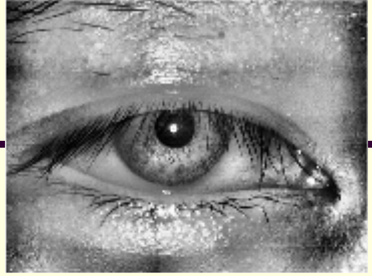



Altered Biometric Data

Arun Ross

Professor

Michigan State University

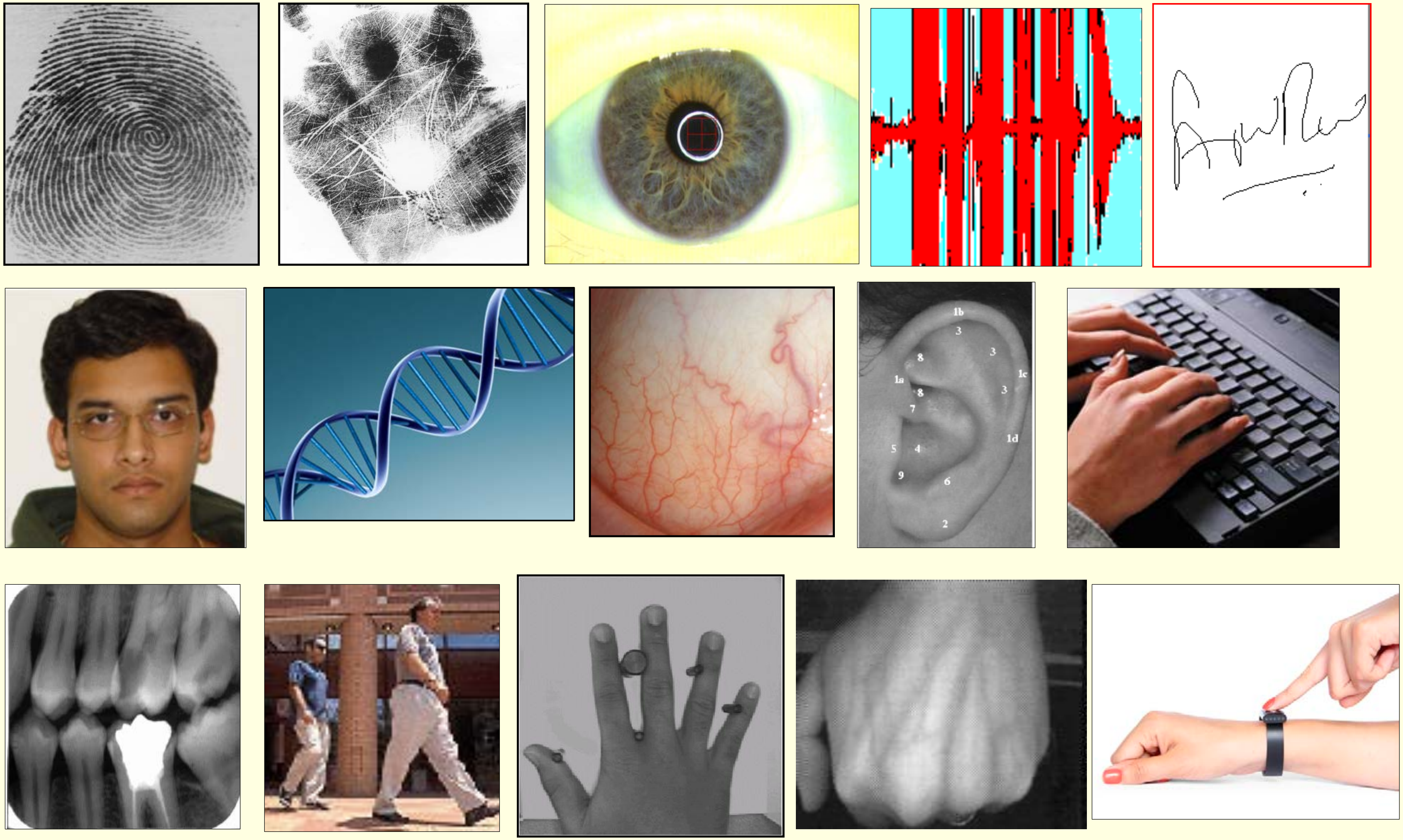
http://iprobe.cse.msu.edu/

Biometrics

- Automated recognition of individuals based on their **biological** and **behavioral** characteristics
- Traits from which **distinguishing**, **repeatable** features can be extracted

