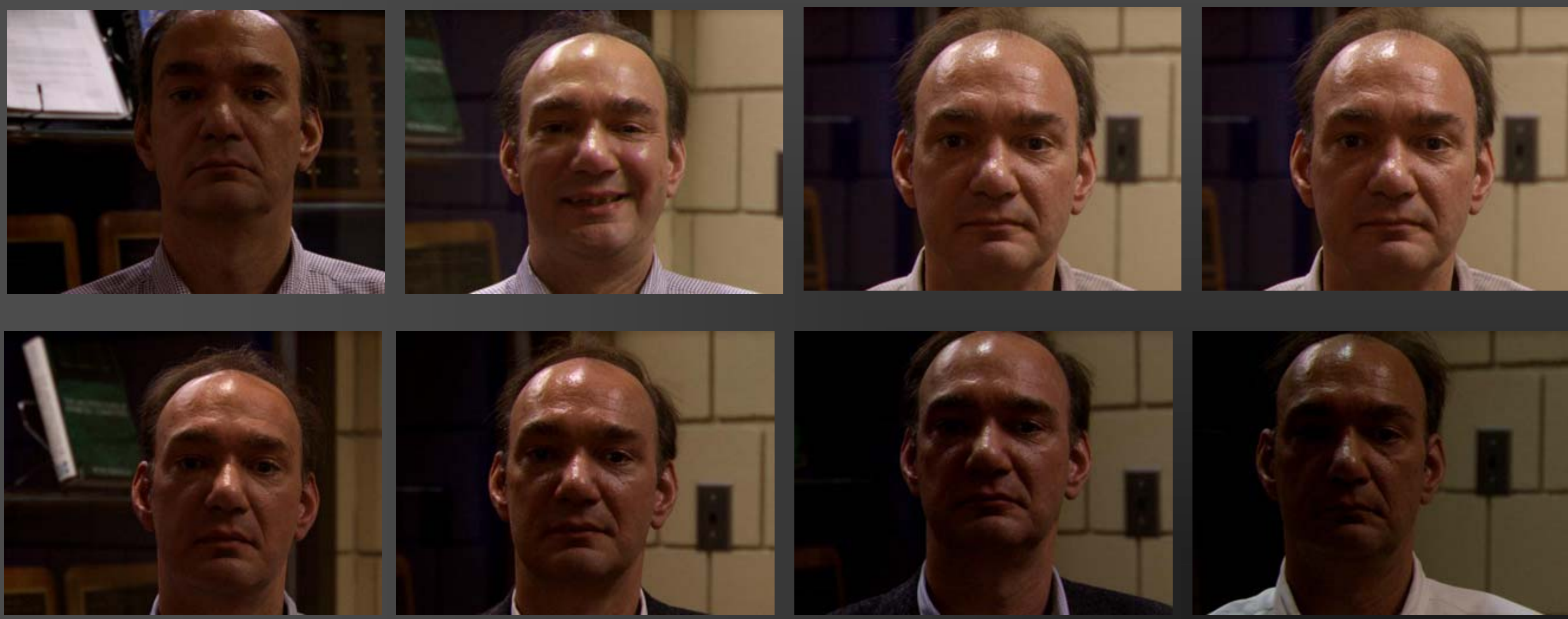
Enhanced Local Texture Feature Sets for Face Recognition under Difficult Lighting Conditions

Xiaoyang Tan and Bill Triggs

INRIA & Laboratoire Jean Kuntzmann,

655 avenue de l'Europe, Montbonnot 38330, France

The Challenge of Difficult Lighting Conditions



Related work

Model Illumination Directly

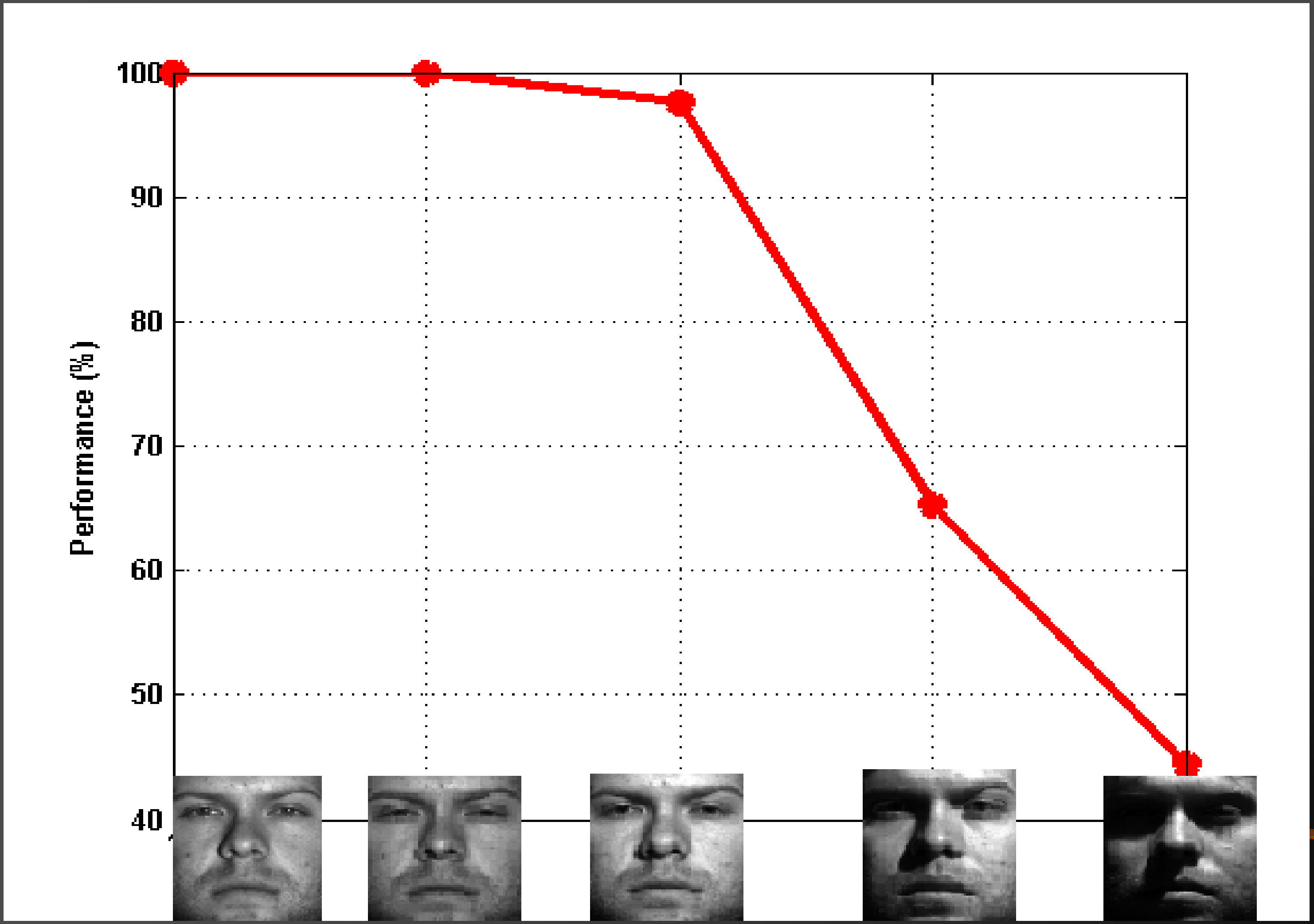
Gradient Angle [H. Chen'00]
Nine point of light [K. Lee'05]
Harmonic image exemplars [W. Zhang'03]
Illumination cones [Belhumeur'98]

