Pore-scale Facial Feature Extraction and Its Application

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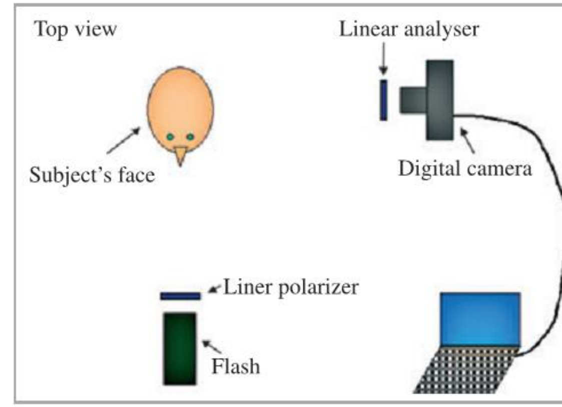
Outline

- Introduction
  - Motivation; state of the art.
- Distinctive features from pore-scale facial keypoints
  - Different scales of facial features; pore index and quantity-driven detection; relative-position descriptor.
- Face matching using pore-scale facial features
  - Candidate-constrained matching.
- Face verification using pore-scale facial features
  - Feature dimension reduction; feature matching and robust fitting; similarity measurement.
- Conclusions and applications
  - Facial Pores as a new biometric; Twins identification; Face recognition; Forensic

Motivation



Linear polarizer

- Why Pore Scale?
- Applications:
  - Quantitative dermatology
  - Tracking and animation
  - 3D face reconstruction
  - Face recognition/verification
  - Biometrics

State of the art

- Pore-scale facial feature extraction and matching
  - a point matching to a surrounding region [1]
  - a point matching to a line (NCC, DAISY)
  - Uncalibrated [2]

[1] S.K. Madan, K.J. Dana, and O.G. Cula, "Quasiconvex Alignment of Multimodal Skin Images for Quantitative Dermatology", CVPRW2009

[2] Y. Lin, G. Medioni, and J. Choi., "Accurate 3d face reconstruction from weakly calibrated wide baseline images with profile contours", CVPR2010.

State of the art

- HR face recognition
  - texture based [1]
  - keypoint-detection based [2]

[1] D. Lin and X. Tang, “Recognize high resolution faces: From macrocosm to microcosm”, CVPR2006.

[2] U. Park and A. K. Jain. “Face matching and retrieval using soft biometrics”, Information Forensics and Security, 5(3):406–415, 2010.

- Other related skin researches
  - Texture based [3] [4]

[3] O. G. Cula, K. J. Dana, F. P. Murphy, and B. K. Rao, “Skin texture modeling,” IJCV, vol. 62, no. 1-2, pp. 97–119, 2005.

[4]J. Xie et al., ” A Study of Hand Back Skin Texture Patterns for Personal Identification and Gender Classification”, Sensor, vol. 7, pp. 8691-8709, 2012

Open problems

- Are the pores different for intra-person?
- Are the pores different for inter-person?
- Are the pore features robust?
  - Poses; Aging; Expressions; Lighting; Resolutions; Blurring; Noise

Scope of this work

- Distinctive features from pore-scale facial keypoints
- Face matching using pore-scale facial features
- Face verification using pore-scale facial feature

