Color Constancy in 3D-2D Face Recognition

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Color-Aware Face Recognition

- State-of-the-art Face Recognition (FR) methods assume white illumination
- Object color appearance varies with illuminant color

Contributions:

- First group to study color constancy (CC) in FR
- Controlled ground truth experiments to determine theoretical **maximum performance improvement**
- Integration of a CC method in 3D-2D FR system to determine **practical performance gain**

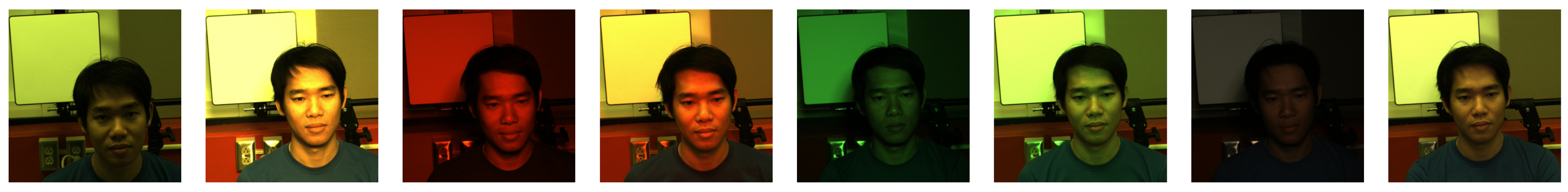
Databases

Dataset 1: Strong illumination changes

- 5 subjects under 9 lighting conditions
- Scenes contain Lambertian surface

Dataset 2: Real-world conditions

- 9 subjects under natural illumination
- Gallery computed on indoor, probe on outdoor images



Methodology

Investigate FR performance under

- no color correction
- near-perfectly known illuminant color information
- a more realistic setup, using illuminant color estimates

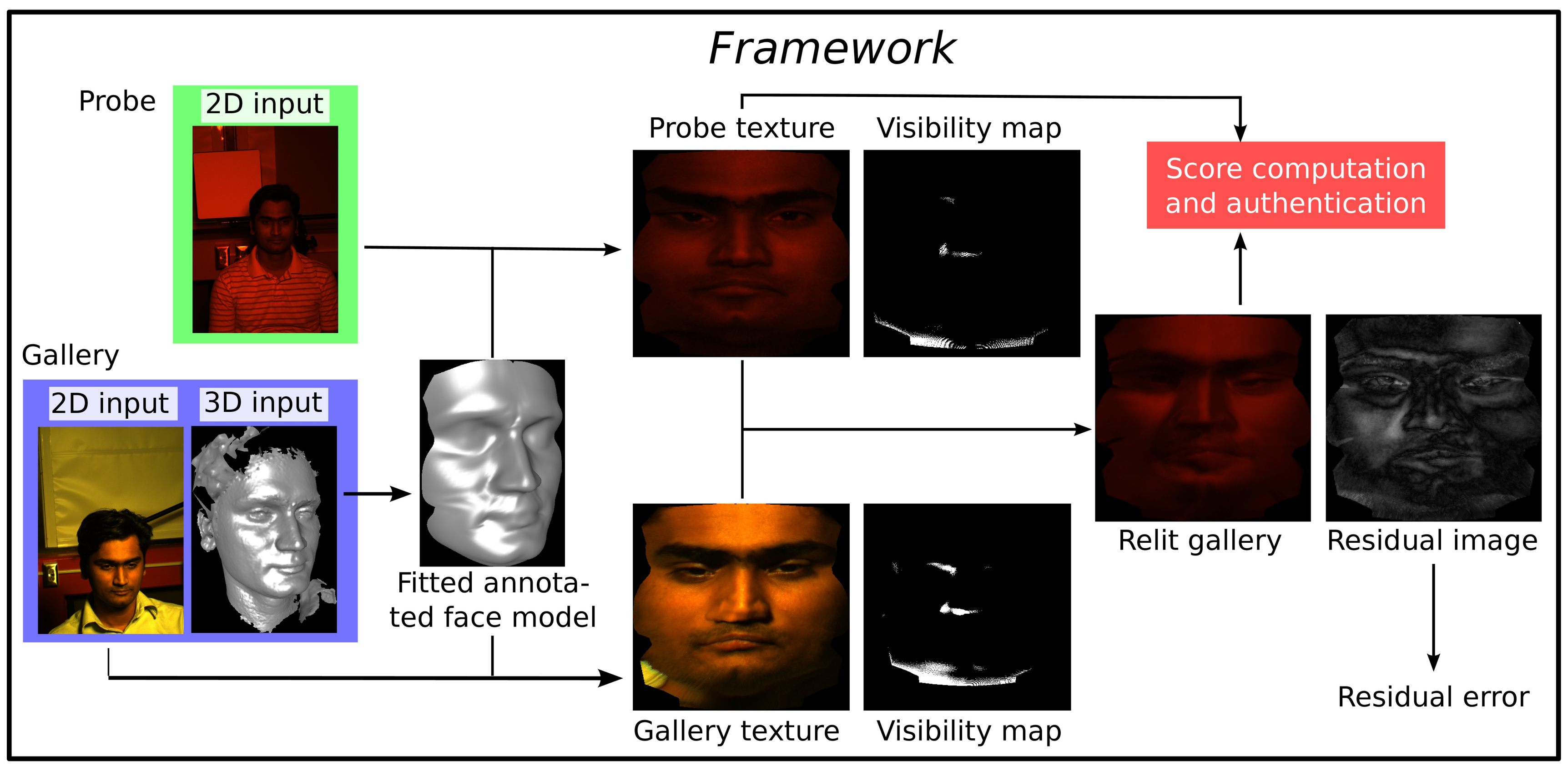
FR Framework based on Toderici *et al.* [1]: **3D-aided 2D FR**

