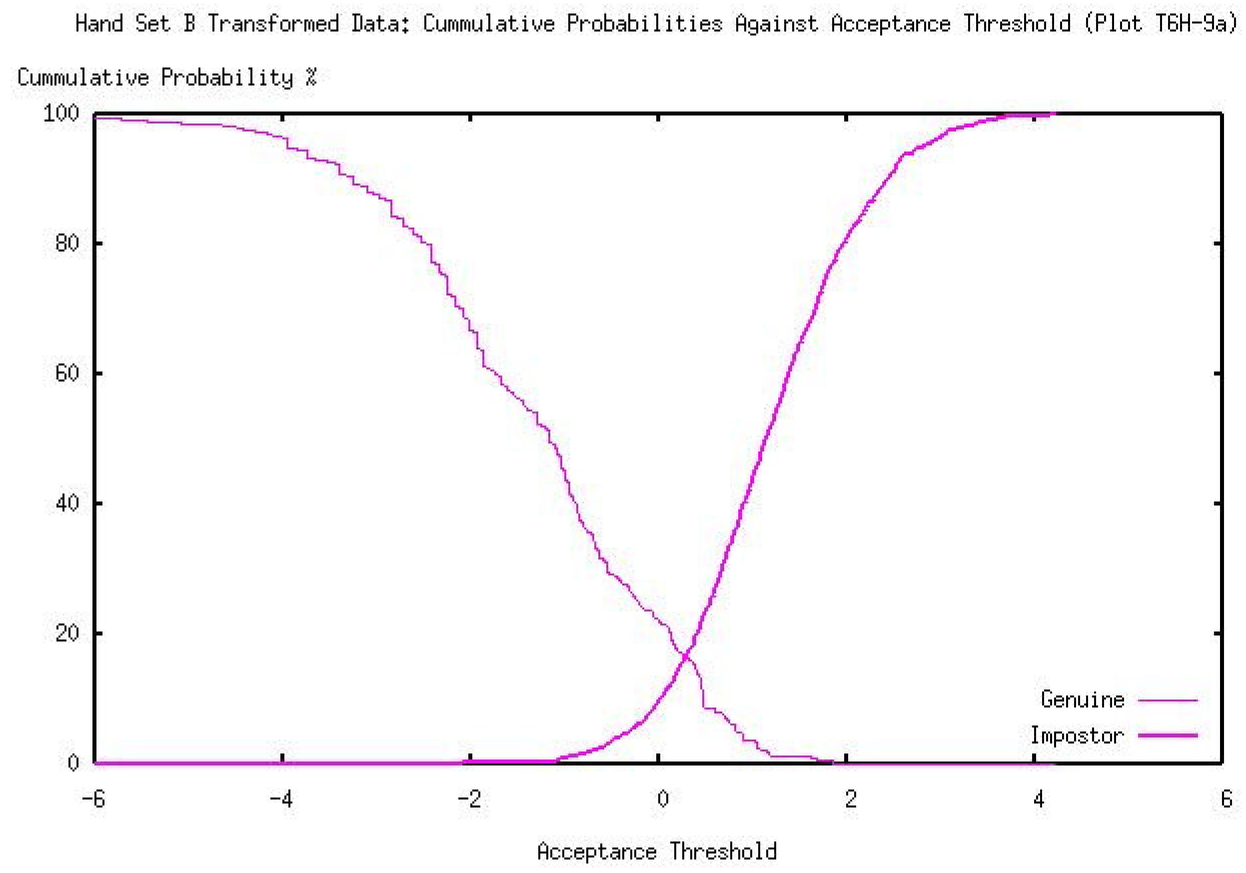
Score Normalisation: What it Does (1)

Plot of FNMR (genuine) and FMR (impostor) against unnormalised scores, for hand geometry subsystem. Note EER of 16.6%.