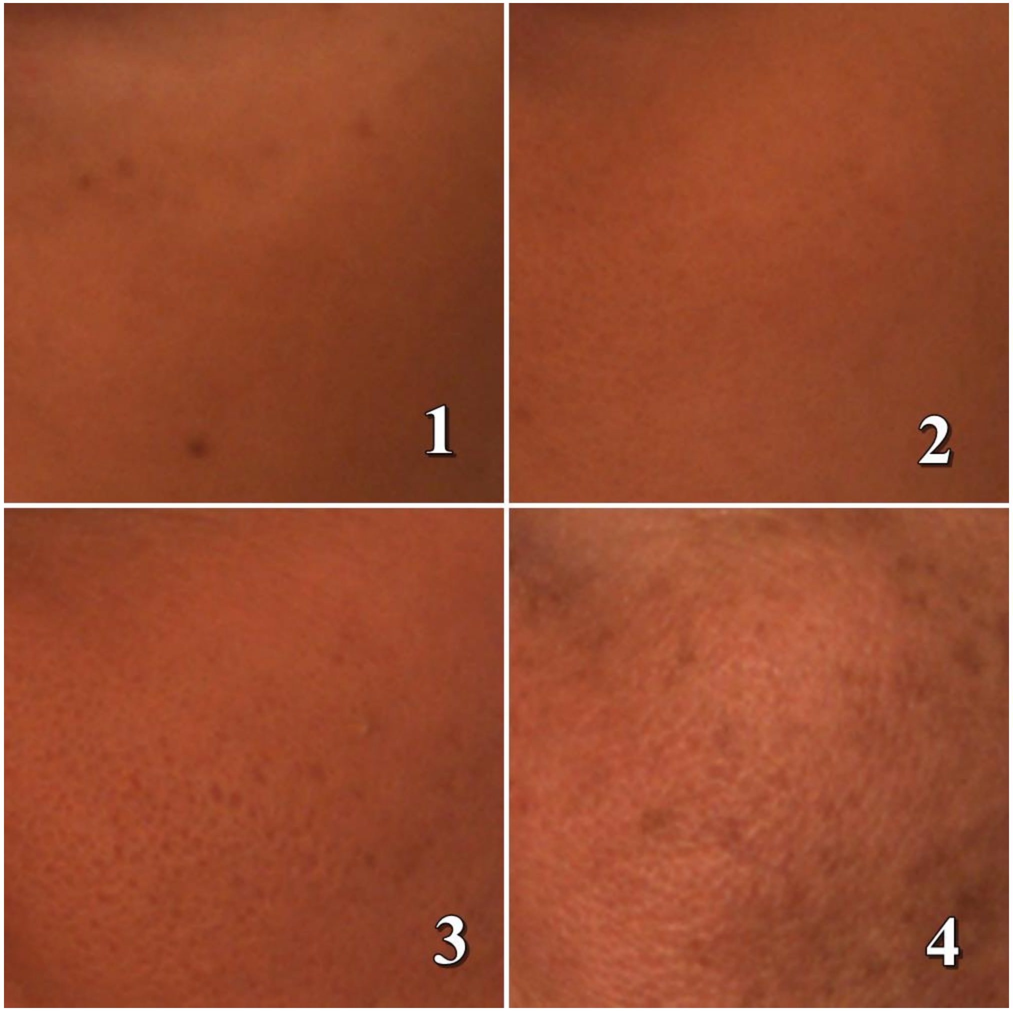
- Dong Li, Huiling Zhou and Kin-Man Lam, High-Resolution Face Verification Using Pore-scale Facial Features, IEEE Transactions on Image Processing, 24(8), pp. 2317-2327, 2015, doi: 10.1109/TIP.2015.2412374.
- Dong Li and Kin-Man Lam, Design and Learn Distinctive Features from Pore-scale Facial Keypoints, Pattern Recognition, 48(3), pp. 732-745, 2015, doi: 10.1016/j.patcog.2014.09.026.

Different scales of facial features

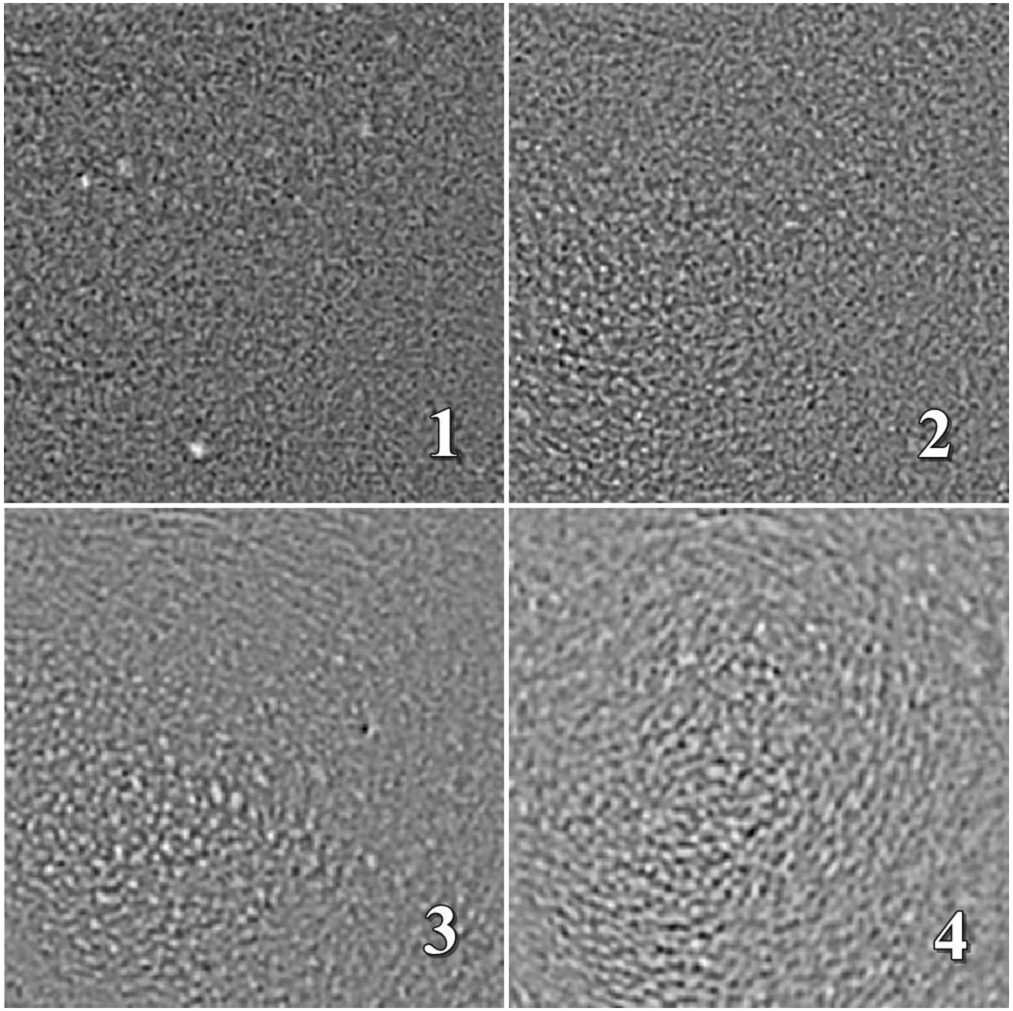
- Primary facial features
  - Eyes, eyebrows, nose, mouth, and face boundary
- Marker-scale facial features
  - Involves ten categories, such as freckle, mole, scar, wrinkle, etc.
- Pore-scale facial features
  - Pores, fine wrinkles, and hair

