Image Enhancements, Biometric (Sample) Quality and Recognition Accuracy

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NIST Biometric Quality Workshop II

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Outline

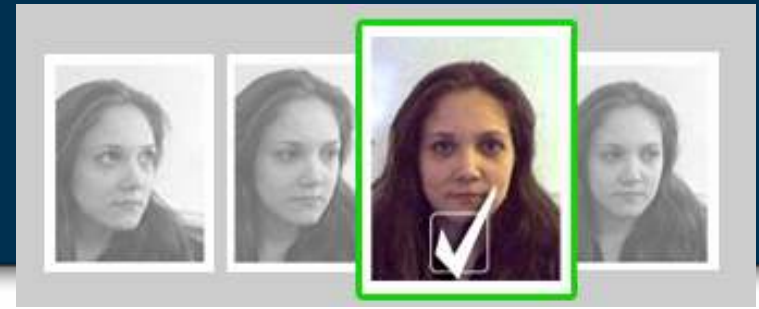- **Image Quality and Recognition Algorithms**
  - Relationship between the Quality and Recognition Algorithm

- **Image Quality Enhancements**
  - What types of quality defects are easily recoverable?
  - What are the options when there is missing information?
  - What is the impact on recognition performance when enhancements are applied?

- **Speculating on Future Quality Algorithms**
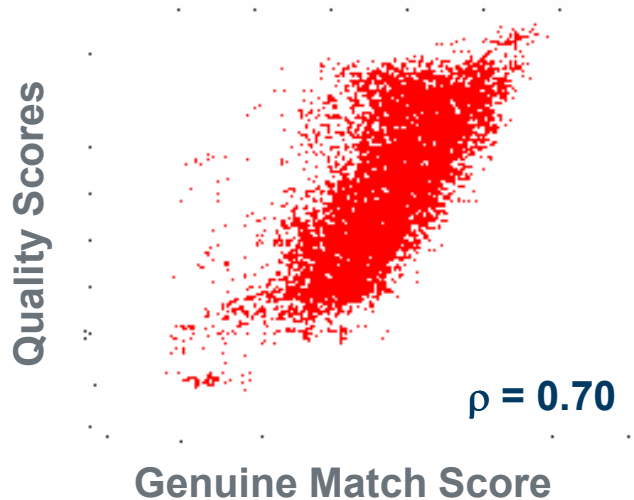
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Biometric Quality Review

- **The definition of quality is subjective and relative; here we focus on quality assessment algorithms designed to predict match performance**

    - A human's definition of quality is often different than the machine's
    - We recognize there is a place for human based quality metrics -- manual verification of faces, manual adjudication of fingerprints, and biometric sample printing

- **Several quality assessment approaches have been shown to be effective at indicating match performance. These are ideal for**

    - Enrollment feedback
    - Fusion weighting
    - Estimating system performance

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Quality Metrics Predict Match Performance

Iris

Quality Scores

Genuine Match Score

ρ = 0.70

Face

ρ = 0.75

Finger

ρ = 0.67
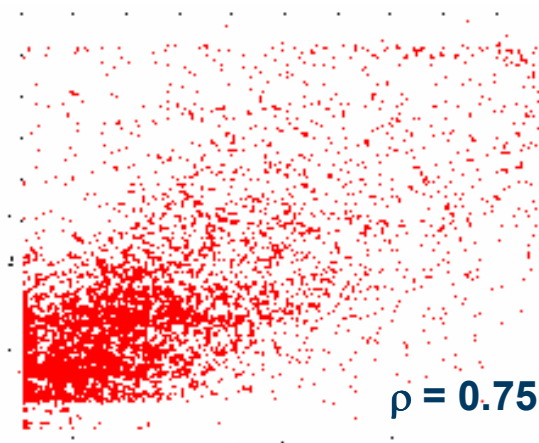
- **Linear combination of several factors, primarily:**
  - Intensity
  - Iris area
  - Focus
  - Pupil and Iris Diameter
  - Texture Energy
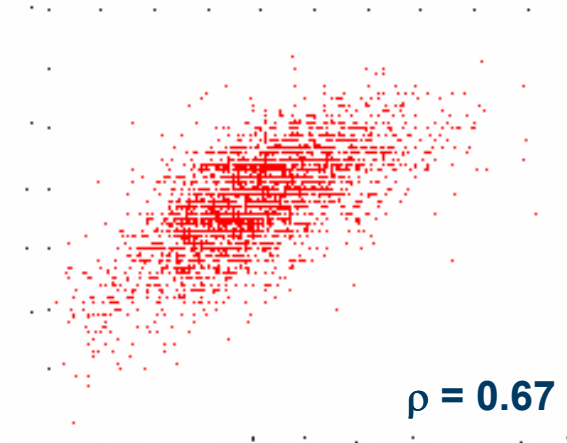 - Gaze Angle

(ρ is the correlation coefficient)

- **27 metrics combined though a NN. Quality checks derived from ISO 19794-5 Requirements**
  - Contrast
  - Lighting/Shadows
  - Resolution
  - Focus
  - Pose
  - Eyes Open
  - Glasses present
  - Etc…

- **Rules based combination of several factors including:**
  - Ridge clarity
  - Number of minutiae in reliable area of print
  - Area of good ridge quality
  - Etc..