Find Illumination Insensitive descriptors

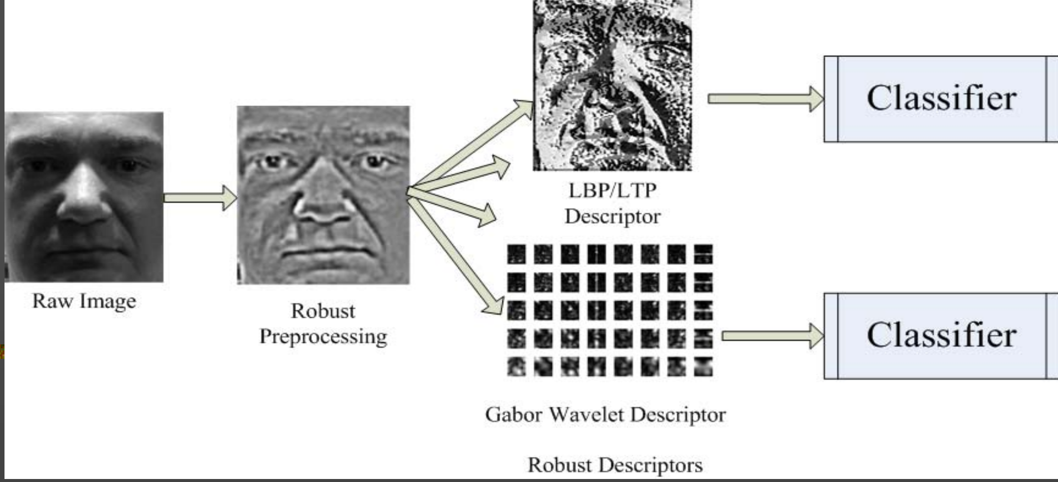
Generic Illumination Normalization:
Histogram equalization
Self Quotient Image (SQI) [H. Wang'04]
Logarithmic Total Variation (LTV) [T. Chen'06]

Illumination-Insensitive Descriptors:
Edge maps [Adini'97]
Gabor wavelets [Wiskott'97]
Local Binary Patterns (LBP) [Ahonen'04]
SIFT [Lowe'04]

Performance of LBP descriptors under Illumination Variations



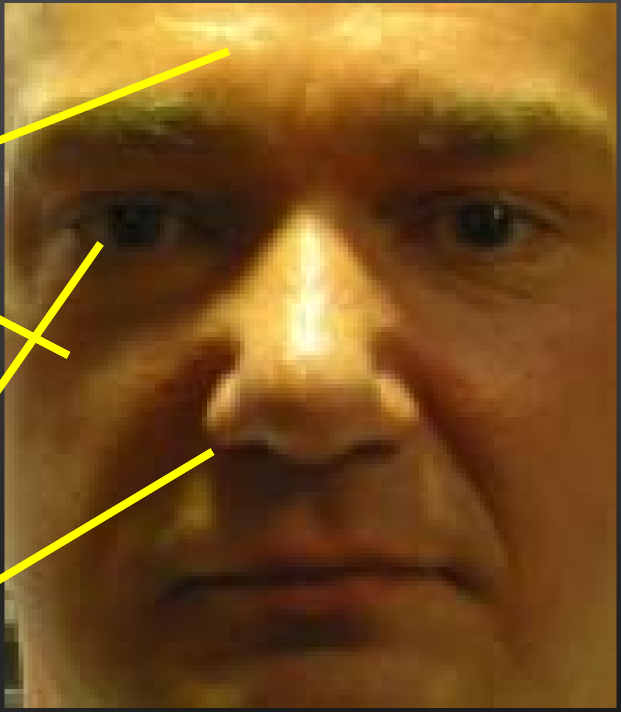
Our Approach



- Combine robust preprocessing and robust descriptors
  - experiments show that including both is useful
  - Belongs to approach II, don't need any training images.

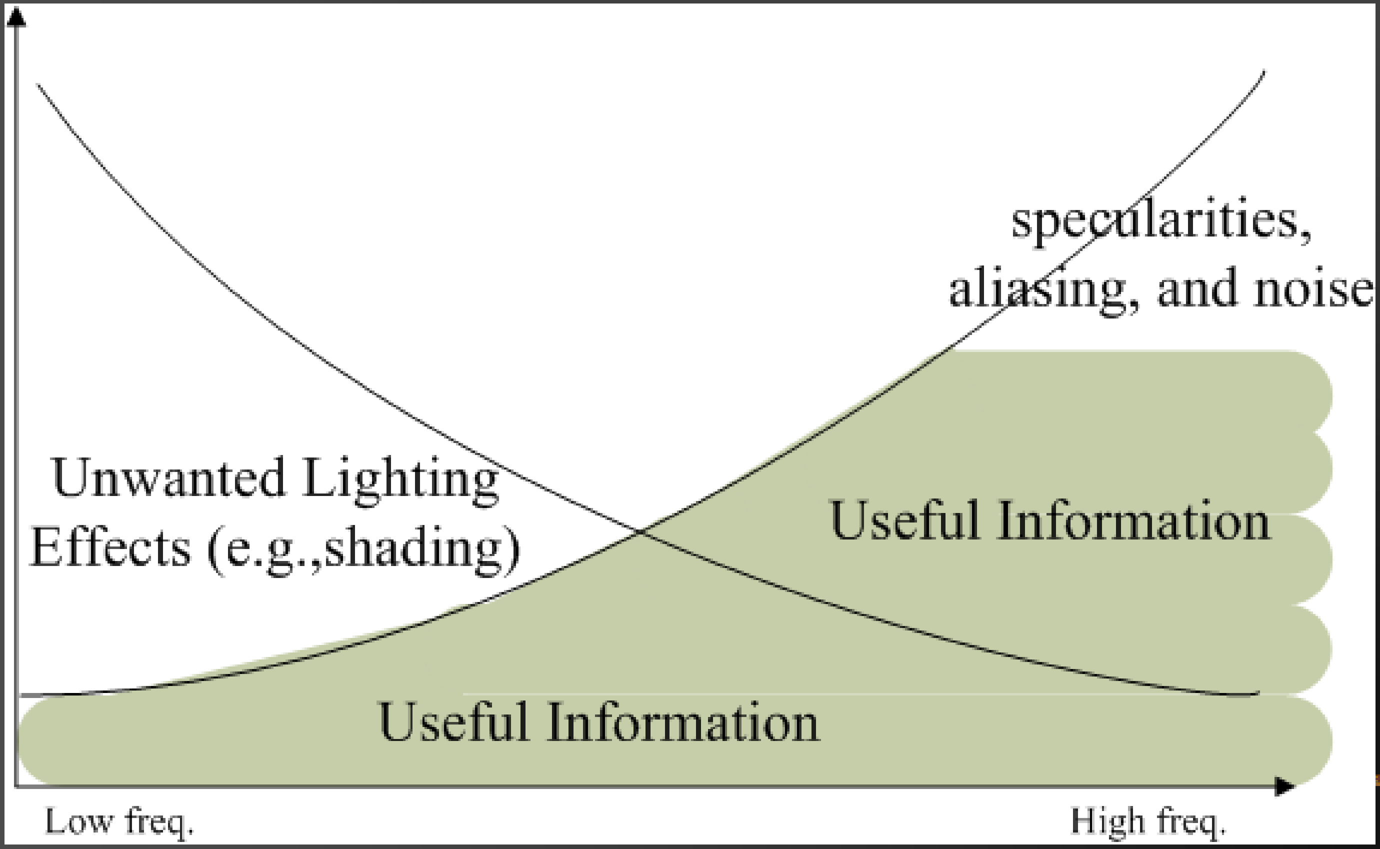
Preprocessing: what to remove ?