Observation on pores

Observation on pores



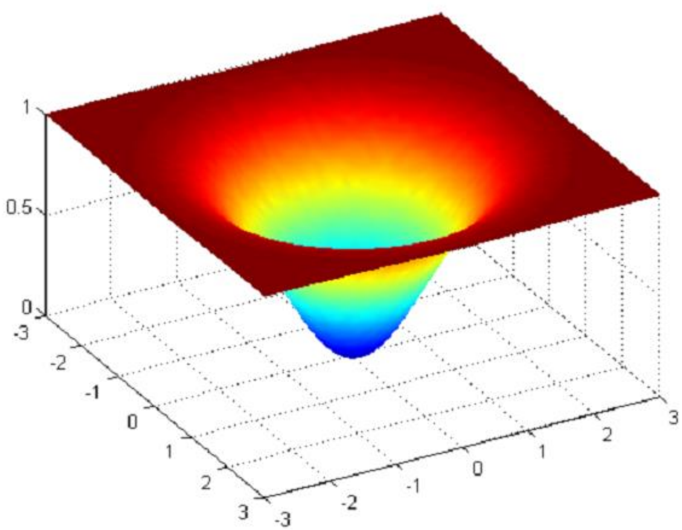
Observation on pores

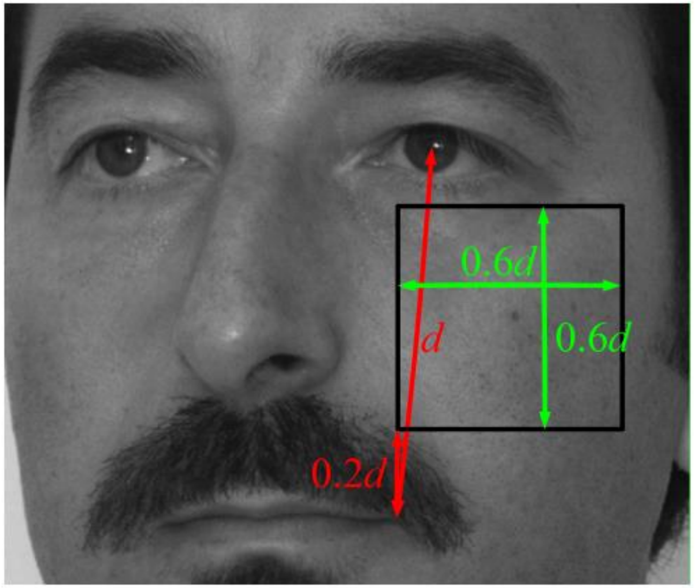


Pore-scale facial-feature detection

- Most are blob shaped → DoG detector
- Only darker keypoints
- Similar quantity → adaptive threshold
- Pore-scale facial-feature Modeling

$$pore(x, y, \sigma) = 1 - 2\pi\sigma^2 G(x, y, \sigma)$$





The number of DoG octaves

$$
\begin{aligned}
& D_{pore}(x, y, \sigma_1, \sigma_2) \\
= \; & [G(x, y, k\sigma_1) - G(x, y, \sigma_1)] * pore(x, y, \sigma_2) \\
= \; & \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} [G(u, v, k\sigma_1) - G(u, v, \sigma_1)] \\
& \cdot pore(x - u, y - v, \sigma_2) du dv.
\end{aligned}
$$