H.T. F. Rhodes, Alphonse Bertillon: Father of Scientific Detection, 1956

Biometric Traits

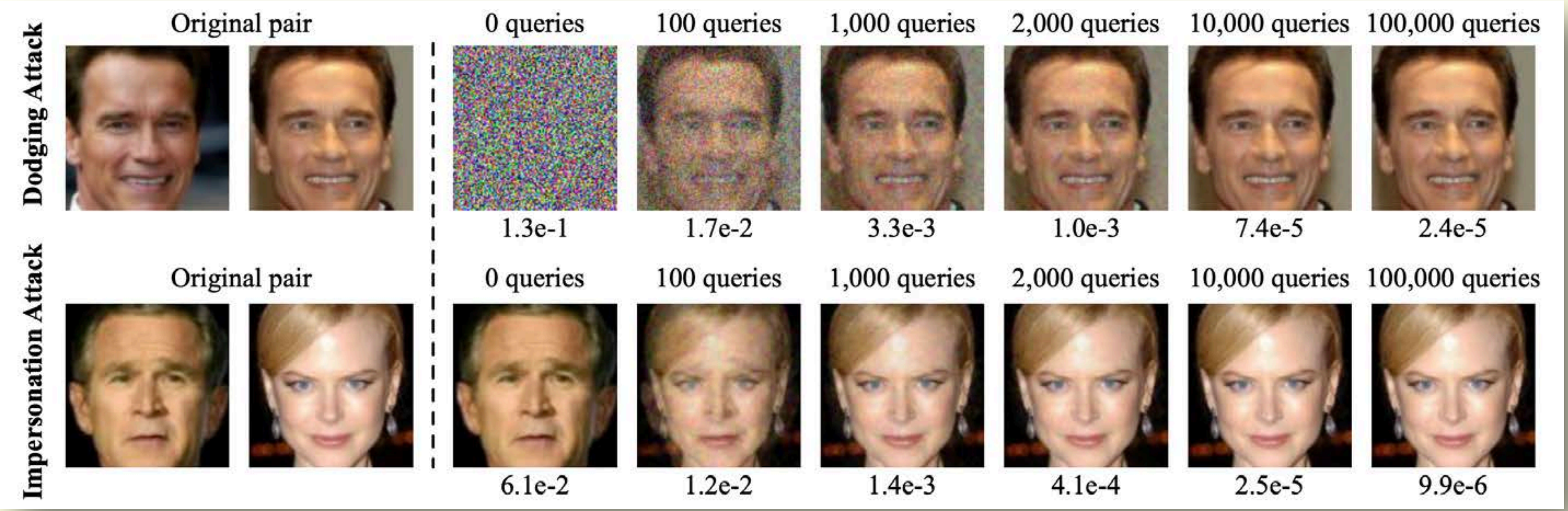


Biometric Matching/Comparison

- Given two biometric samples, estimate two numbers:
  - the likelihood that they are of the same person
  - the likelihood that they are of different people

Altered Data: Blackbox Attacks

- Black-box Attacks



Dong et al, "Efficient decision-based black-box adversarial attacks on face recognition", CVPR 2019

Altered Data: Physical Attacks

- Presentation attacks: face masks
- 3D printed glasses: for dodging and impersonating others
  - Sharif et al., "Accessorize to a crime: Real and stealthy attacks on state-of-the-art face recognition, 2016
- Adversarial patches printed on T-Shirts to evade detectors
  - Thys et al., "Fooling automated surveillance cameras: Adversarial patches to attack person detection," CVPRW 2019

https://syncedreview.com/2019/04/24/now-you-see-me-now-you-dont-fooling-a-person-detector/

Real-world Challenges

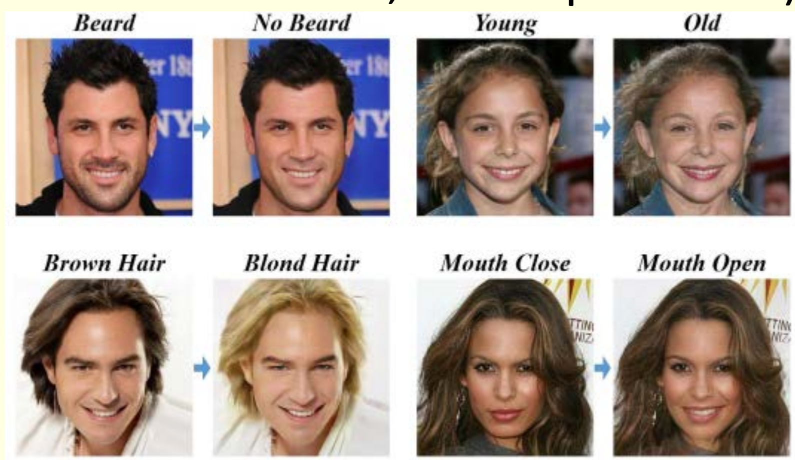
Motivation – Why is the focus on biometric images?

- Widespread use of Photoshop and Snapchat filter on face images
- Deep learning-based manipulations are increasingly prevalent (attribute modifications, makeup transfer)

https://neurohive.io/en/news/adobe-trained-a-neural-network-that-detects-photoshopped-faces/

Media forensics

https://www.hindawi.com/journals/tswj/2013/795408/



https://arxiv.org/pdf/1711.10678.pdf

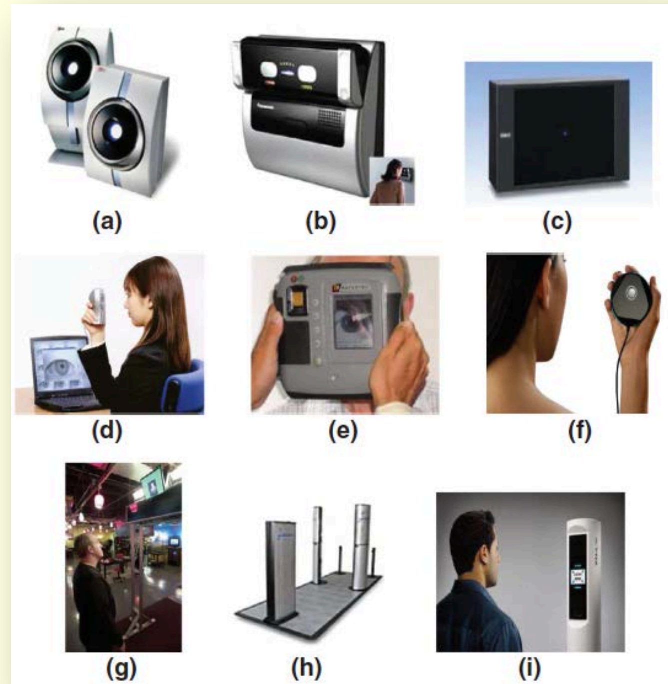
Image Forensics

- **Origin:** Which sensor produced this image?
- **Altered**: Is this an altered image?
- **Relationship:** How are these images related?