- Unwanted illumination effects
  - Non-uniform illumination
  - Shadowing & highlights
  - Aliasing, blurring, noise
- Useful information
  - Facial features : eyes, nose, etc.
  - Ridges, wrinkles, skin details
  - Local shadowing, shading

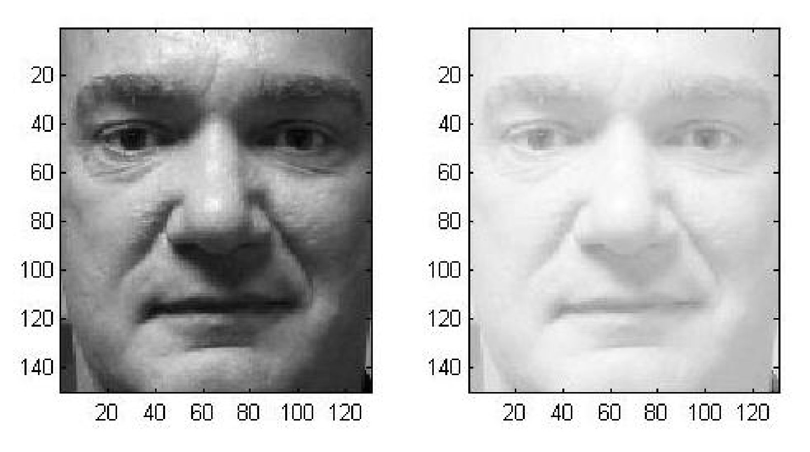


Basic Assumption

- Unwanted lighting effects lie mainly at low frequencies
- Useful information lies mainly at middle & high frequencies

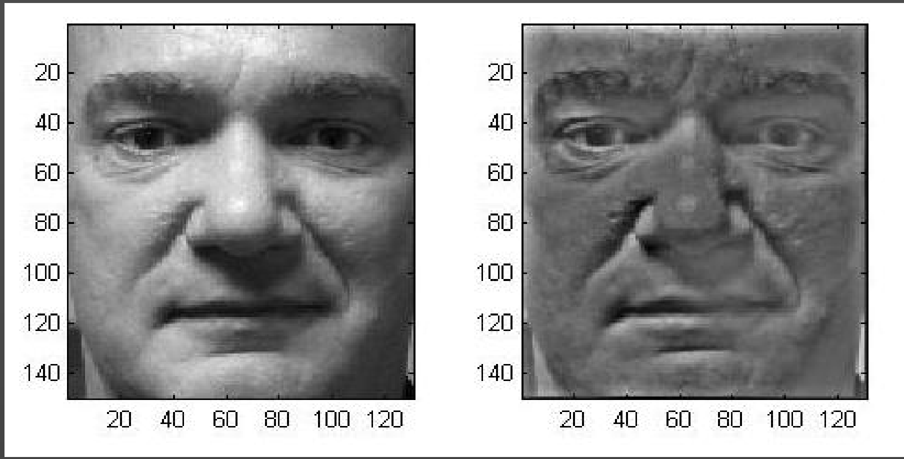


Preprocessing Step 1



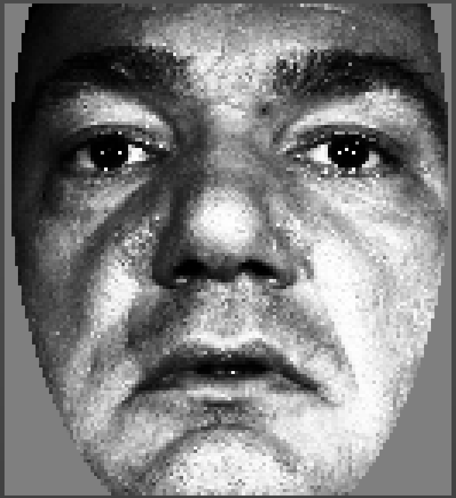
- Lighting is a multiplicative process (Lambertian model)
  - observed value = illumination * albedo (local surface reflectance)
- Log transform corrects this
  - log(grey value) = log(illumination)+log(albedo)
- In practice log transform amplifies noise in dark regions too much
  - use Gamma transform, gamma = 0.2 – 0.5

Preprocessing Step 2



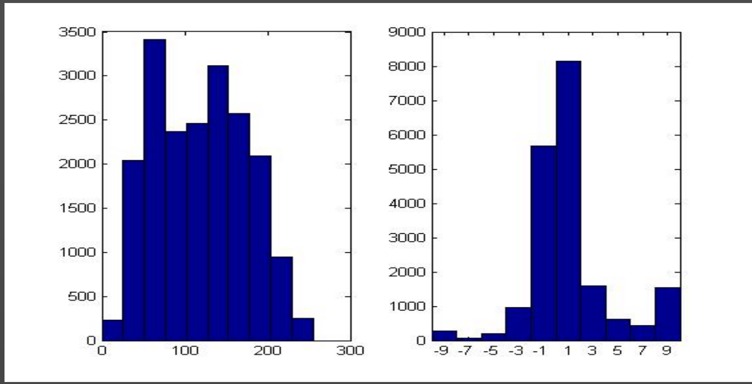
- Bandpass filter suppresses low frequencies (“lighting variations”) and high frequencies (“noise”)
- Use difference of Gaussians (DoG)
  - inner filter reduces aliasing, noise
    - $\sigma < 1$ pixel
  - outer filter suppresses low frequency lighting variation without suppressing too much class information
    - σ several pixels, depending on class