- Set *x*=0, *y*=0, D_{pore} is maximized when

$$\hat{\sigma}_1 = k^{-1/2} \sigma_2.$$

- How many octaves of DoG?
  - When o=3, $\sigma_2 = k^{1/2} \hat{\sigma}_{1,o=3,N_s+1} = k^{1/2} 2^3 \sigma_0 > 6.4$

Adaptive threshold and Pore Index

- The peak value of DoG response:

$$P = D_{pore}(\hat{\sigma}_2) = (k-1)/(k+1).$$

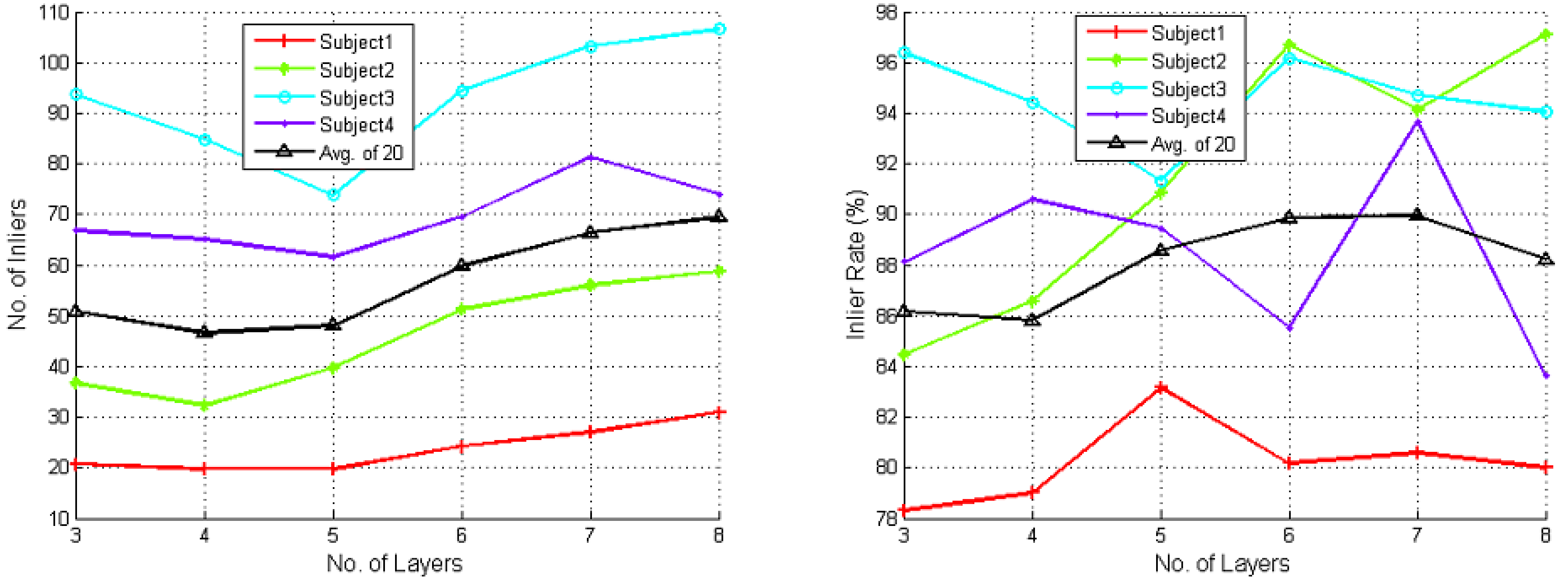
  - The maximized response is independent of the scale of the pores → invariant to image resolutions
  - The peak value is relevant to the sampling frequencies in scale ($k = 2^{1/N_s}$. Each Octave has N_s DoG layers.)
- An adaptive threshold τ is searched on $[0, 0.2 \times P]$
- Pore Index is defined as