From Image to Sensor

IMAGE

SENSORS



Unit Level versus Brand Level

Banerjee, Ross, "Impact of Photometric Transformations on PRNU Estimation Schemes: A Case Study Using Near Infrared Ocular Images," IWBF 2018

Sensor "Noise"

- Pixel Non-Uniformity:
  - Shot noise (random component)
  - Fixed Pattern noise (deterministic component)
- Fixed Pattern noise:
  - Dark-signal non-uniformity (DSNU)
  - Photo-response non-uniformity (PRNU)

General Approach

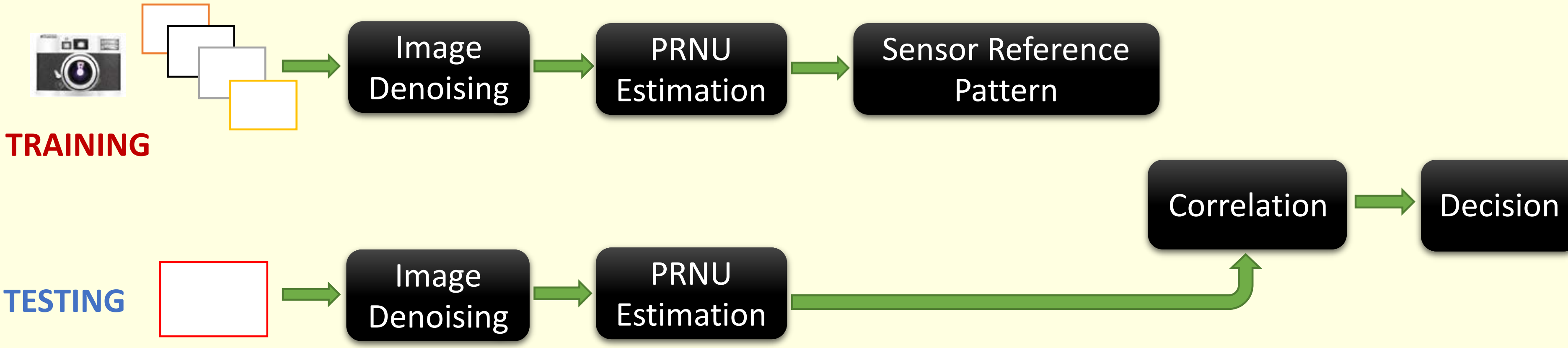
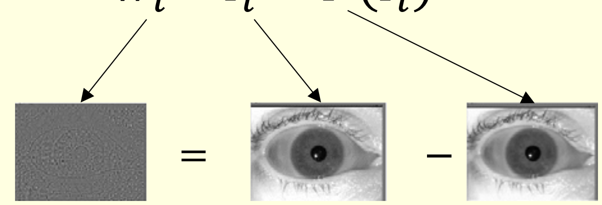


Image Denoising : Extract the PRNU, w_i from an image I_i using a denoising filter, $F(\cdot)$ to suppress scene influences

$$w_i = I_i - F(I_i)$$

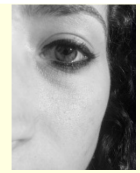
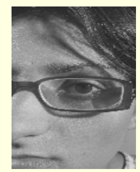
$F(\cdot)$ can be wavelet-based filter



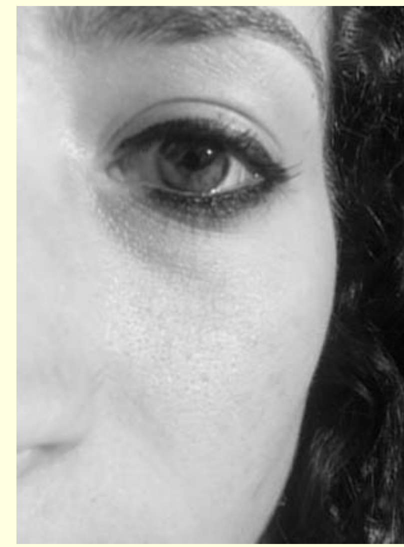
Lukas et al., "Digital camera identification from sensor pattern noise," TIFS 2006

Sensor De-identification

Source Sensor

Original Image	PRNU Spoofed Image
 IP5 1 FRONT	 Galaxy S4 FRONT
 Galaxy S4 REAR	 IP5 2 REAR
 IP5 2 FRONT	 IP5 1 FRONT
 Galaxy S4 FRONT	 IP5 1 FRONT

Target Sensor



Banerjee, Ross, "Smartphone Camera De-identification while Preserving Biometric Utility," BTAS 2019