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Image Quality and Recognition Algorithms

- **This match performance predictability is not surprising when the quality algorithms are built to correlate with match performance**
  - The quality metric learns the capabilities of the matcher and which factors prevent optimal matching
  - The quality algorithm becomes sensitive to the quality defects the matcher can not cope with
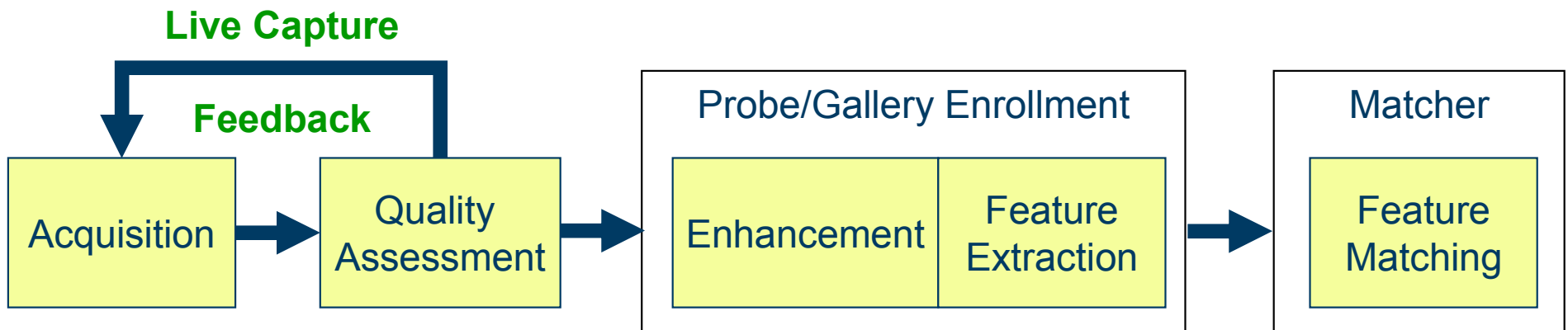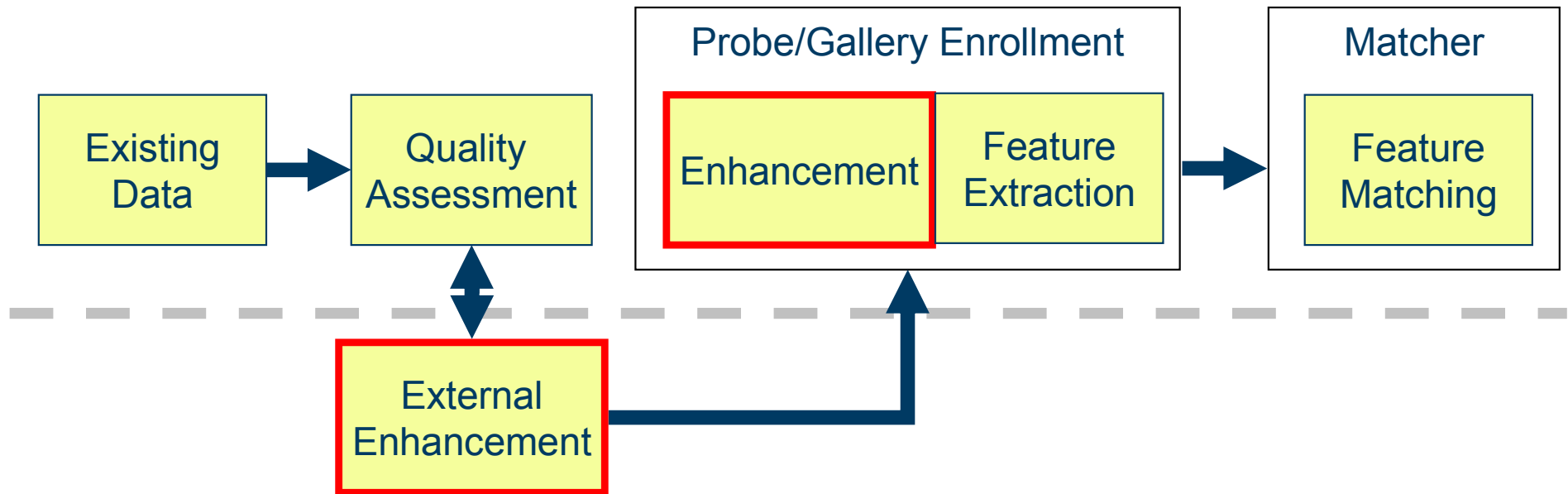
Live Capture

Feedback

| Acquisition | → | Quality Assessment | → | Probe/Gallery Enrollment: Enhancement \| Feature Extraction | → | Matcher: Feature Matching |

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Image Quality and Recognition Algorithms