$$R_{pore} = \tau / P.$$

  - reflects the roughness/contrast of the skin

Parameter selection

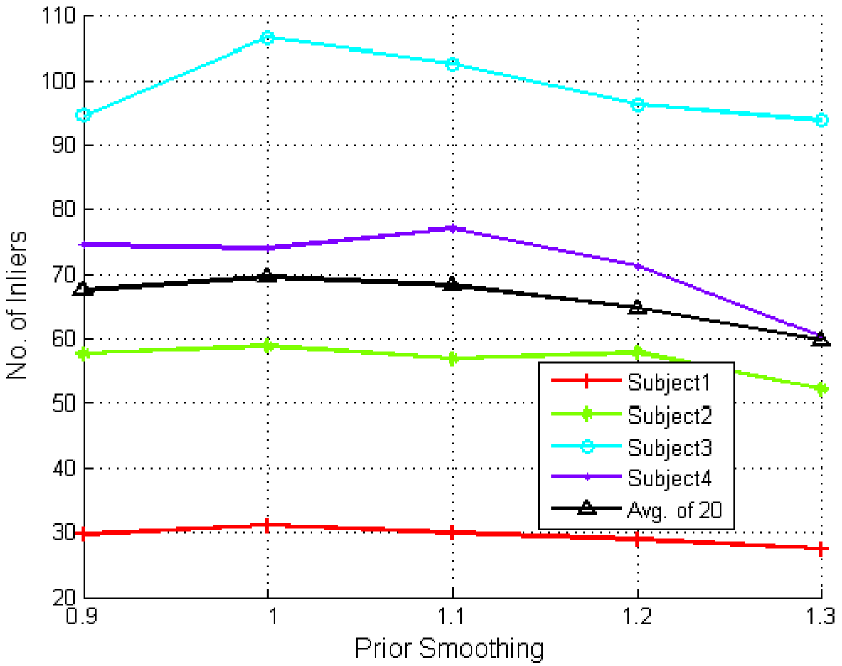
- Sampling frequency in scale

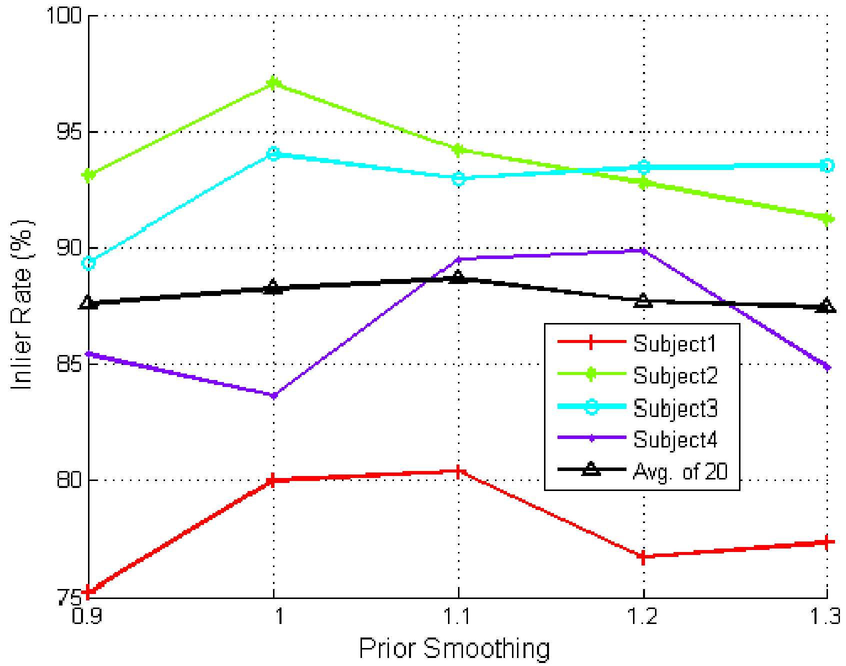


*Inlier Rate=the No. of inliers / the No. of matches

Parameter selection

- Sampling frequency in the spatial domain





*Inlier Rate=the No. of inliers / the No. of matches

Relative-position descriptor

Parameters of the PSIFT and SIFT descriptors.

	PSIFT	SIFT
No. of subregions	8×8	4×4
Support size of total subregions	$6 \times$ scale of keypoints	$3 \times$ scale of keypoints
Support size of each subregion	$0.75 \times$ scale of keypoints	$0.75 \times$ scale of keypoints
No. of Orientation bins	8	8
Dimension of the feature	512	128

Pore-to-pore Correspondences Dataset

- Face images with 10-, 20-, 30- and 45-degree poses of 105 subjects in Bosphorus Database are used.
- 420 cropped cheek-region images
- Matching based on PSIFT and RANSAC
- A track is a set of matched keypoints across the face images of a subject at different poses.
- 4,240 tracks is established containing 4 keypoints corresponding to the 10-, 20-, 30- and 45-degree pose.