Digital Data: DeepFakes

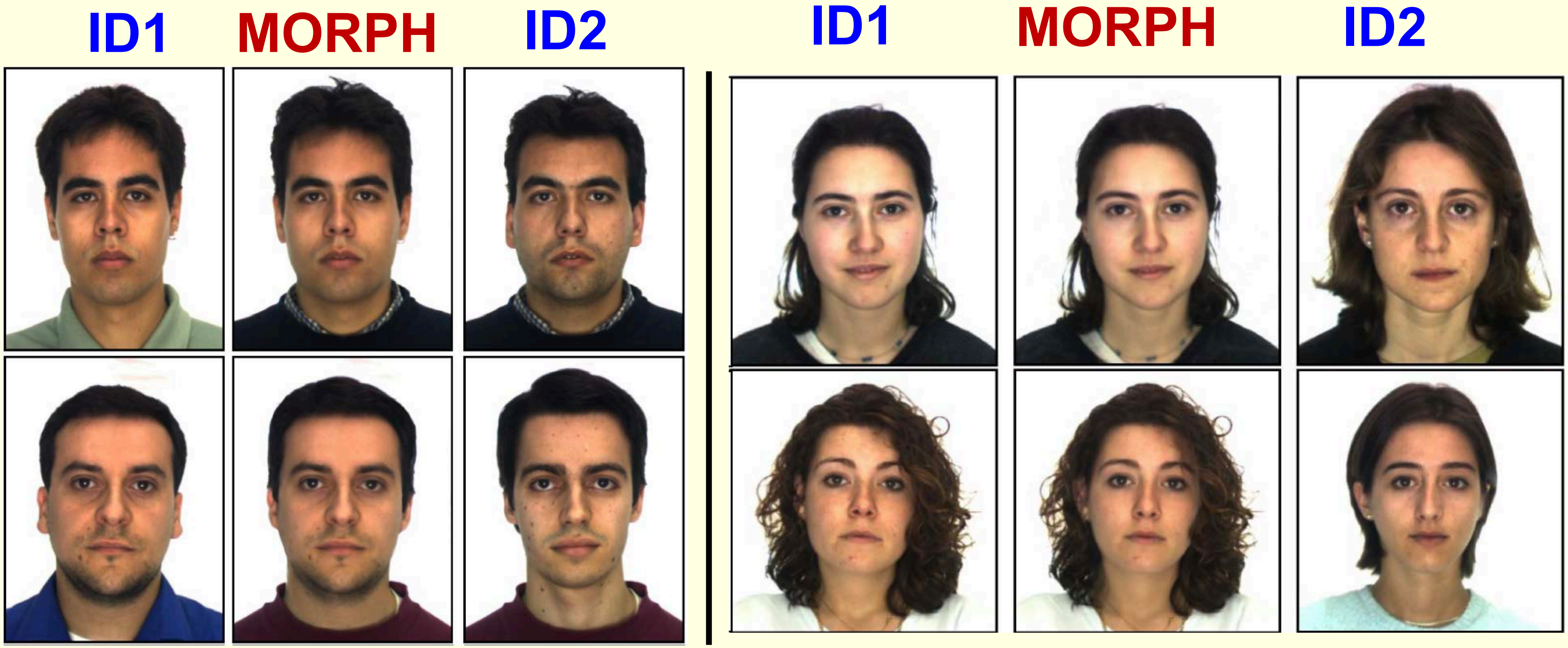
- DeepFakes: Synthetically Generated Images



https://thispersondoesnotexist.com/

Digital Data: Morphed Faces

- Morphed Faces: Combining two face images



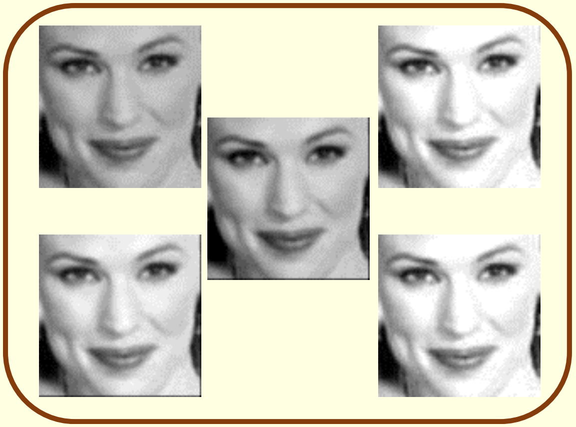
Ferrara et al, "The Magic Passport," IJCB 2014

Also see, Othman and Ross,
"Privacy of Facial Soft Biometrics: Suppressing Gender But Retaining Identity," ECCVW 2014