- **What can we learn by looking at quality in a 'forensic' application?**

- **Here quality measures are used as feedback for humans applying 'extra' enhancements to images in an attempt to improve match accuracy**
  - Humans tend to generate only aesthetically better images
  - Quality metrics are not foolproof in this scenario
- **We may know what quality factors are important in matching, but which sample enhancements are effective at improving match accuracy?**
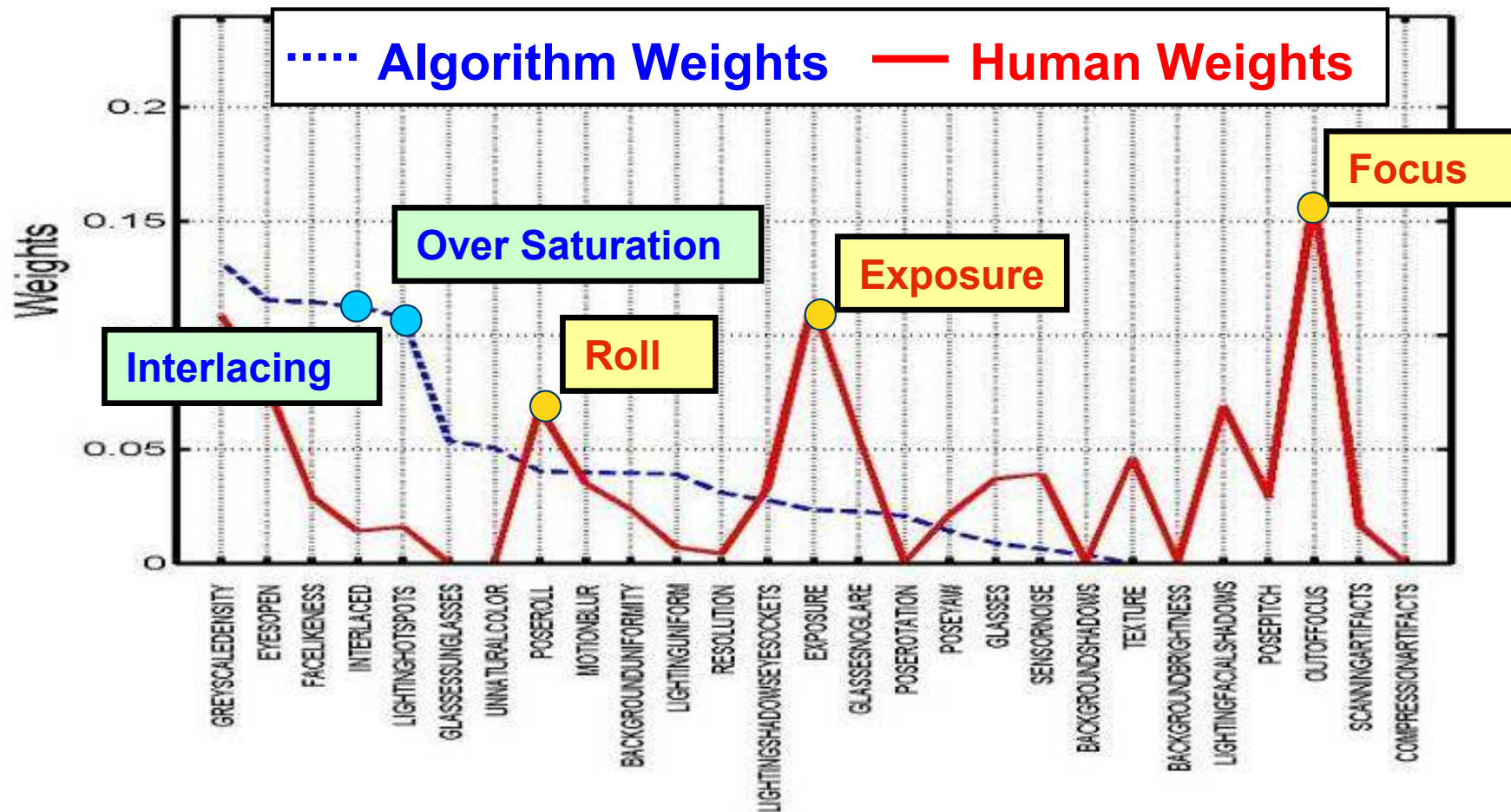
Which sample is better?