Preprocessing Step 3



- (Optional) mask out facial regions that are irrelevant or too variable

Preprocessing Step 4



- Robust contrast normalization
  - normalizes overall range of output values
  - must be resistant to specularities
- We use simple two stage method
  - based on compressive nonlinearity

$$I(x,y) \leftarrow \frac{I(x,y)}{(\mathrm{mean}(|I(x',y')|^a))^{1/a}}$$

$$I(x,y) \leftarrow \frac{I(x,y)}{(\mathrm{mean}(\min(\tau,|I(x',y')|)^a))^{1/a}}$$

Overall Effect

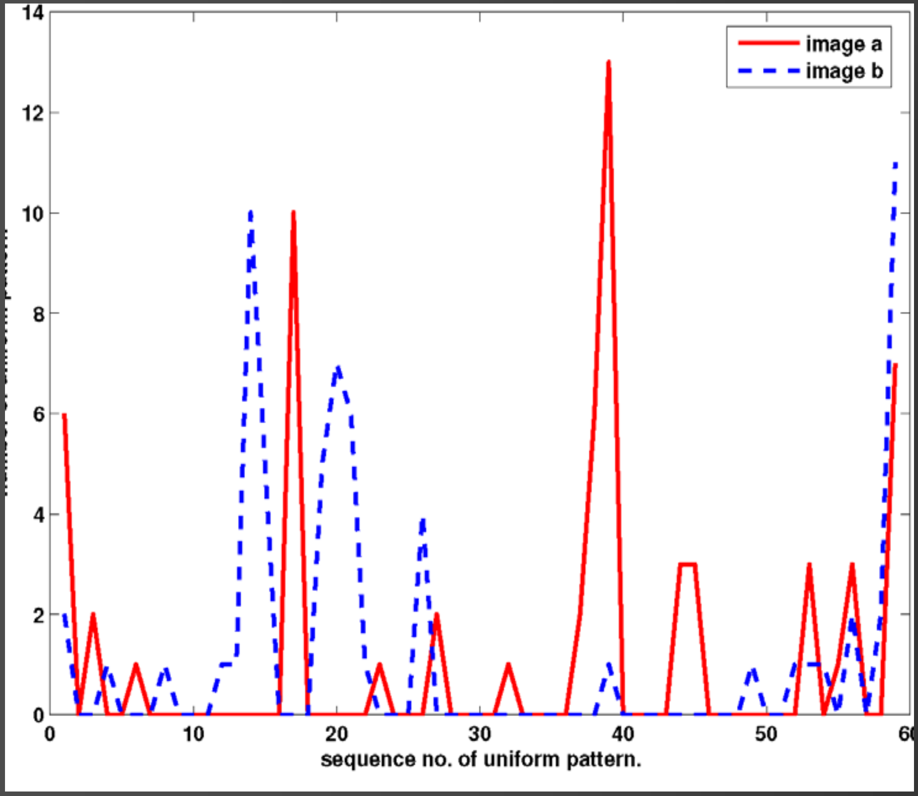
Before Normalization

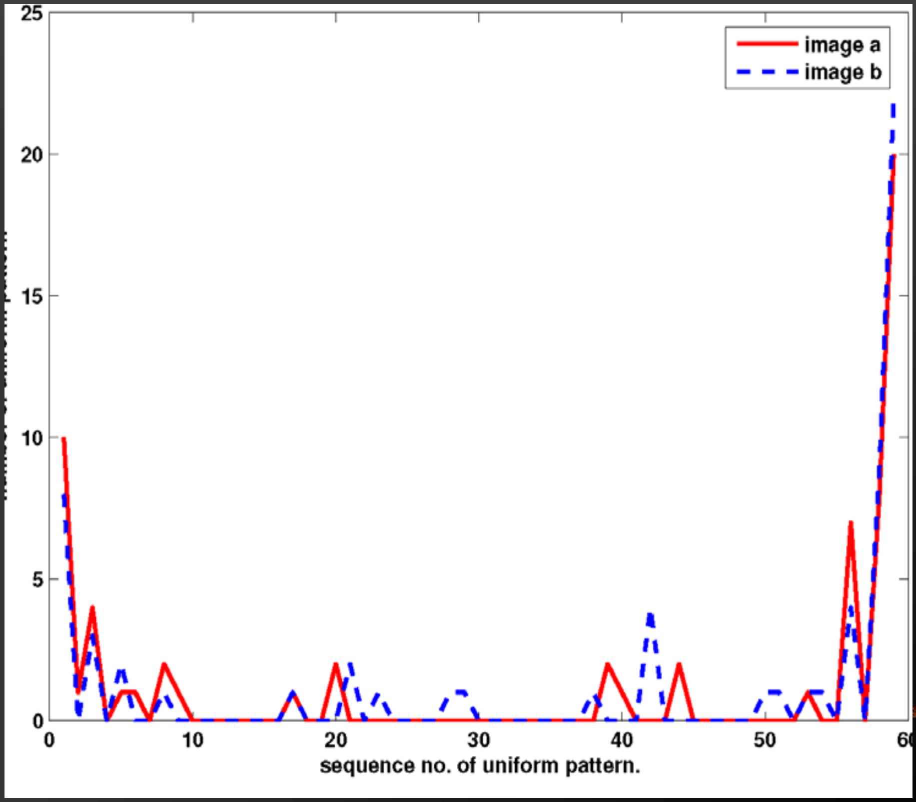
50 ms per image with 120x120 pixels

After Normalization

Effect of Preprocessing on the LBP Descriptor

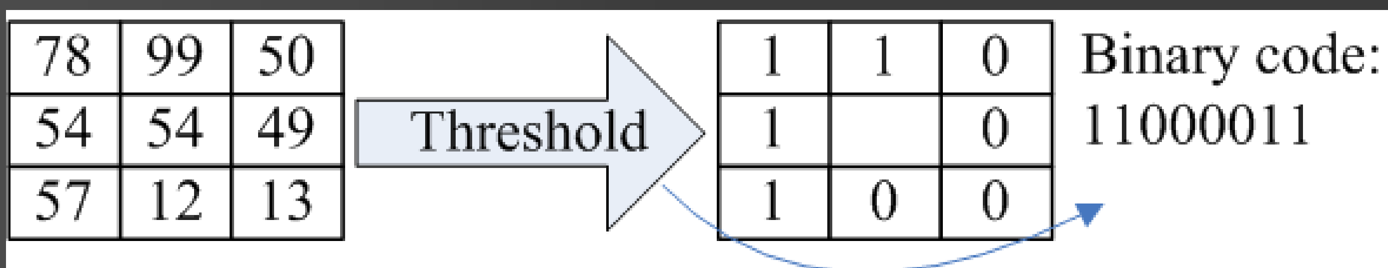
LBP Histograms for the marked region before and after illumination normalization





Local Binary Patterns (LBP)