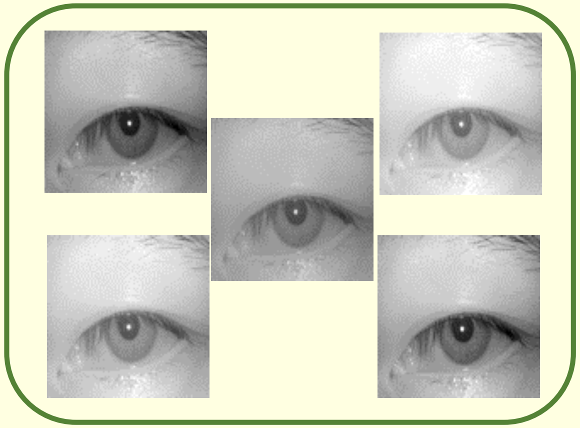
Digital Data: Near Duplicates

- Near Duplicates: Subtly Modified Images

Brightness adjustment



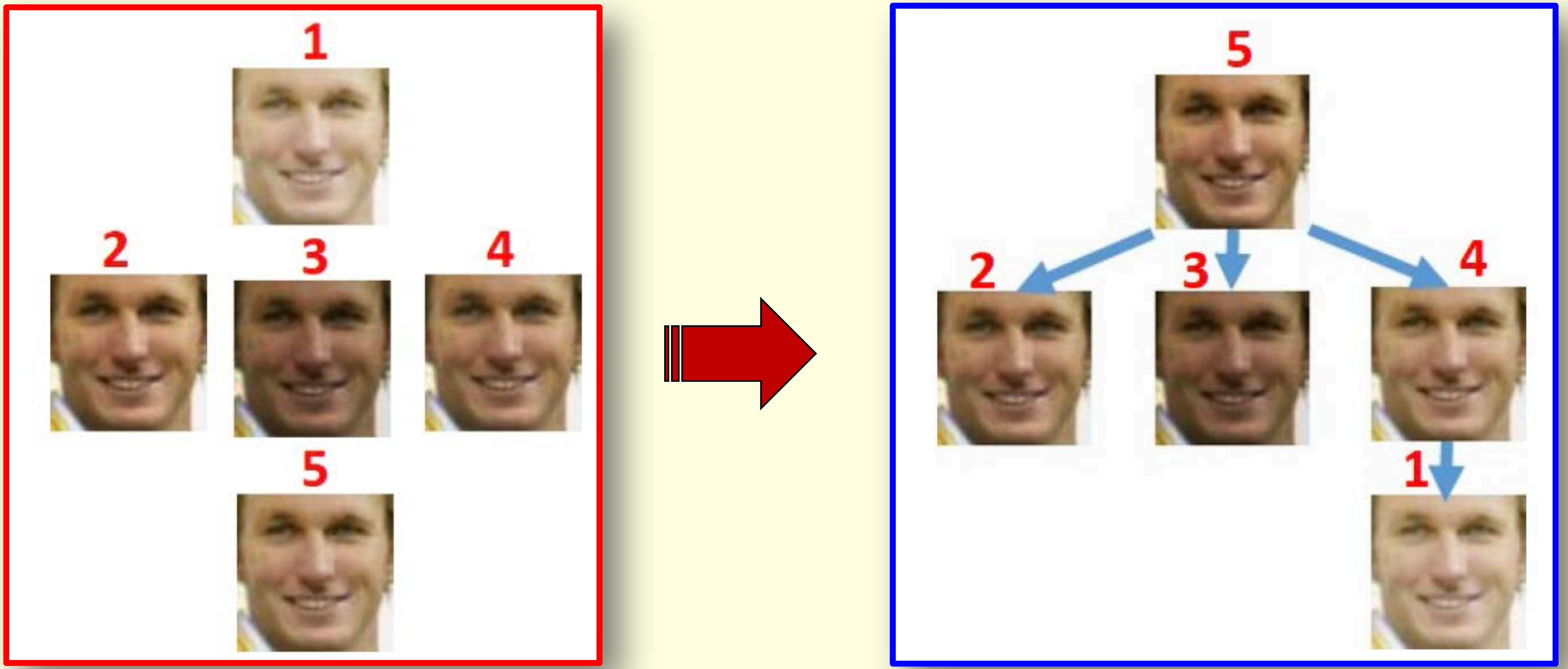
Gamma transformation



Rotation

Relationship Between Images

- Phylogeny Tree: Relationship between near duplicate images



S. Banerjee and A. Ross, "Face Phylogeny Tree Using Basis Functions," IEEE TBIOM, 2020

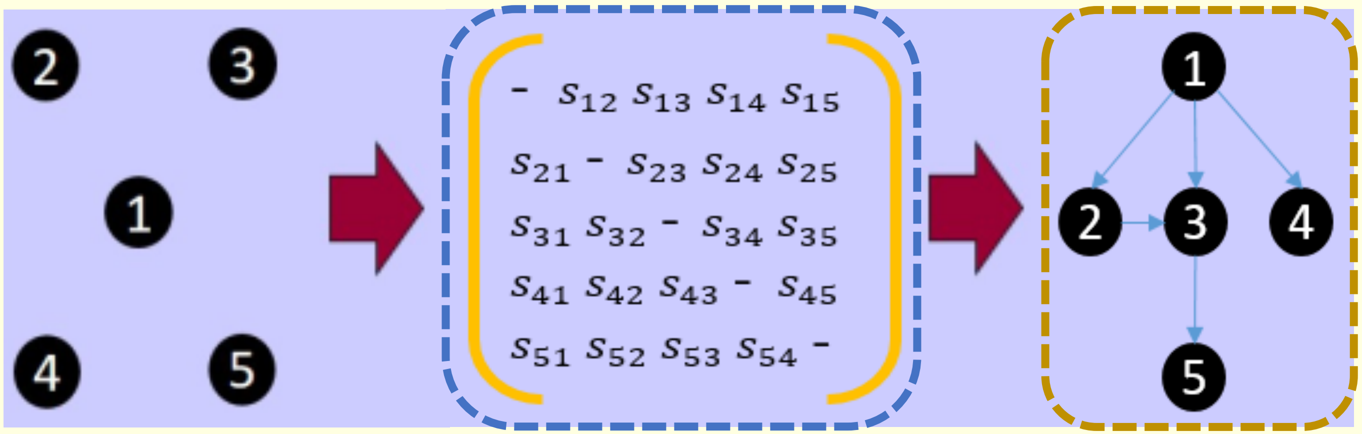
Importance of Problem

- Deduce whether a set of photometrically transformed images originated from a single source image or multiple sources
- Detection of image tampering hinted by significant photometric variation between two images
- Determination of transformation parameters relating two images

Forensics + Data Analysis

Image Phylogeny Tree (IPT)

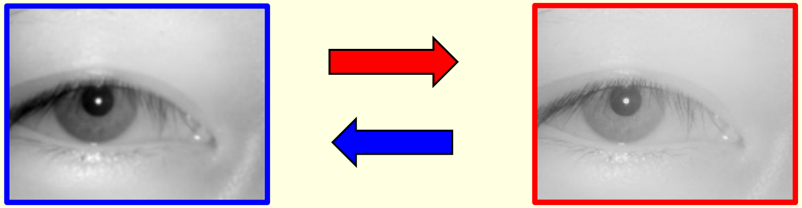
- IPT construction is a 2-step process:
  - STEP I : Computing pairwise asymmetric measure
  - STEP II: Using a tree-spanning algorithm



Set of 5 near-duplicate photometrically related images	Compute an asymmetric similarity/dissimilarity matrix depicting pair-wise relationships	Use a tree-spanning algorithm to construct IPT

What are the Challenges?

- Photometric Transformations ▸ Large number
  - E.g., Brightness, Contrast, CLAHE, Gamma, Median, Gaussian
- Each Transformation ▸ multiple parameters
  - E.g., Gaussian: window size and variance
- Each Parameter ▸ multiple values
  - E.g., Window size: 3x3, 5x5, 9x9, 13x13, ….
- Need to distinguish between A→B and B→A



Our Approach

- Use a generic parametric transformation function to model the relationship between any two images
- Given two images, **A** and **B**, estimate the parameters of the function in both directions
- Use the likelihood of the parameters to determine which of the two cases is more likely, i.e., **A → B** or **B → A**

- **Banerjee and Ross, "Face Phylogeny Tree: Deducing Relationships Between Near-Duplicate Face Images Using Legendre Polynomials and Radial Basis Functions," BTAS 2019**
- **Banerjee and Ross, "Face Phylogeny Tree Using Basis Functions," IEEE TBIOM 2020**