This image is under exposed….
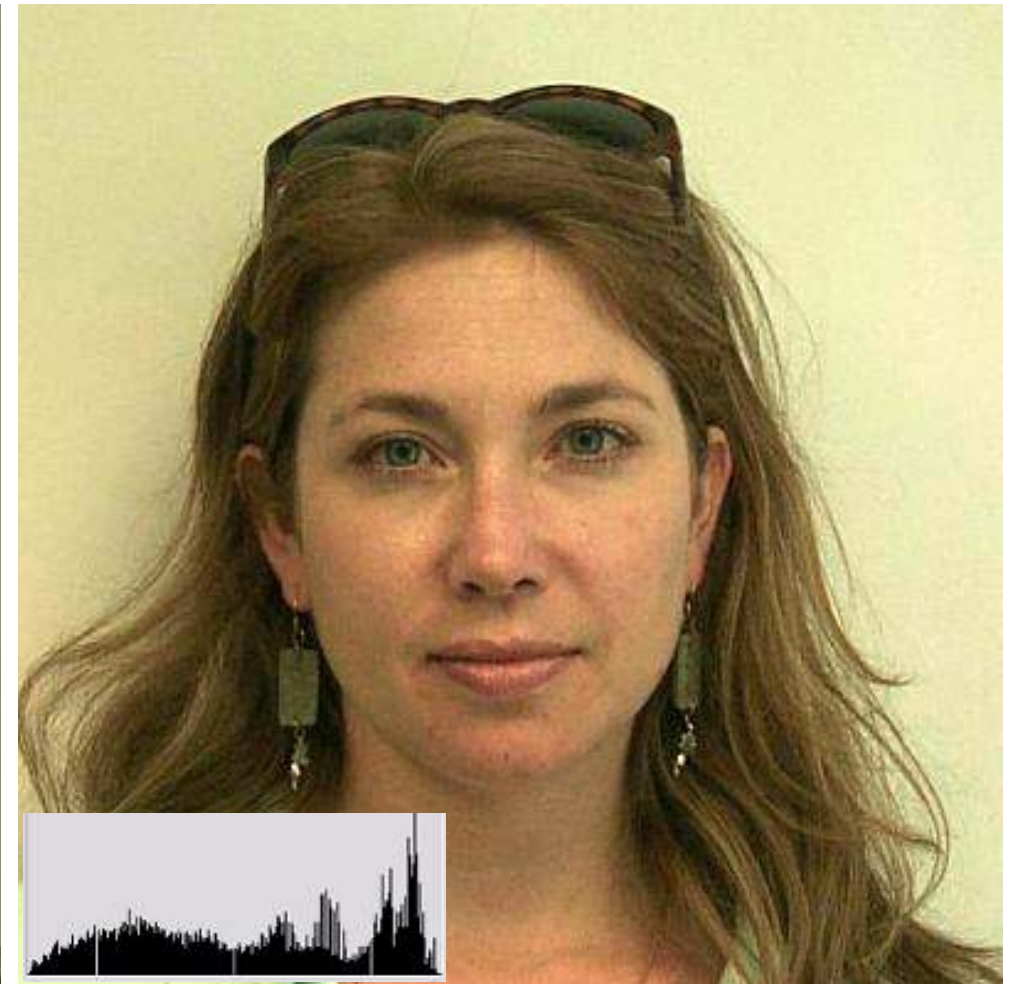
… the same image exposure adjusted and sharpened… it looks the same to the matcher

Perception of Face Quality

- We studied the different factors of face quality for humans and machines and found the following weights per quality factor:

Common (Easy to Perform) Enhancements

- **Common transformations and enhancements (applied by humans)**
  - **Rotation, translation and cropping**
    - Over cropping may hurt registration
    - Rotation is sometimes helpful for registration/or speeding up matching
  - **Down-sampling or up-sampling data to get the desired resolution**
    - May help registration in some cases.. But typically not recommended
  - **Adjusting the sharpness, white balance, brightness or contrast**
    - Most algorithms do what is needed internally
- **De-interlacing, which is often overlooked, may be helpful**

De-Interlace
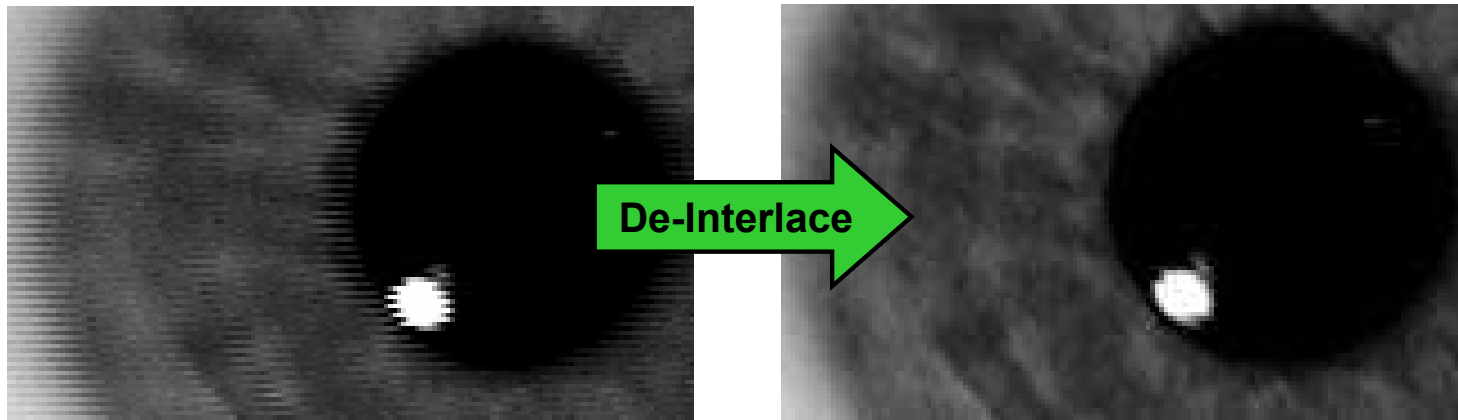
Illumination Correction

- Specialized illumination correction can benefit match performance
  - Better registration
  - Normalizing feature characteristics
- <u>NOT the same as adjusting the brightness and darkness</u>
- Over/Under saturation (complete loss of information) cannot be corrected, but is renormalized to allow proper functioning of the match algorithm's intensity normalization