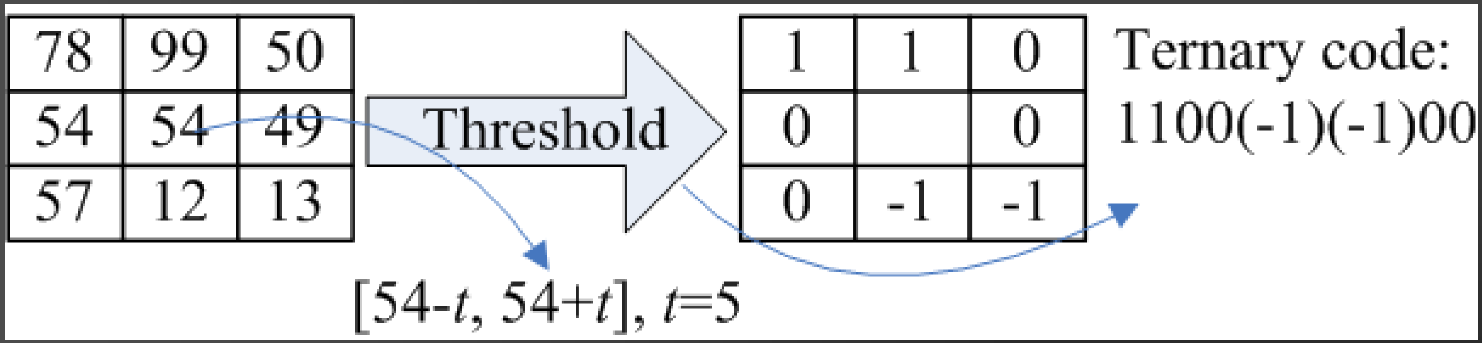
- Threshold local image at centre pixel value
- Resulting binary patterns are pixel-level descriptors
- Histogram locally to get local texture descriptors

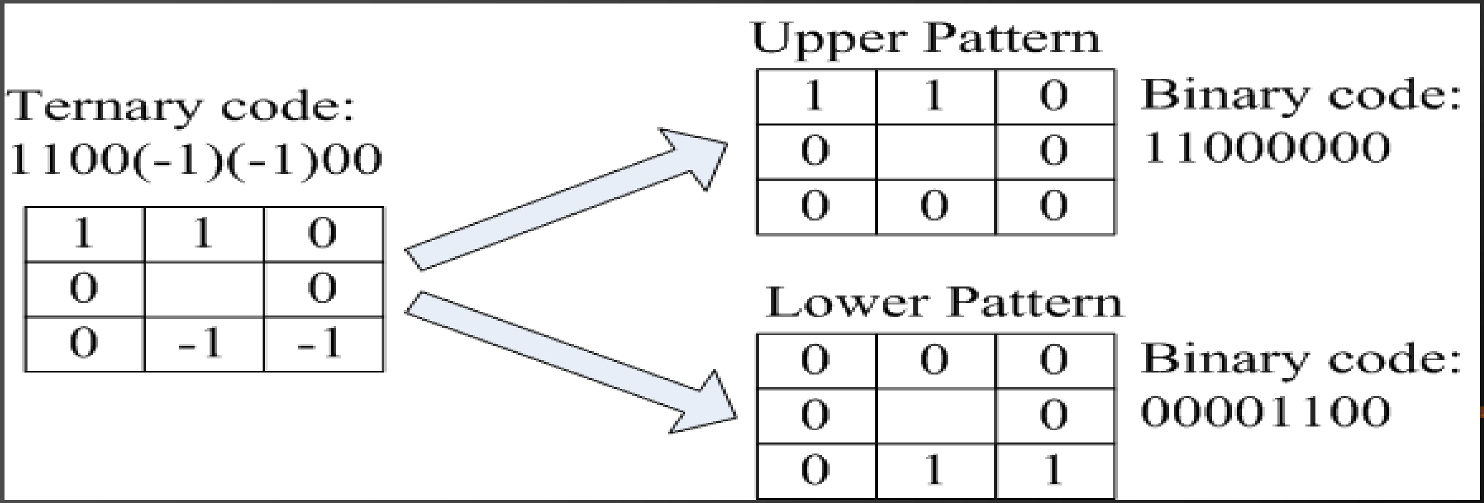


- + Robust to most lighting changes
- - Sensitive to noise in near-uniform regions
  - e.g. many facial regions (cheek, forehead…)

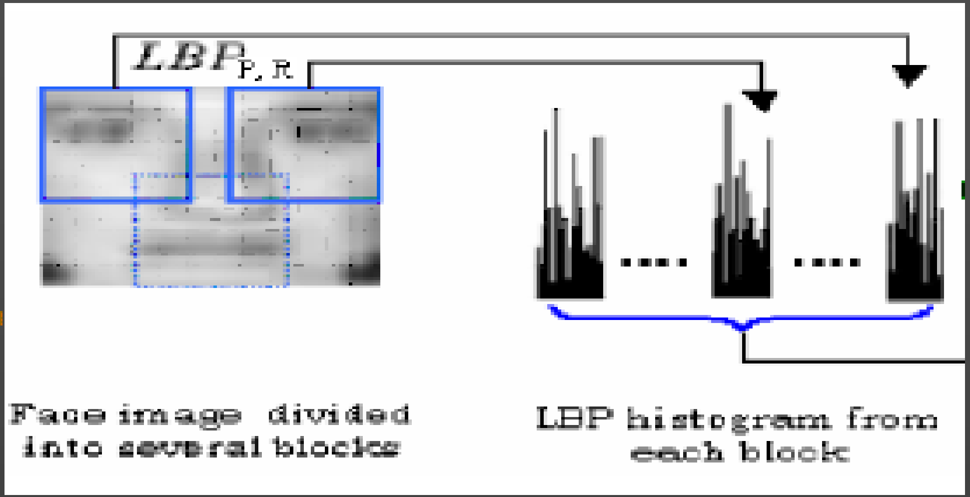
Local Ternary Patterns (LTP)

- 3-valued generalization of LBP
- Adds a threshold / gap to counter noise sensitivity





LBP / LTP Similarity Metric



- Past LBP work
  - partition image into regular grid
  - build local histogram of LBP codes in each grid cell
  - use χ 2 histogram distance to compare images
- Limitations
  - Arbitrary image partition, (cells) not aligned well with facial features
  - Local histogramming
    - abrupt spatial quantization causes aliasing
    - loss of spatial resolution within each grid cell

Robust Image Matching Scheme

- For a reference image X, a test image Y
  - Take each LBP/LTP pixel code in X

    No image partition, No local histogramming

  - Test whether a similar code appears at a nearby position in Y

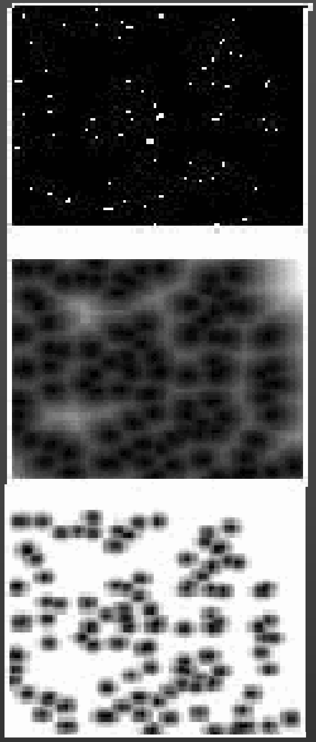
    Controllable degree of spatial looseness

  - With a weighting that decreases smoothly with image distance.