Transformation Function

Source image

Parameters

Target image

$$B(u,v) = \mathrm{T}[A(u,v)|\alpha]$$

Transformation Function

Transformation Function

- Model transformation from $\boldsymbol{A} \rightarrow \boldsymbol{B}$ such that the pair-wise photometric error (PE) is **minimized** for all pixels p

$$\min_{\boldsymbol{\alpha}} PE\,(\boldsymbol{A}, \boldsymbol{B}) = \min_{\boldsymbol{\alpha}} \sum_{p=1}^{N} \|\boldsymbol{B}(p) - \tau(\boldsymbol{A}(p); \boldsymbol{\alpha})\|_2^2$$

- We approximate transformations using a set of **basis** functions

- Banerjee and Ross, "Face Phylogeny Tree: Deducing Relationships Between Near-Duplicate Face Images Using Legendre Polynomials and Radial Basis Functions," BTAS 2019
- Banerjee and Ross, "Face Phylogeny Tree Using Basis Functions," IEEE TBIOM 2020

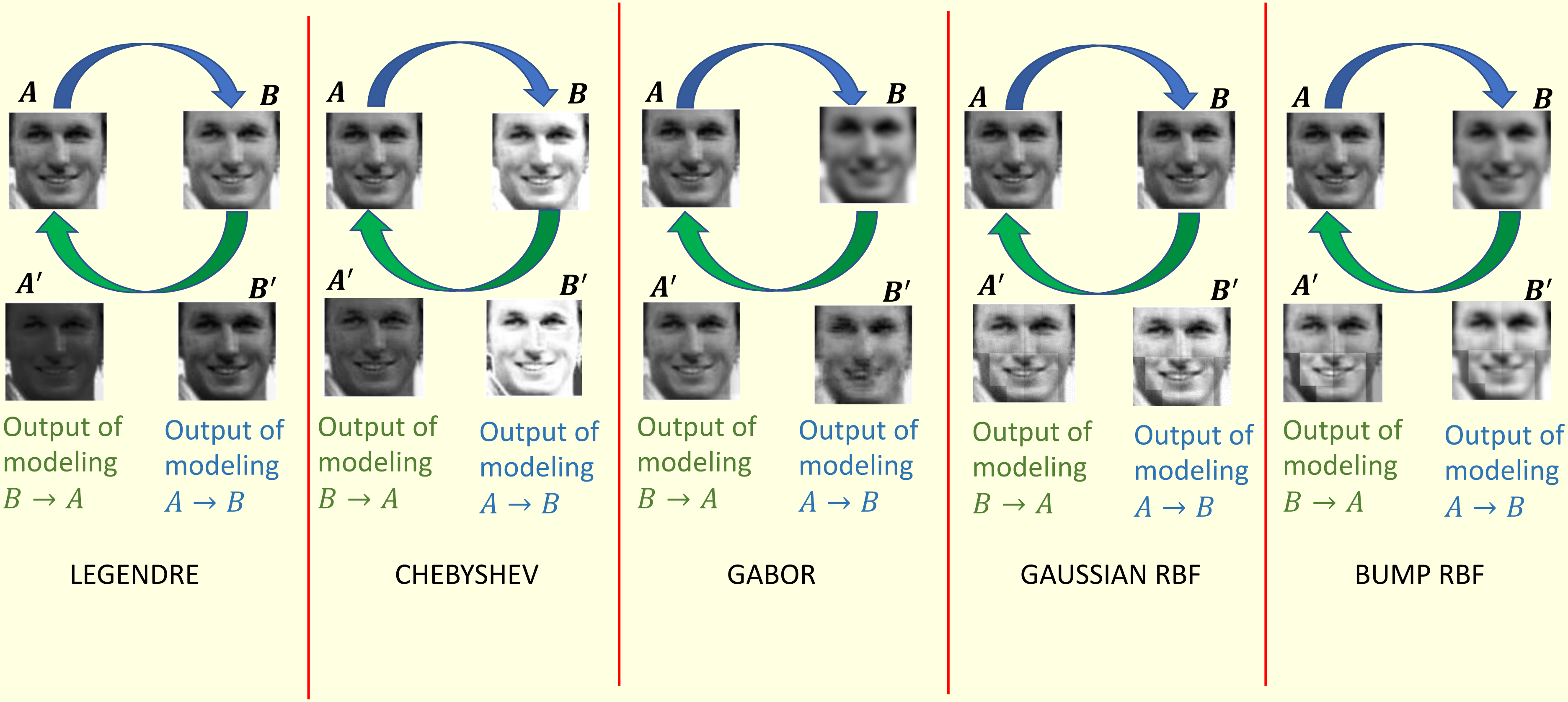
Basis Functions

Basis Functions		Utility	Formulation
Polynomials	Legendre	Used for image template matching and image reconstruction	$L_n(p) = 2^n \sum_{k=0}^{n} p^k \binom{n}{k} \binom{\frac{n+k-1}{2}}{n}$
	Chebyshev	Used for approximating complex functions (spectral convolutions)	$C_n(p) = p^n \sum_{k=0}^{\lfloor \frac{n}{2} \rfloor} \binom{n}{2k} (1 - x^{-2})^k$
Wavelets	Gabor	Used as texture descriptors, acts as bandpass filters	$\varphi(p, \theta, \lambda) = g(p, \lambda) \cdot w(p, \theta)$ $\lambda = \{2, 3, 4, 5\};\ \theta = \{0^\circ, 45^\circ, 90^\circ, 135^\circ\}$
Radial Basis Functions	Gaussian	Used for interpolation	$K(p) = exp\|p - \mu\|^2$
	Bump	Used as smooth cutoff functions	$K(p) = exp\left(-\frac{1}{1 - p^2}\right)$

p: *Pixel intensity value* ; n: *Polynomial order* ; μ: *Mean pixel intensity value* ; λ: *Scale* ; θ: *Orientation*

Banerjee and Ross, "Face Phylogeny Tree: Deducing Relationships Between Near-Duplicate Face Images Using Legendre Polynomials and Radial Basis Functions," BTAS 2019