- Efficient illumination correction is usually performed inside the match algorithms, but sometimes you may be able to do better than the native enhancement…

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Advanced Enhancements

- **What are the options when trying to recover or estimate lost sample information?**
  - Piece together information from multiple samples
  - Use prior knowledge about the sample, capture system, or class of data
- **Information loss (low fidelity capture or behavioral issues) is often due to**
  - Out-of-focus, motion blur, insufficient image resolution, etc…
  - Occlusions (reducing possible information overlap)
  - Severe sample misalignment and potential lack of sample overlap
  - Capture system equipment deficiencies, configuration, over compression
  - Behavioral issues that reduce match-able data
  - Print patterns, watermarks, scanning artifacts, background or foreground interference, scans of damaged photos/prints and deterioration from sample replication
  - Etc…
- **Let's look at some methods that compensate for these issues…**

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Increasing S/N and Resolution (in Video)

- **If you have a video sequence you can use multiple frames to reduce noise and gain some resolution**
- **Marginal improvement in accuracy compared to matching all frames independently, but good visually**

Improving Sample Overlap (Multiple Samples)

- **The concept of creating a Mosaic from multiple instances of the sample can improve performance and can reduce storage requirements for gallery data**
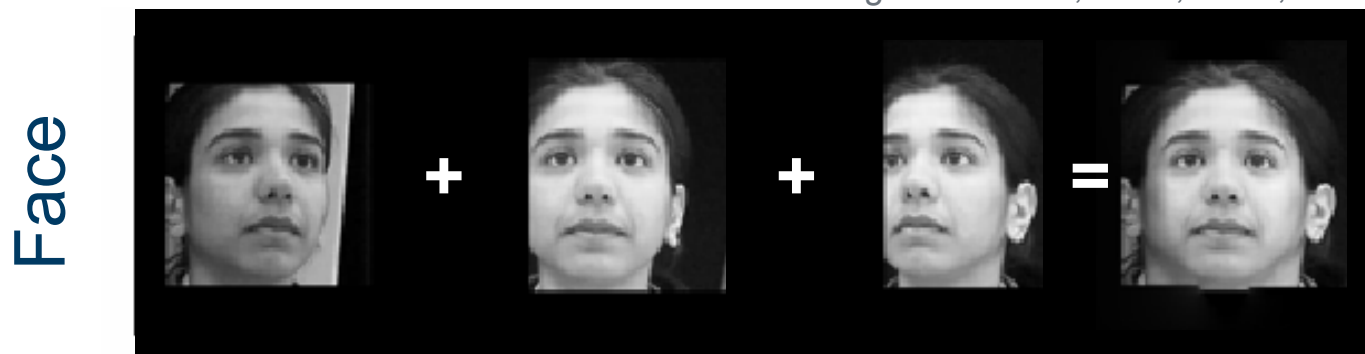

Finger

Image from Ross, Shah, Shah; SPIE

Face

Image from R. Singh, M. Vatsa, A. Ross and A. Noore

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Improving Quality with a Single Sample

- **Use prior knowledge about the biometric class to make a best guess at any missing information**
- **A common example is a minutiae extractor's internal enhancement**
  - This enhancement is possible due to the expectations of ridge structure