    Improved outlier- robustness

A Distance Transform(DT)-Based Implementation is proposed…

Distance Transform Based Similarity Metric



- For a reference image X, a test image Y
  - Find their LBP/LTP codes
  - Transform these into a set of sparse binary images, one for each code
  - Calculate the distance transform image of each binary reference image
  - For each test image position, look up corresponding reference distance

Distance Transform Based Similarity Metric 2

- Distance calculation

$$D(X,Y) = \sum_{\text{pixels } (i,j) \text{ of } Y} w\left(d_X^{k_Y(i,j)}(i,j)\right)$$

  - Each pixel of d^k gives the distance to the nearest image X pixel with code k
  - $k_Y(i,j)$ is the code value of pixel (I,j) of image Y
  - w is a monotonically increasing function

Experiments on FRGC104

Controlled

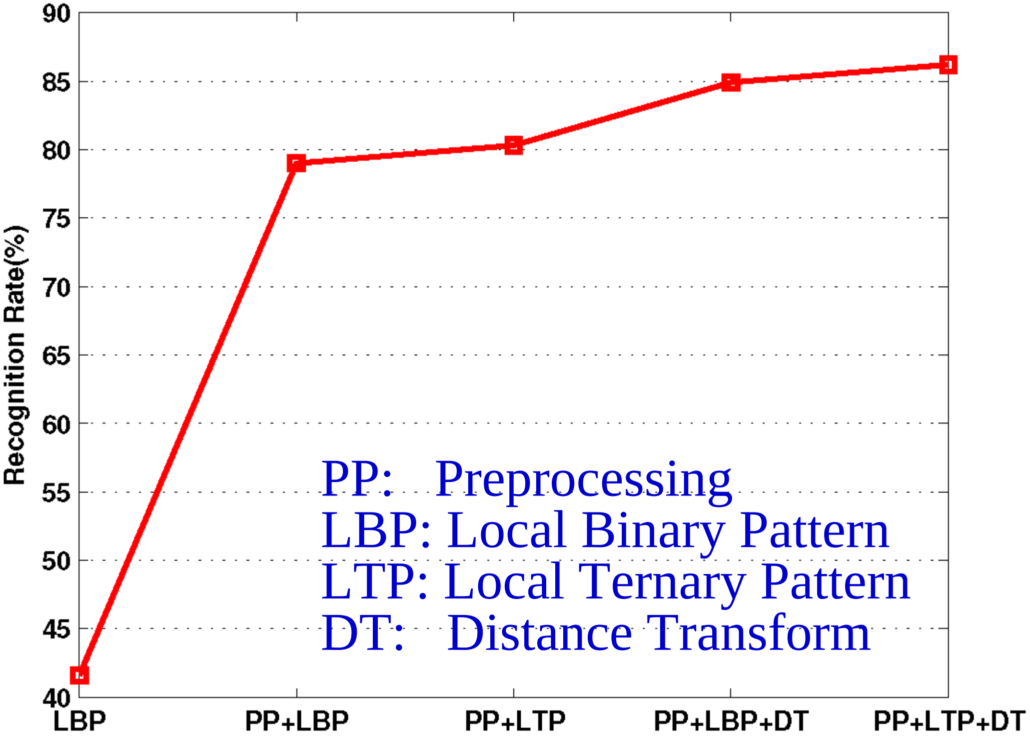
Uncontrolled

Before Normalization

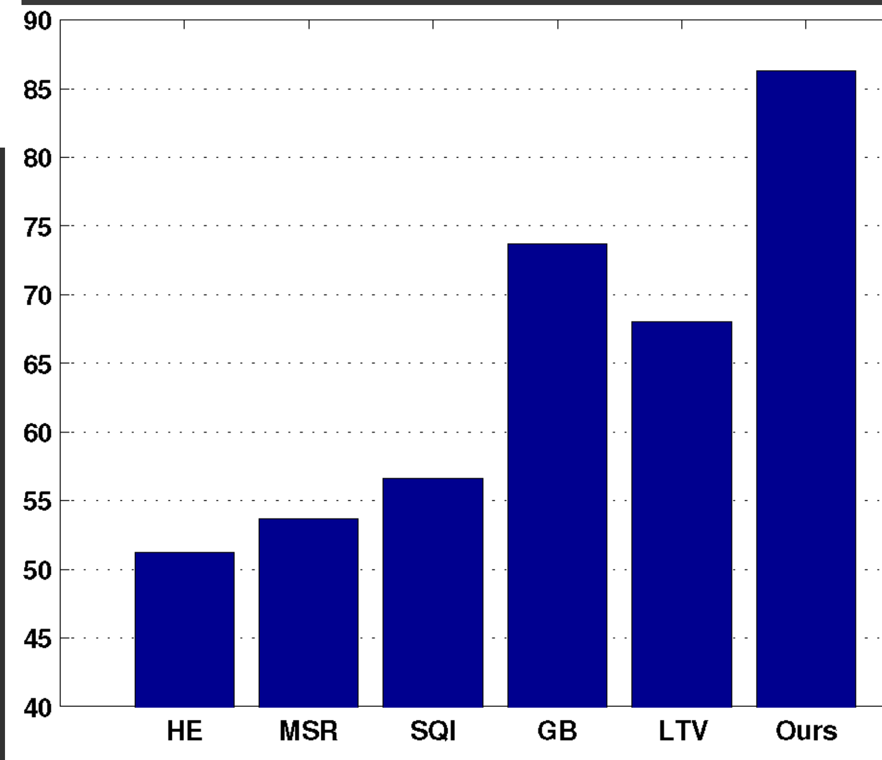
After Normalization

Experimental Results

- FRGC-104

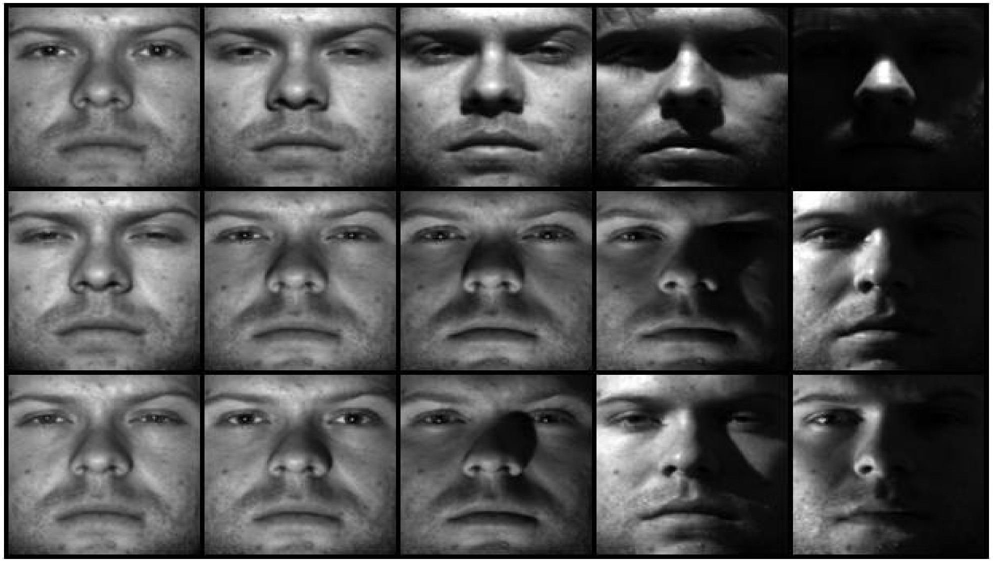


- Comparison of different preprocessing methods



Experiments on Extended Yale B

Each column represents some examples of a subset.