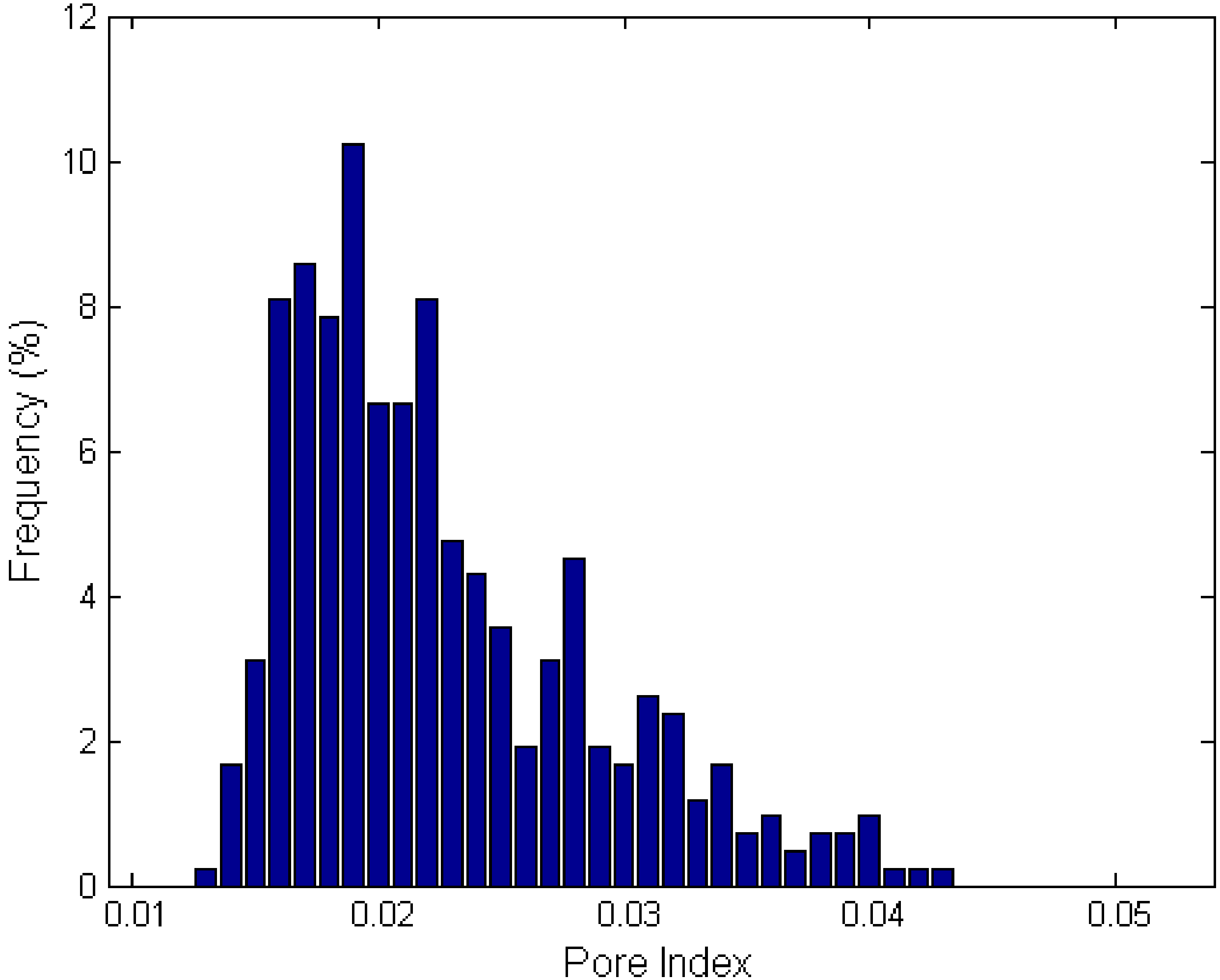
Discriminant Learning

- Distortions are hard to model
- A supervised learning procedure based on LDA is proposed.
- 4,240 classes(tracks), 4 pore images in a class