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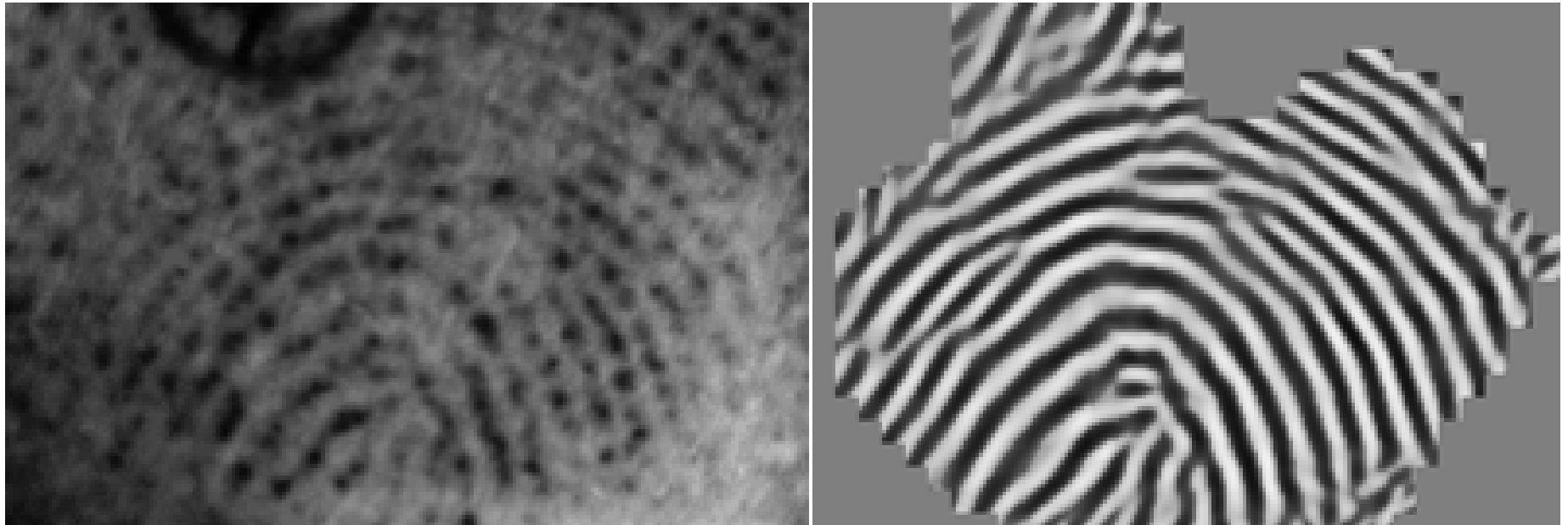
(Externally Applied) Ridge Enhancement

- Like with the illumination correction, if you have a better enhancement, you can use it in addition to existing enhancements (for lights-out latent)
- Here, we apply an enhancement that looks at multiple flow components simultaneously and picks the one that looks most like a fingerprint
- Note: These types of enhanced images will not work properly with NFIQ

Original Image

Multi-Flow vs. Internal Enhancement
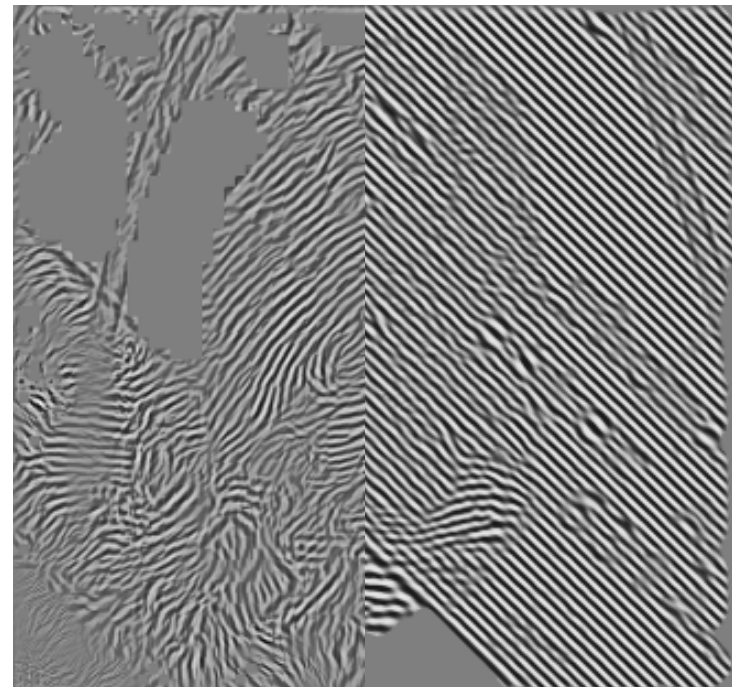
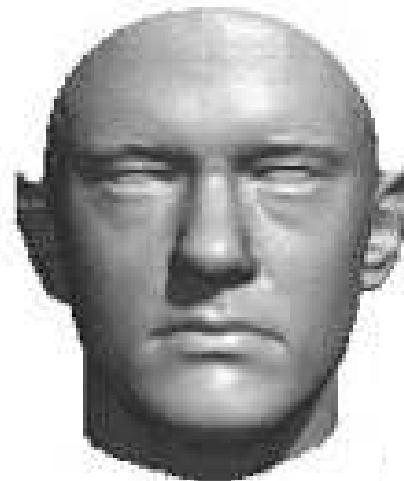# Pose Compensation