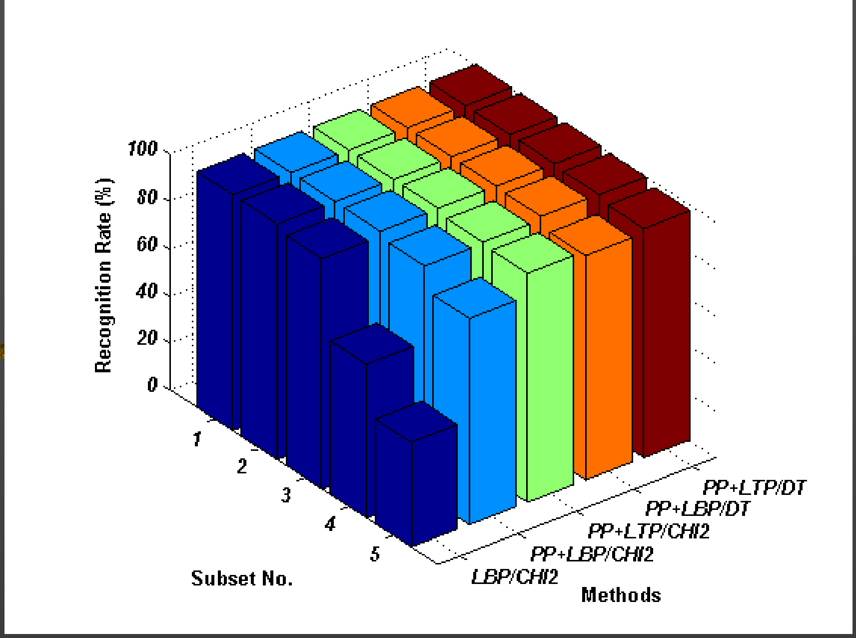


Before Normalization

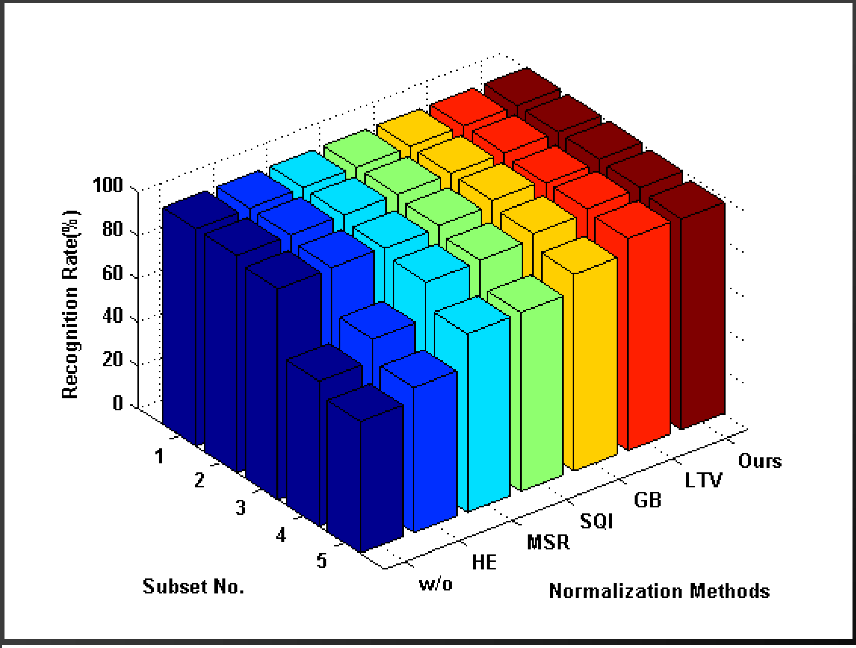
After Normalization

Experimental Results

- Extended Yale-B
- Our preprocessing with various feature sets



- LTP/DT with various preprocessing methods



- CMU PIE

Methods	HE	MSR	SQI	GB	LTV	Ours
Accuracy	98.3	98.3	98.5	99.7	100.0	**100.0**

Preliminary Experiments On FRGC ver. 2

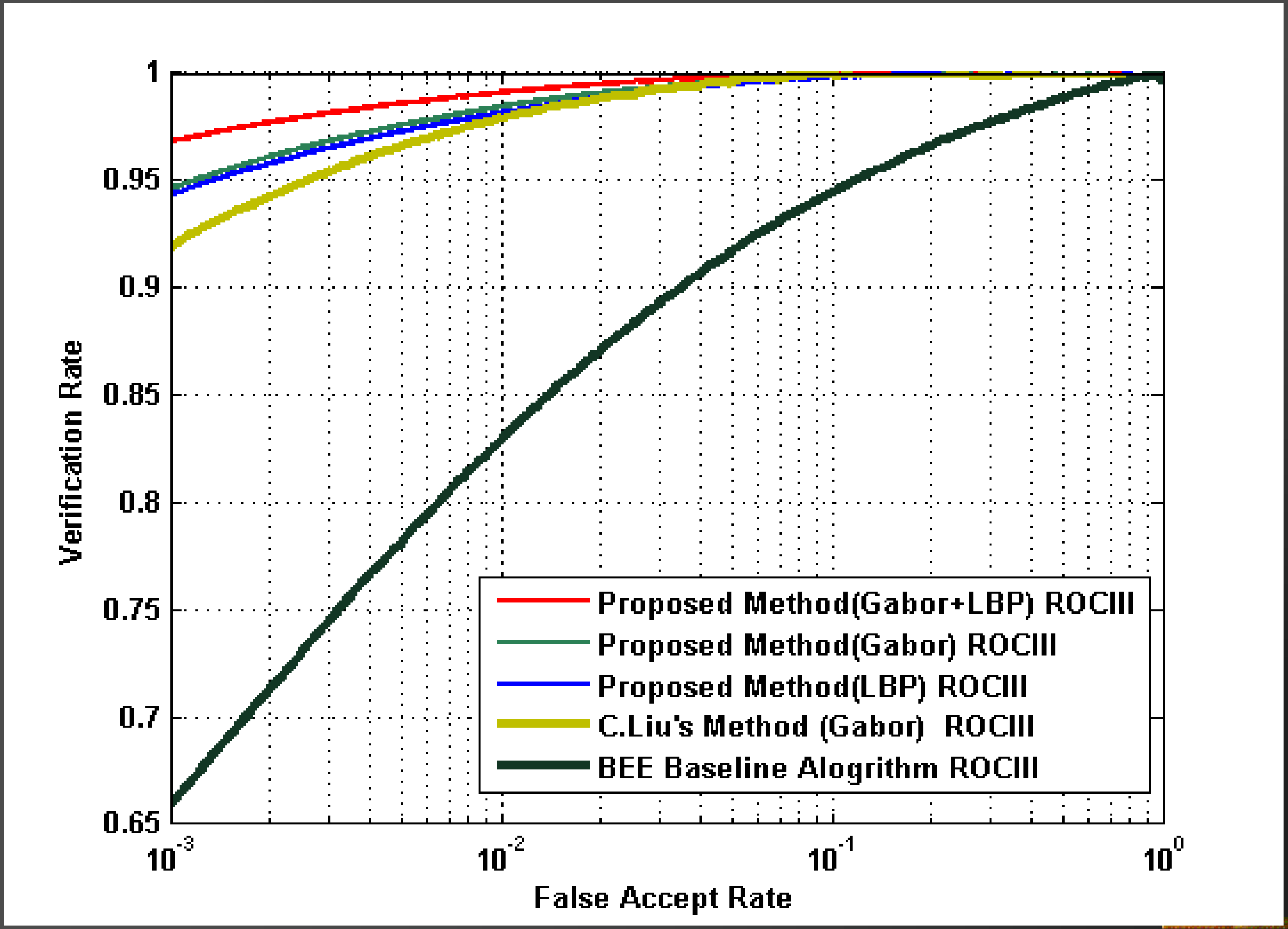
- Database size and image quality

Experiment1	Training	12,776	Controlled &Uncontrolled
	Target	16,028	Controlled
	Query	16,028	Controlled
Experiment4	Training	12,776	Controlled &Uncontrolled
	Target	16,028	Controlled
	Query	8,014	Uncontrolled

Preliminary Experiments On FRGC version 2

- Overall pipeline
  - Robust photometric normalization
  - Separate feature extraction (LBP/Gabor,etc)