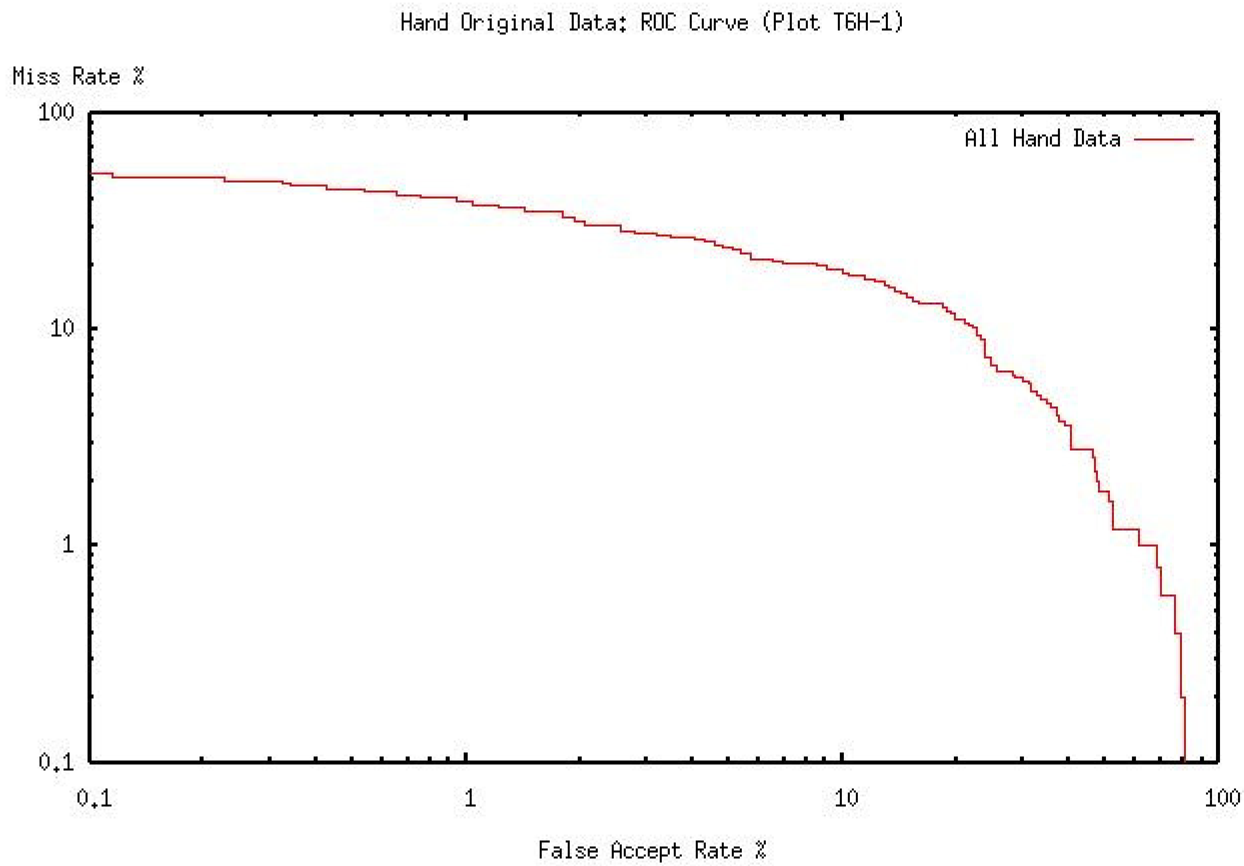
Score Normalisation: What it Does (2)

Same data for FNMR (genuine) and FMR (impostor), but plotted after score normalisation to log(LRGI). Note the unchanged EER of 16.6%.