Illuminant normalization in relighting step:

$$\mathcal{R}(\vec{x}) = \mathcal{T}^p(\vec{x}) - \vec{i}^{\,p}_s(\vec{x}) - (\vec{i}^{\,p}_d(\vec{x}) + \vec{i}^{\,p}_a(\vec{x})) \cdot \frac{\mathcal{T}^g(\vec{x}) - \vec{i}^{\,g}_s(\vec{x})}{\vec{i}^{\,g}_d(\vec{x}) + \vec{i}^{\,g}_a(\vec{x})}$$

Gallery texture $\mathcal{T}^g(\vec{x})$ is adapted to the probe texture $\mathcal{T}^p(\vec{x})$, taking into account the specular and diffuse components $\vec{i}_s(\vec{x})$, $\vec{i}_d(\vec{x})$ of scene reflectance, respectively, and the ambient illumination $\vec{i}_a(\vec{x})$ for gallery and probe.

The illuminant color can be incorporated in the FR system by directly inserting its chromaticity in $\vec{i}_s(\vec{x})$, $\vec{i}_d(\vec{x})$, and $\vec{i}_a(\vec{x})$.



Two ways to estimate illuminant color from input:

- **Ground truth** with a Lambertian surface: Positioned next to subject, in the background of the scene
- Compute via a **physics-based CC algorithm**: Illuminant estimation by voting [2] on face region

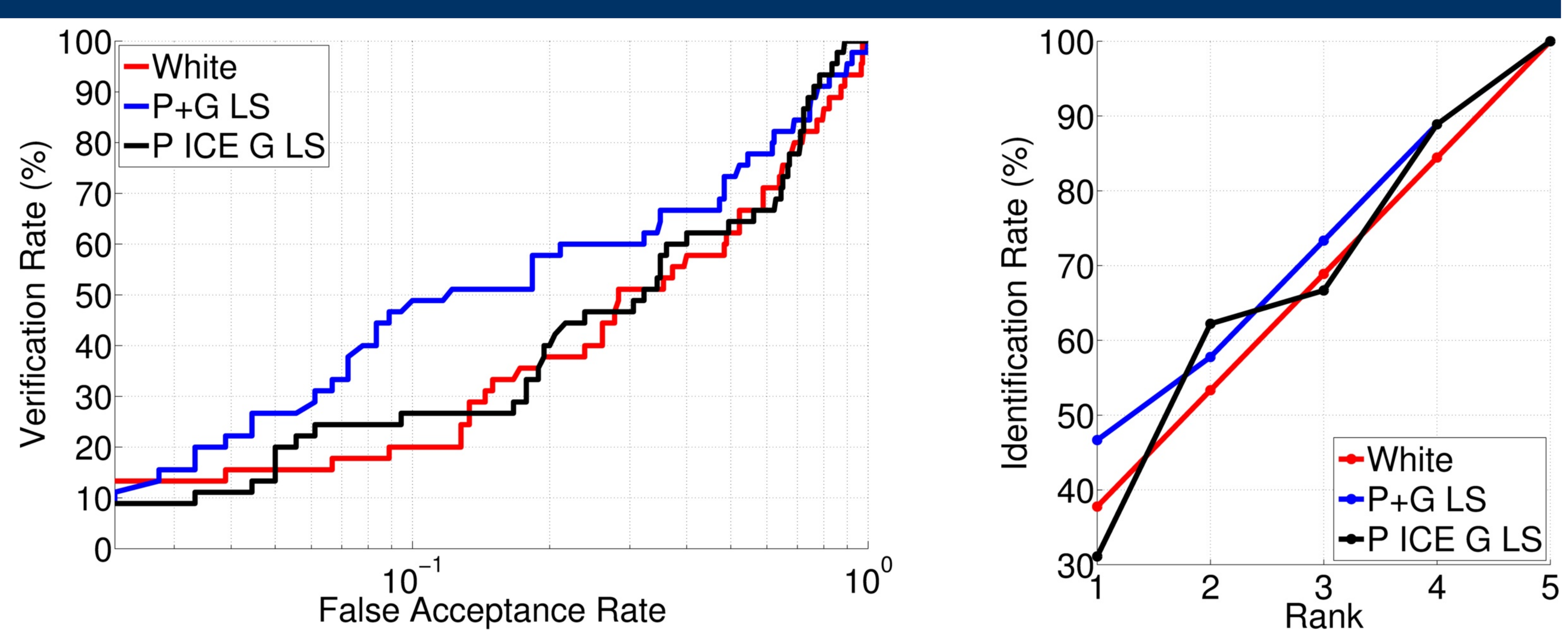
Experiments

Performance gain in different CC scenarios:

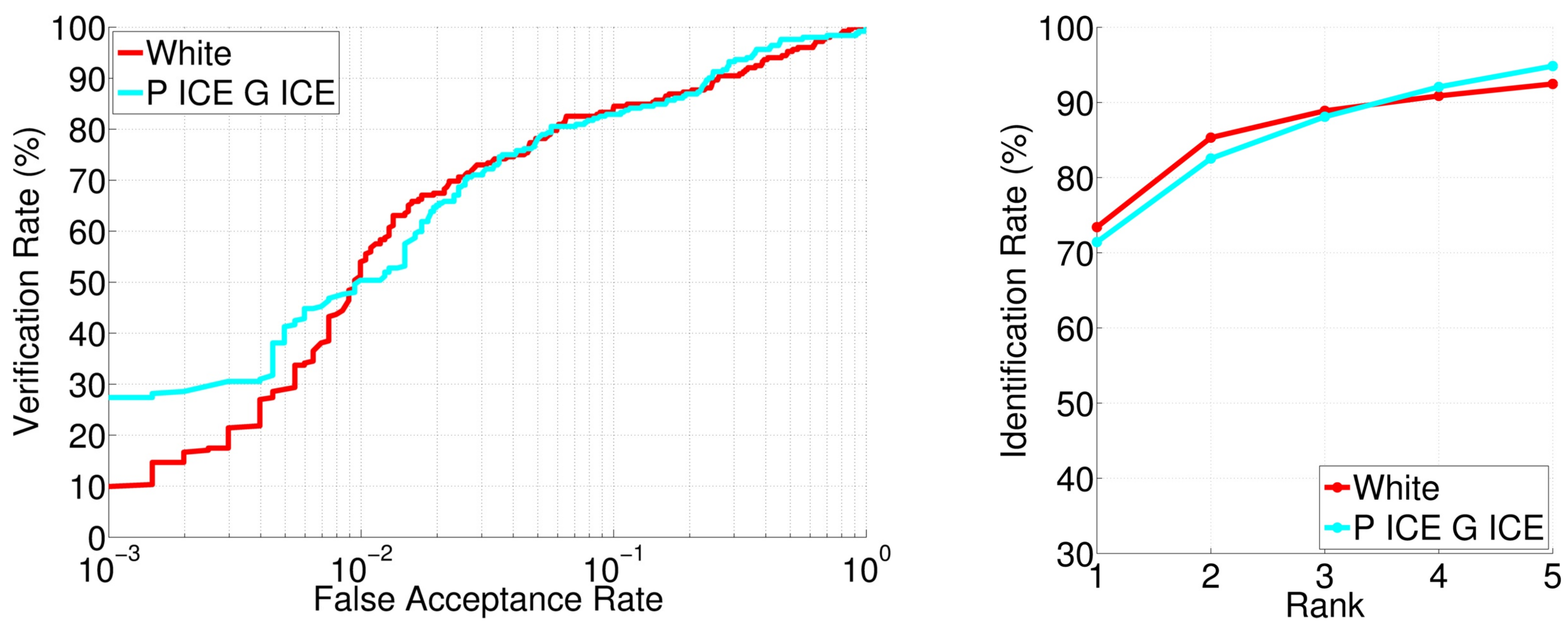
- GT from Lambertian surface: **16% AUC**
- CC on gallery and/or probe: **4% - 7% AUC**
- For real-world images, the verification performance considerably increases at low FARs: **17% at 10^{-3}**

Short identifier	Setup	AUC
White	fixed illuminant to white	0.605
P LS	LS on probe	0.577
G LS	LS on gallery	0.527
P+G LS	LS on probe and gallery	**0.705**
P ICE	illuminant color estimation on probe	0.642
G ICE	illuminant color estimation on gallery	0.564
P ICE G LS	illuminant color estimation on probe, LS on gallery	0.630
P LS G ICE	LS on probe, illuminant color estimation on gallery	0.650
P+G ICE	illuminant color estimation on probe and gallery	0.635

Table 1: Experimental setup and their respective short identifiers.



Verification and Identification on the 5-subject colored light dataset.



Verification and Identification on the indoor/outdoor dataset.

References

[1] Toderici et al.: "Bidirectional Relighting for 3D-Aided 2D Face Recognition", IEEE CVPR, pp. 2721-2728, 2010.

[2] Riess et al.: "Illuminant Color Estimation for Real-World Mixed-Illuminant Scenes", IEEE CPCV, pp. 782-789, 2011.