Illumination Invariant Face Recognition From Single Image of Partially Shadowed Face

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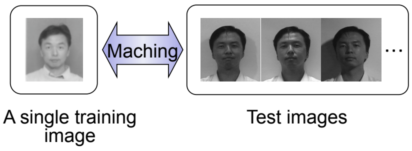
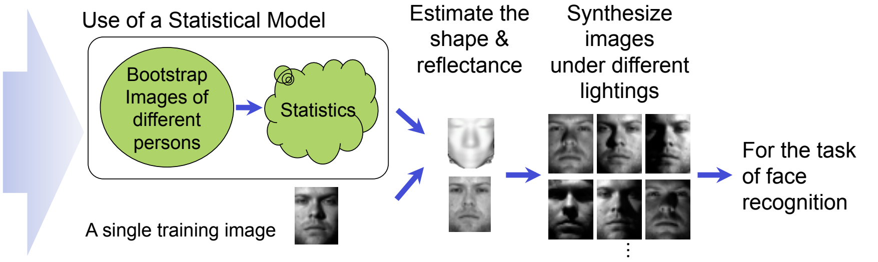
Objective

We propose a novel method for face recognition under varying illumination conditions, using a single training image for each person.



◇It is not always possible to provide a large number of training images for each person

◇It is not trivial to predict appearance variation



Proposed Method

Estimating Illumination s

The illumination of a single training image is estimated by using the average shape & albedos

$$B^T_{average}\,\mathbf{s} = \mathbf{i}$$

$$\mathbf{s} = B^{T+}_{average}\,\mathbf{i}$$

Reflectance Equation

The intensity under a directional light is given as:

Intensity (p-th pixel) — $i_p = \mathbf{n}_p^T \mathbf{s} + e_p(\mathbf{s})$

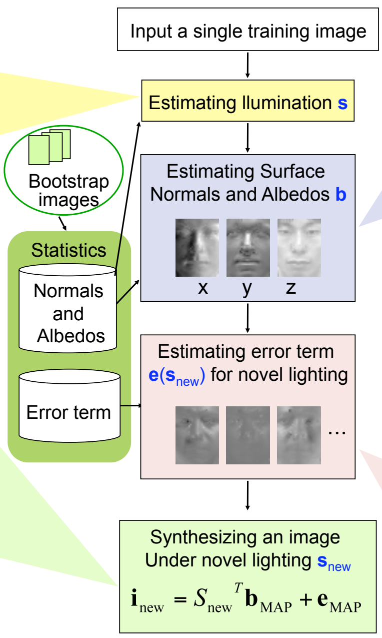
The diffuse component — n : normal including albedo, s : illumination

The error term

Image (P-dimensional vector) — $\mathbf{i} = S^T\mathbf{b} + \mathbf{e}(\mathbf{s})$

$$\begin{bmatrix} i_1 \\ i_2 \\ \vdots \\ i_P \end{bmatrix} = \begin{bmatrix} \mathbf{s}^T & 0 & \cdots & 0 \\ 0 & \mathbf{s}^T & & \vdots \\ \vdots & & \ddots & 0 \\ 0 & \cdots & 0 & \mathbf{s}^T \end{bmatrix} \begin{bmatrix} \mathbf{n}_1 \\ \mathbf{n}_2 \\ \vdots \\ \mathbf{n}_P \end{bmatrix} + \begin{bmatrix} e_1(\mathbf{s}) \\ e_2(\mathbf{s}) \\ \vdots \\ e_P(\mathbf{s}) \end{bmatrix}$$

Modeling & Rendering from a Single Image



$$\mathbf{i}_{\text{new}} = S_{\text{new}}^T \mathbf{b}_{\text{MAP}} + \mathbf{e}_{\text{MAP}}$$

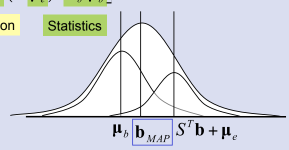
Estimating Surface Normals Including Albedos b

MAP estimation by assuming a Gaussian distribution

$$\mathbf{b}_{MAP} = \arg\max_{\mathbf{b}} P(\mathbf{b}|\mathbf{i}) = \arg\max_{\mathbf{b}} P(\mathbf{b})P(\mathbf{i}|\mathbf{b})$$

$$= \left[S\Sigma_e^{-1}S^T + C_b^{-1}\right]^{-1}\left[S\Sigma_e^{-1}(\mathbf{i}-\boldsymbol{\mu}_e) + C_b^{-1}\boldsymbol{\mu}_b\right]$$

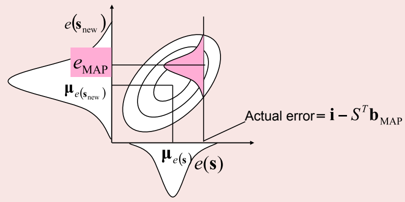
Input illumination / Statistics



Estimating Error Term for Novel Lighting e(s_new)

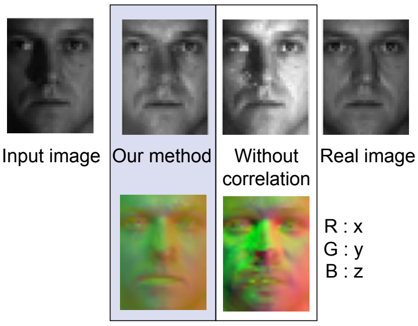
MAP estimation by assuming a jointly Gaussian distribution between e(**s**) and e(**s**$_{new}$)

$$e_{\text{MAP}} = \boldsymbol{\mu}_{e(\mathbf{s}_{\text{new}})} + \mathbf{R}^T\Sigma_e^{-1}\left(e(\mathbf{s}) - \boldsymbol{\mu}_{e(\mathbf{s})}\right)$$



Experimental Results

Synthesized Images



Estimated Normals Including Albedos

Face recognition

Test images: CMU-PIE DB
- 21 images per person
- 68 people

grouping pixels (6 areas)

Bootstrap images for computing statistics: Yale database B
- 40 images per person
- 10 people frontal face images

Computing individual subspaces of synthesized images and searching for the closest subspace to identify this person.

Comparison with Zhou et al.'s Method(ECCV2004)

Methods	Recognition rate [%]												
	f8	f9	f11	f12	f13	f14	f15	f16	f17	f20	f21	f22	average
Zhou et al.	60	72	66	76	78	77	66	56	42	63	74	71	67
Our method	96	99	96	99	100	99	99	96	81	96	99	99	97

conducted under the same condition as reported

Effectiveness of Correlation

Methods	Recognition rate [%]
Without correlation	68
Our method	86

A training image illuminated from the side

Mihoko Shimano et al., "Face recognition under varying illumination based on MAP estimation incorporating correlation between surface points", In Proc. Asian Conf. Computer Vision, 2006.