- Many face recognition algorithms do not match well at strong (yaw and pitch) pose
- Again we employ models, this time to moved from 2D to 3D and back to 2D to estimate the frontal view (or optionally render several views)
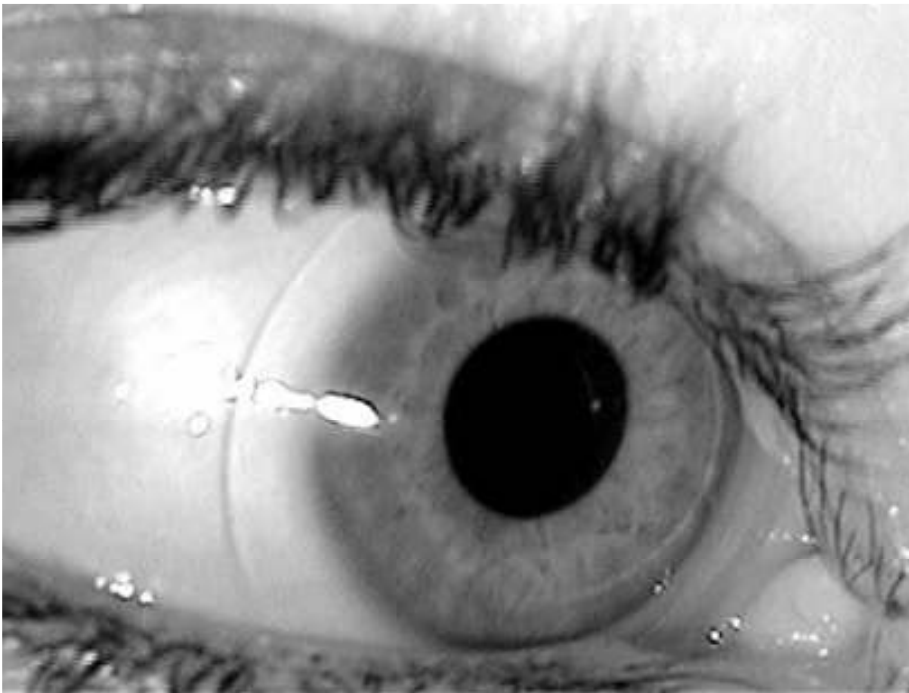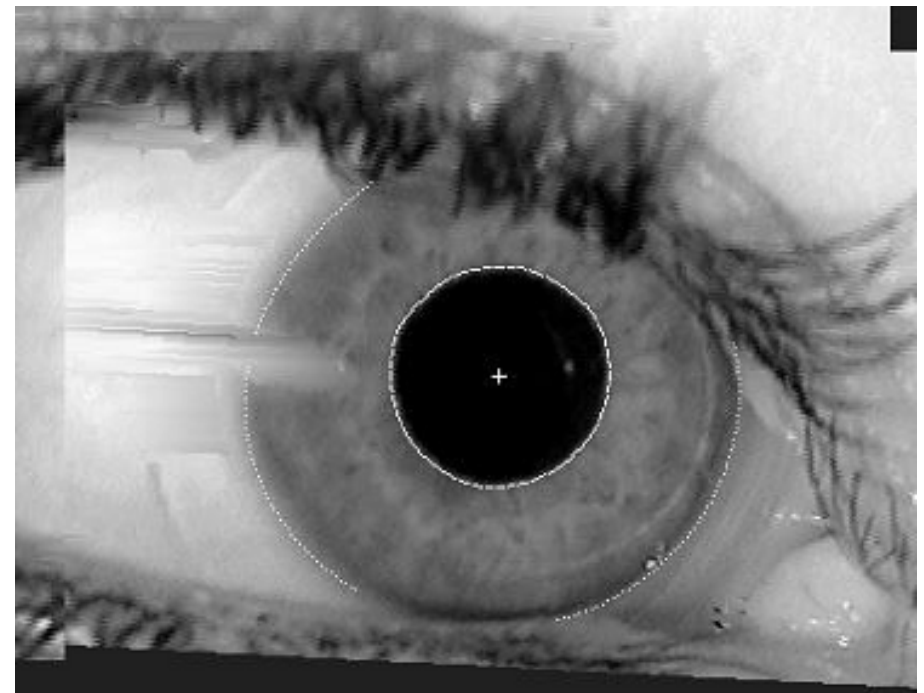- This can be very effective (see FRVT 2002)

Original →→→ Frontal Render

Images from Vetter, T. and Blanz, V.

Off-Axis Gaze

- **Iris matchers can deal with off-axis gaze with a similar approach:**
  - Detect the gaze (a quality factor)
  - Re-render the iris to frontal gaze
- **Some iris algorithms can correct the gaze automatically**

Original

Frontal Render

Automatic results from Daugman07 algorithm

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Periodic Artifact and Half-tone Removal

Original

Enhanced

- Removing half-tone-like patterns does not always improve recognition accuracy (depends on scale of face)
- However, in some cases it will remove the non-face related correlations which can lead to false matches
- This can be performed automatically in some cases

Original

Enhanced

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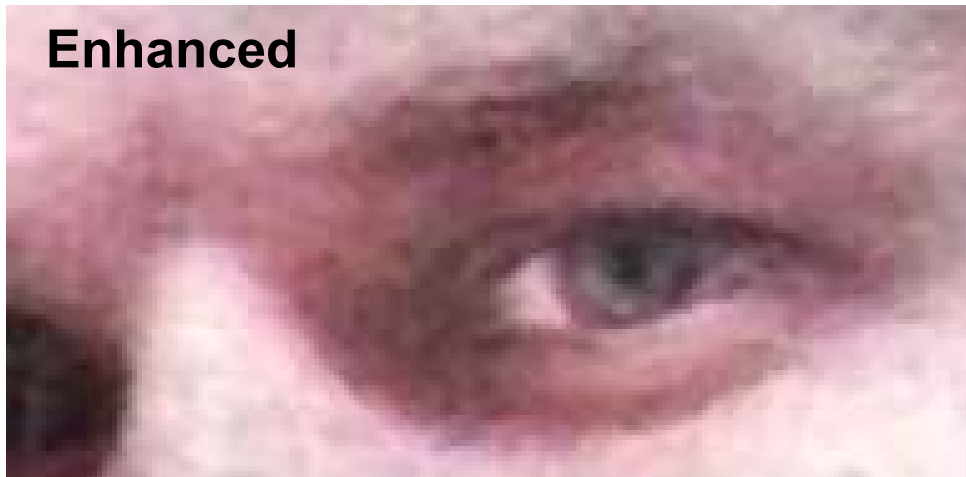
Manual Markup of Occlusions