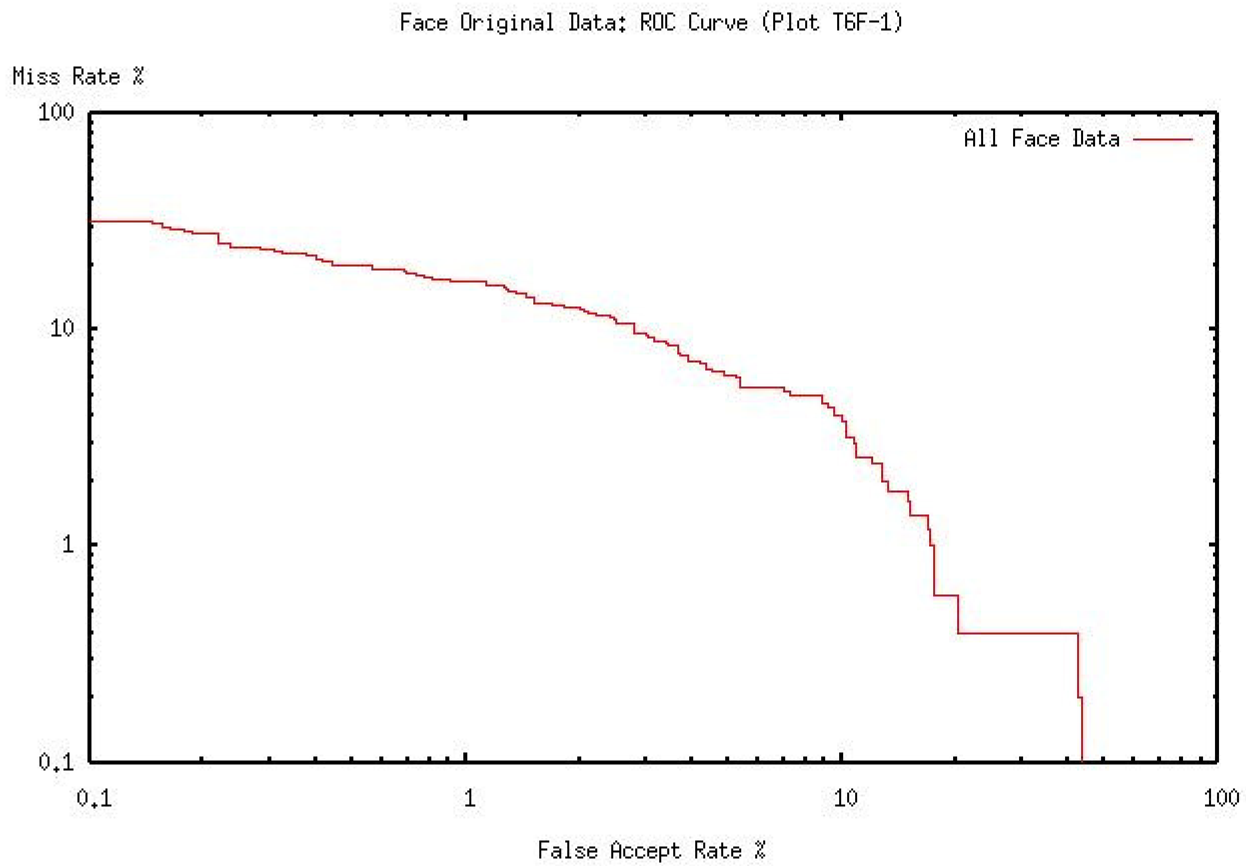
Example Performance (1)

Example Receiver Operating Characteristic (ROC) curve, in this case for Hand Geometry. ROC curves plot FNMR (or Miss Rate, vertical axis) against FMR (or False Accept Rate, horizontal axis).



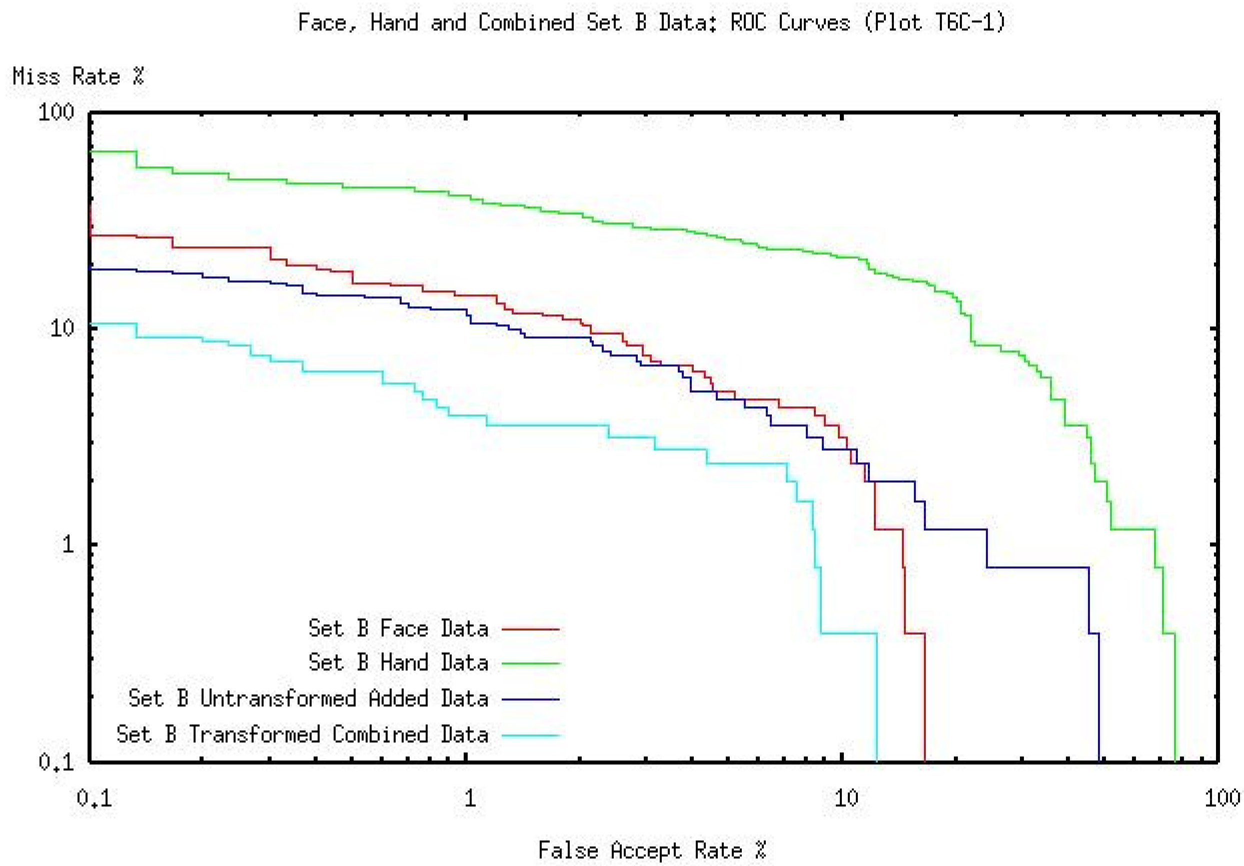
Example Performance (2)