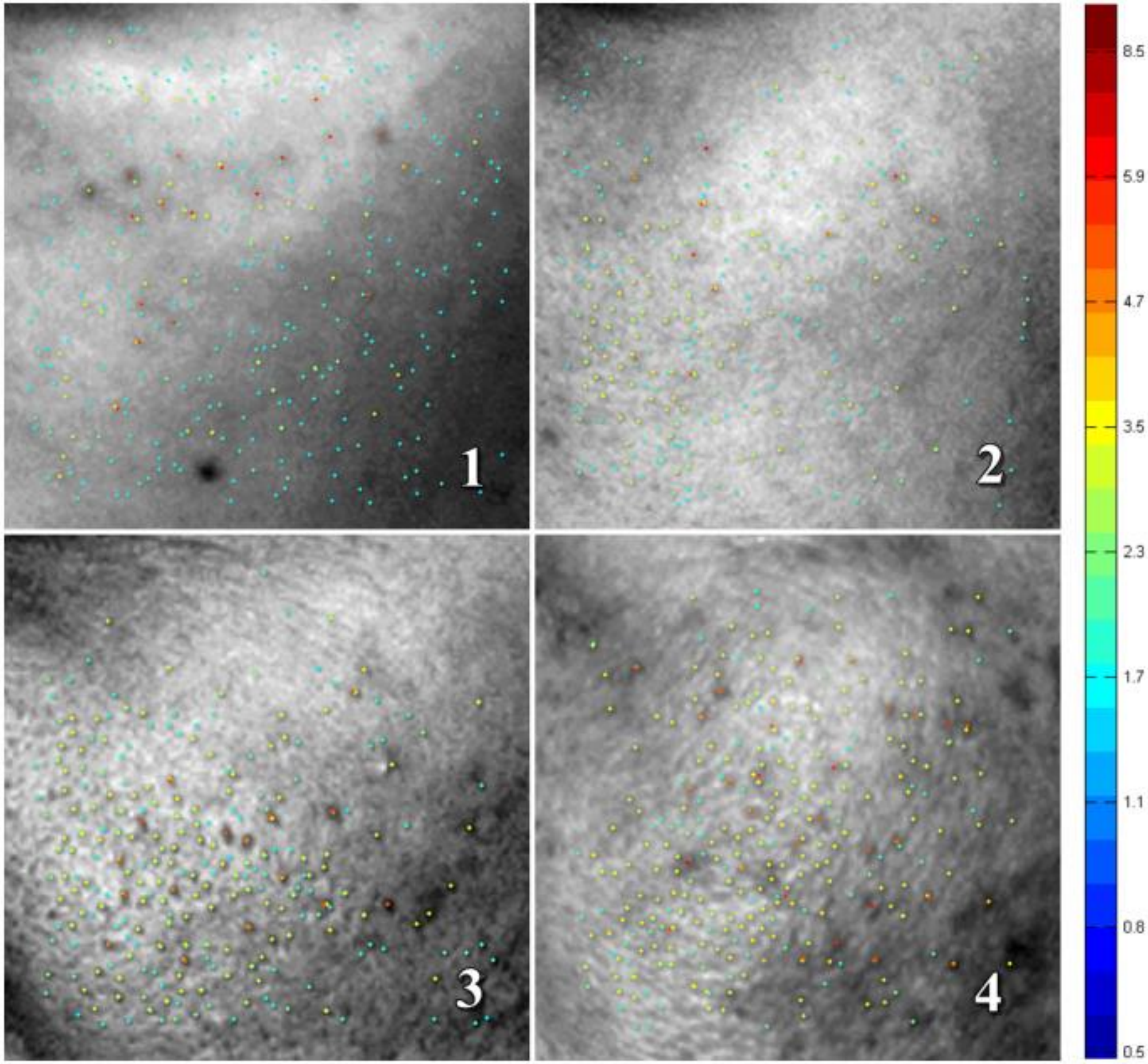
Experiments on Cropped Skin images

- Dataset
  - Bosphorus face database
  - 105 subjects, 420 skin images with different poses
  - Original resolution is about 1,400x1,200 pixels
  - After cropped, the skin region is about 350x350 pixels