Basis Functions



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- **Banerjee and Ross, "Face Phylogeny Tree Using Basis Functions," IEEE TBIOM 2020**

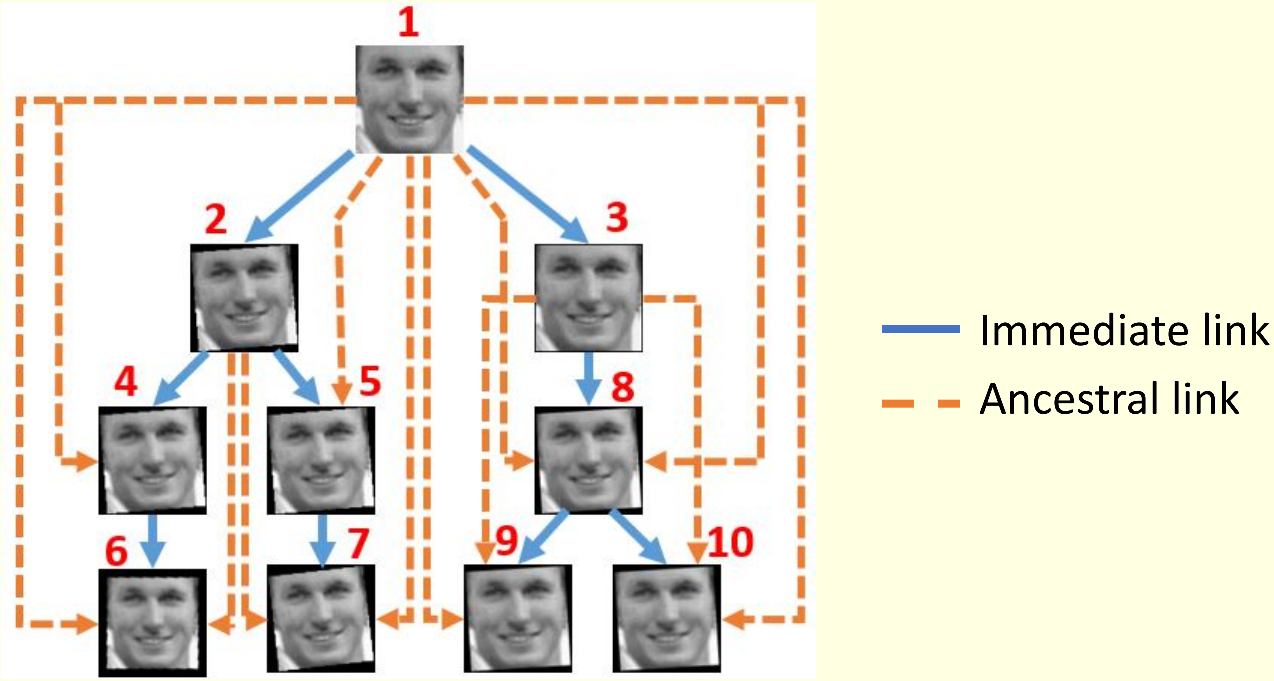
Asymmetric Measure

- Modeling the transformation in both directions results in two estimated parameter vectors $(\boldsymbol{\alpha}, \boldsymbol{\beta})$
- Compute the likelihood ratio $\left(\boldsymbol{\Lambda}_{\alpha} = \frac{p_f(\boldsymbol{\alpha})}{p_r(\boldsymbol{\alpha})}, \boldsymbol{\Lambda}_{\boldsymbol{\beta}} = \frac{p_f(\boldsymbol{\beta})}{p_r(\boldsymbol{\beta})}\right)$ of the estimated parameters to obtain asymmetric measure
- Use depth first search to construct IPT

- Banerjee and Ross, "Face Phylogeny Tree: Deducing Relationships Between Near-Duplicate Face Images Using Legendre Polynomials and Radial Basis Functions," BTAS 2019
- Banerjee and Ross, "Face Phylogeny Tree Using Basis Functions," IEEE TBIOM 2020

Experiments

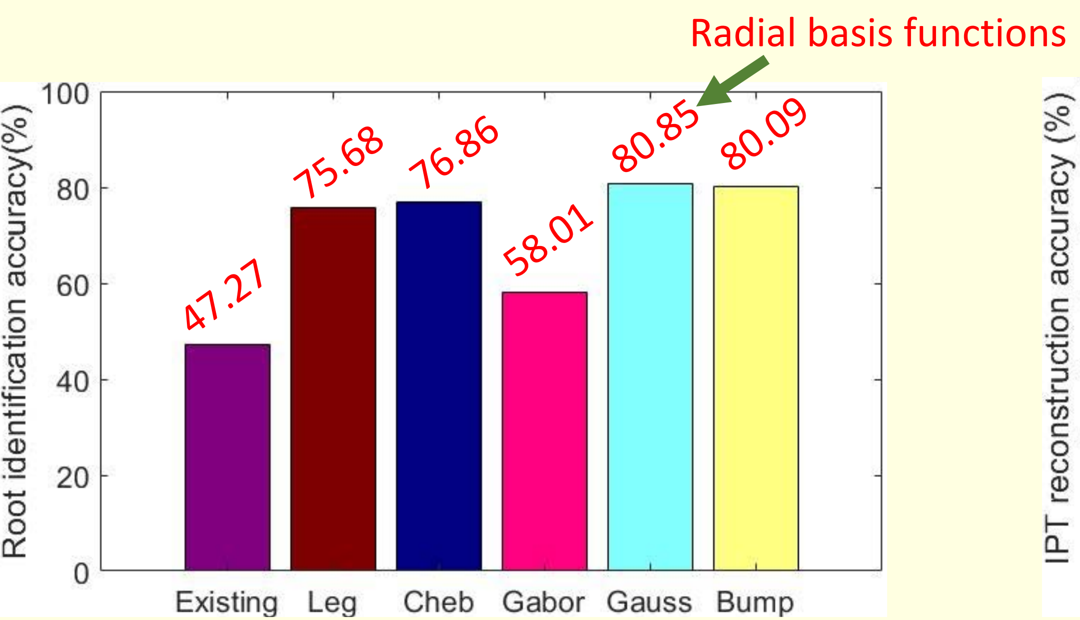
- We generated 2,727 IPTs by subjecting face images to random sequence of 4 transformations resulting in 27,270 images