This ROC curve, for a facial biometric subsystem, is closer to the lower left point, representing better overall performance. Thus its FMR/FNMR performance is better than that of the hand geometry subsystem shown on the previous slide.



Example Performance (3): Combination by Biometric Gain does Better

The BGI combination (light blue) gives a good improvement over the whole range of operating thresholds. BGI also does better than just adding the unnormalised scores (dark blue).



Status of Standardisation of Multi-Modal Combination

The relevant international committee is ISO/IEC JTC/1 SC/37 “Biometrics”. They have been developing several standards over the last 3 years.

On multi-modal combination, their main work is on the upcoming technical report (type 2), ISO 24722 (draft), entitled “Technical Report on Multi-Modal Biometric Fusion”.

Work was approved in February 2004 and the first working draft was circulated in August. It was decided not to work on an international standard straight away, as the technology was felt to be insufficiently mature.

My personal expectation is that the technical report will be issued in 2006, and that work will progress almost immediately towards preparation of an international standard.

Claims of Which to be Wary

Decision combination is a good enough approach. This is an alternative to score combination, as used with Biometric Gain. Decision combination ignores the quality of each particular match. It performs much less well than good approaches that use the scores.

Correlation of scores invalidates simple combination approaches. Much concern is expressed over this for multi-algorithmic and multi-instance combination too. However, even though the theory is not yet thoroughly understood, there are good reasons to believe some simple score combination approaches, like Biometric Gain, give useful and consistent performance improvements.

Biometric Gain, and related approaches, require too much characterisation data. They do require characterisation data, and there are complications concerning population dependences. However, the same sort of data is required to plot ROC curves, and so properly measure performance. Such data is already available in most serious applications of biometrics.

What should We be Doing: Just Now and Soon?

Manufacturers and Systems Developers. Make available scores using both raw values and with LRGI normalisation. Consider making available, raw ROC data for device characterisation. Expect some large procurers to require score normalisation defined by independent evaluation laboratories.

Government and Large Users. Consider seriously the use and implications of multi-modal and multi-instance combination, especially for Detection of Multiple Applicants and for very high-security verification applications.

Other Organisations Operating Biometric Systems. Be aware of the possibilities. Note increased costs and transaction times are unlikely to be warranted for most small- and medium-scale applications. Here multi-instance is often more appropriate than multi-modal.

Standards Bodies. Provide multi-modal standards for large-scale implementations. Define standards for device characterisation data.

Conclusions

Multi-modal and other multi-biometric combination can reliably improve FMR/FNMR performance.

There can also be improvements in universality and in making attacks more difficult.

There are usually additional costs associated with equipment procurement and increased transaction times.

Score combination, using a sound statistical approach such as Biometric Gain, is the best technical approach.

Such approaches require characterisation data for each biometric device. This can come from manufacturers or from independent evaluation laboratories. Large operating organisations could derive their own data.

The field of multi-biometrics is evolving; it also has some technically complicated detailed aspects. Expert advice should be sought, by those who cannot justify acquiring a full in-house capability.