- **Correct masking (and segmentation) of face, finger, and iris positively impact performance.**

- **Detection of occlusions is a valuable quality factor**
  - hats-on
  - glasses-glare
  - noisy background
  - eyelashes or eyelid occlusions
  - Etc..

- **Automatic masking cannot compete with even an untrained examiner. Human sample markup typically improves performance**
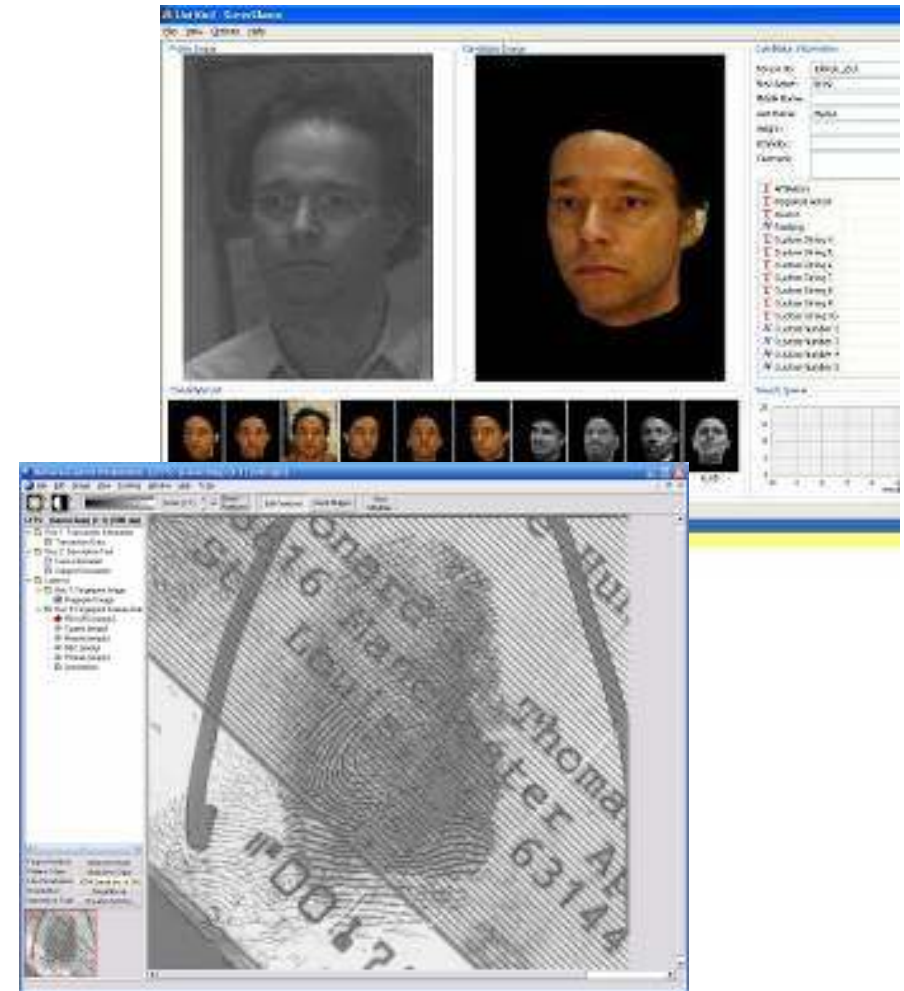
Workstations for Manual Markup

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Future Quality Metrics (Tying this all Together)

- Returning to the topic of quality… biometric quality algorithms are effective at predicting match performance because they detect sample flaws <u>**AND are aware of matcher capabilities**</u>. This awareness tightly couples quality metrics to match algorithms.

- <u>**The definition of quality is not static.**</u> Image enhancements, like the ones presented here, will eventually find their way into enrollment algorithms. The relationship between quality and match technology suggests that Quality metrics will need to evolve with the match technology

- Will biometric quality evolve into a universal quality measure?
  - Yes, if match technologies asymptote to the signal processing and statistical limits. Quality assessment will likely become <u>more</u> interoperable and quality will likely become a measure of relevant information loss
  - No, if there remains a large technology gap between vendors. A single quality algorithm will not be a great predictor of match performance in general. A quality standard will require vendor IDs, calibration sets, etc..

End

Thank you.

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