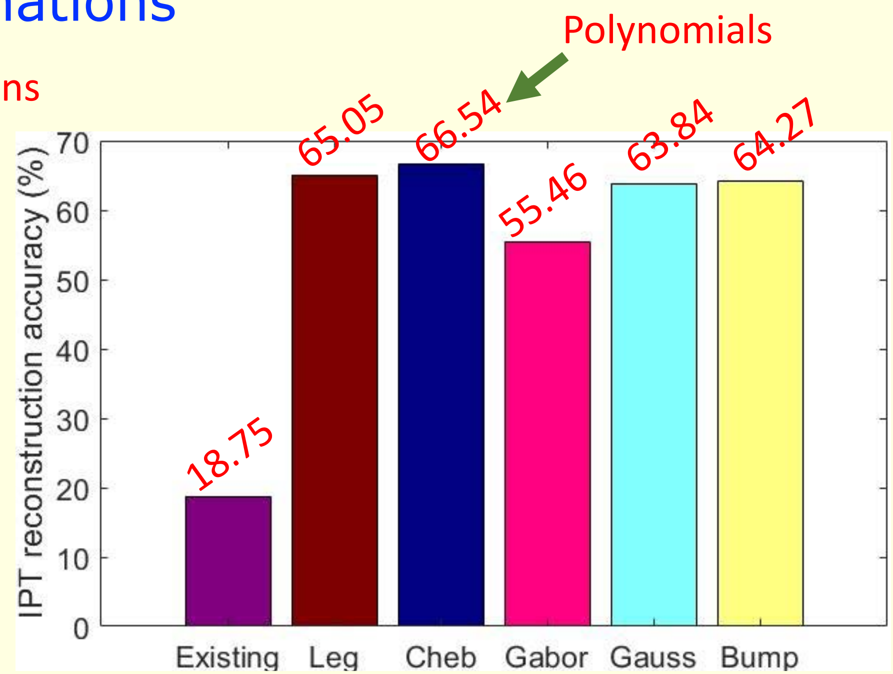


- Banerjee and Ross, "Face Phylogeny Tree: Deducing Relationships Between Near-Duplicate Face Images Using Legendre Polynomials and Radial Basis Functions," BTAS 2019
- Banerjee and Ross, "Face Phylogeny Tree Using Basis Functions," IEEE TBIOM 2020

Performance

- We compared the performance with an existing method
- The problem is hard:
  - face images vs natural scenes
  - subtle photometric transformations





ROOT IDENTIFICATION **IPT RECONSTRUCTION**

Banerjee and Ross, "Face Phylogeny Tree: Deducing Relationships Between Near-Duplicate Face Images Using Legendre Polynomials and Radial Basis Functions," BTAS 2019

Generalizability

- **Unseen modalities**: 7,260 near-duplicate iris images from CASIA Iris V2 Device 2 dataset
- **Unseen transformations**: 175 near-duplicates using Photoshop and 1,080 near-duplicates using deep learning-based transformations

Experimental Settings		Root identification accuracy (%)	IPT reconstruction accuracy (%)
Unseen modality	Iris	95	68
Unseen transformations	Photoshop	90	100
	Deep learning-based	83	65

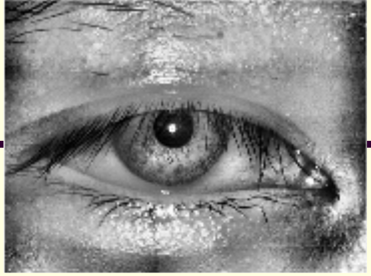
- Banerjee and Ross, "Face Phylogeny Tree: Deducing Relationships Between Near-Duplicate Face Images Using Legendre Polynomials and Radial Basis Functions," BTAS 2019
- Banerjee and Ross, "Face Phylogeny Tree Using Basis Functions," IEEE TBIOM 2020

Summary

- Information can be derived from a single biometric image
  - Demographic attributes
  - Environmental characteristics
  - Sensor properties; etc.
- Digital Image Forensics:
  - Which sensor did this image come from?
  - Has this image been digitally tampered?
  - What is the relationship between a set of near-duplicate images?
- Privacy:
  - Semi-adversarial Networks (SAN): Differential Privacy

Digital Image Forensics

- El-Naggar, Ross, "**Which Dataset is this Iris Image From?**," WIFS 2015
- Kalka, Bartlow, Cukic, Ross, "**A Preliminary Study on Identifying Sensors from Iris Images**," CVPRW 2015
- Banerjee, Ross, "**From Image to Sensor: Comparative Evaluation of Multiple PRNU Estimation Schemes for Identifying Sensors from NIR Iris Images**," IWBF 2017
- Banerjee, Ross, "**Computing an Image Phylogeny Tree from Photometrically Modified Iris Images**," IJCB 2017
- Banerjee, Ross, "**Impact of Photometric Transformations on PRNU Estimation Schemes: A Case Study Using Near Infrared Ocular Images**," IWBF 2018
- Banerjee, Mirjalili, Ross, "**Spoofing PRNU Patterns of Iris Sensors while Preserving Iris Recognition**," ISBA 2019
- Banerjee, Ross, "**Smartphone Camera De-identification while Preserving Biometric Utility**," BTAS 2019
- Banerjee, Ross, "**Face Phylogeny Tree: Deducing Relationships Between Near-Duplicate Face Images Using Legendre Polynomials and Radial Basis Functions**," BTAS 2019
- Banerjee, Ross, **"Face Phylogeny Tree Using Basis Functions,"** IEEE TBIOM 2020

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