  - Discriminant nonlinear feature extraction with Kernel LDA and feature-specific kernel
  - Cosine-distance based nearest neighbor classification
  - (Optional) score-level fusion of multiple features

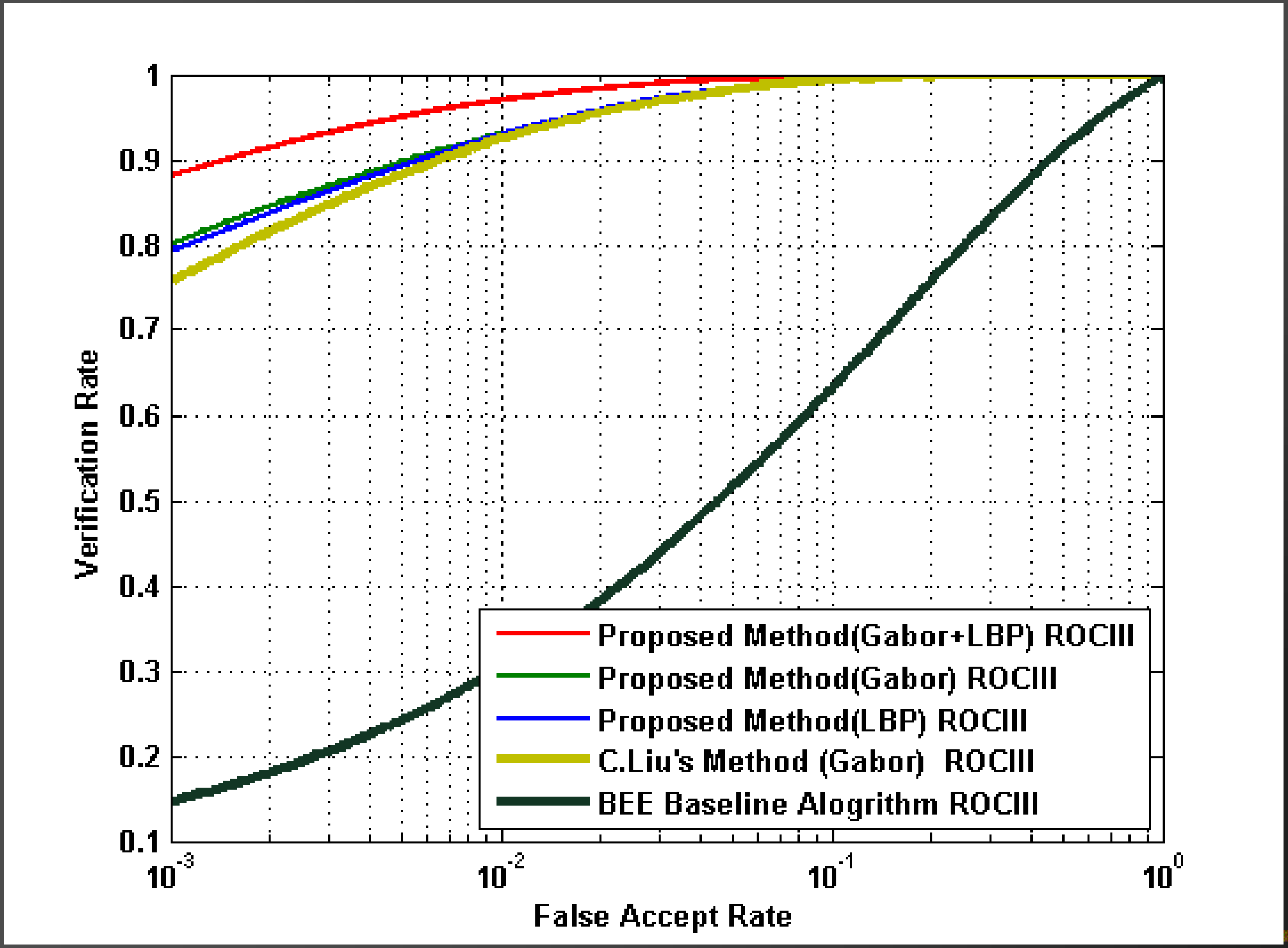
Preliminary Experimental Result on FRGC201(Exp.1)



Same 6388 training images as C.Liu's PAMI'06 paper

Robust Preprocessing +Robust Descriptor(LBP/Gabor) +Kernel Trick

Preliminary Experimental Result on FRGC204 (Exp.4)



Same 6388 training images as C.Liu's PAMI'06 paper

Robust Preprocessing +Robust Descriptor(LBP/Gabor) +Kernel Trick

Conclusion

- Simple preprocessing greatly improves face recognition performance under difficult lighting conditions
- LTP feature generalizes LBP
- DT based LBP/LTP similarity metric
- State of the art performance on several major face databases

See papers in AMFG'07 at ICCV

Thank You!