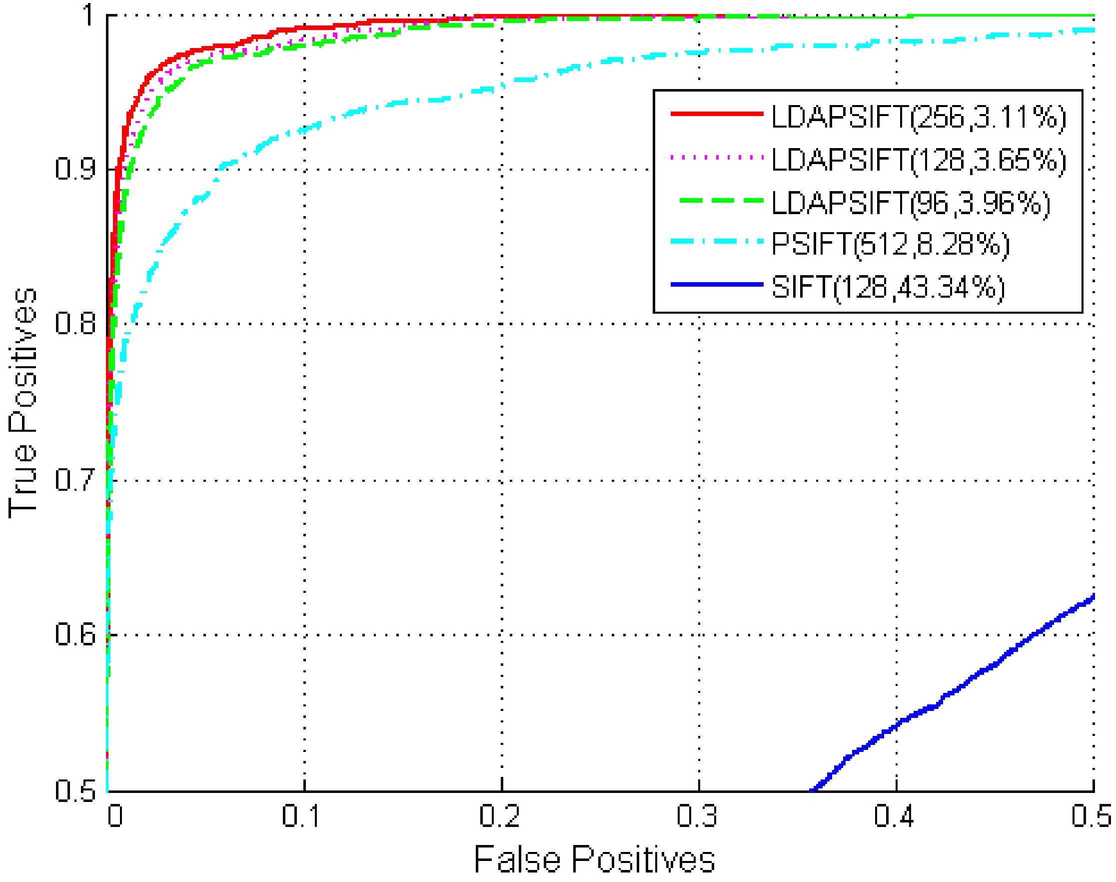
Statistics of Pore Indices



Visualization



ROC Curves of Different Descriptors



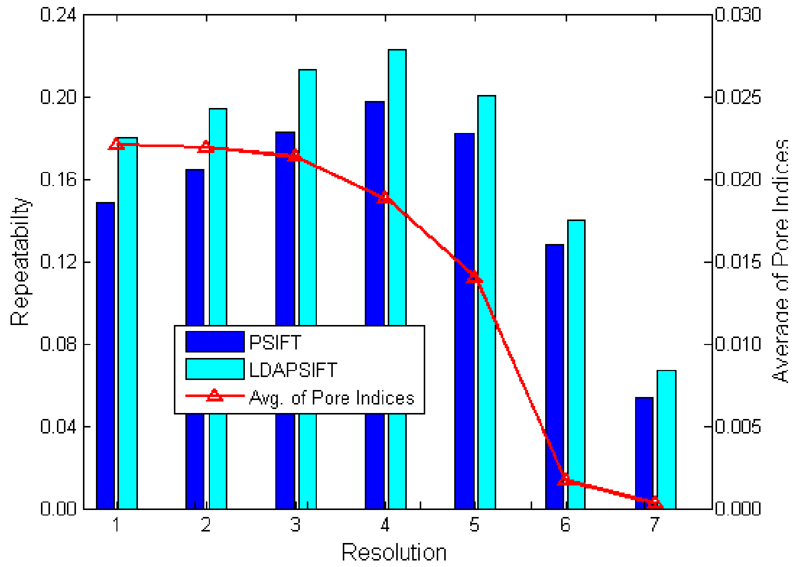
Experiments: Skin matching

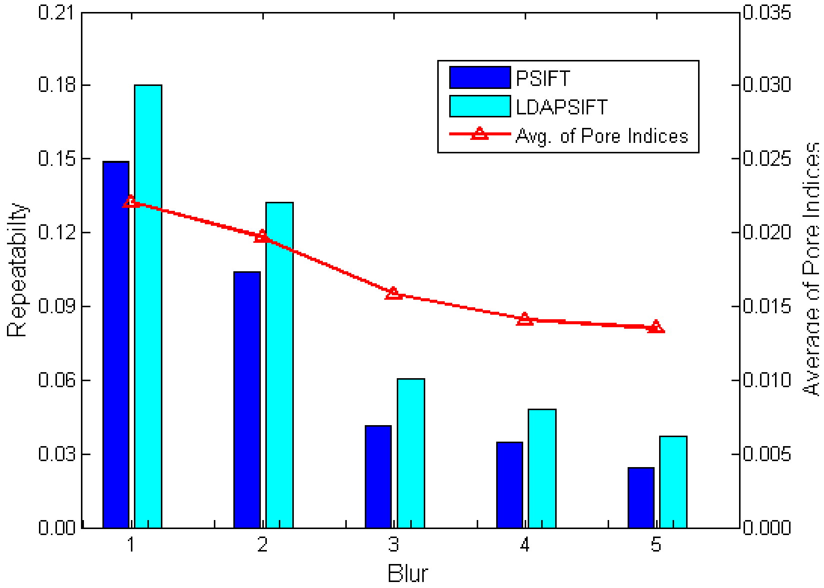
- The influences of each stage of our algorithm
  - Matching from 10 degrees to 45 degrees

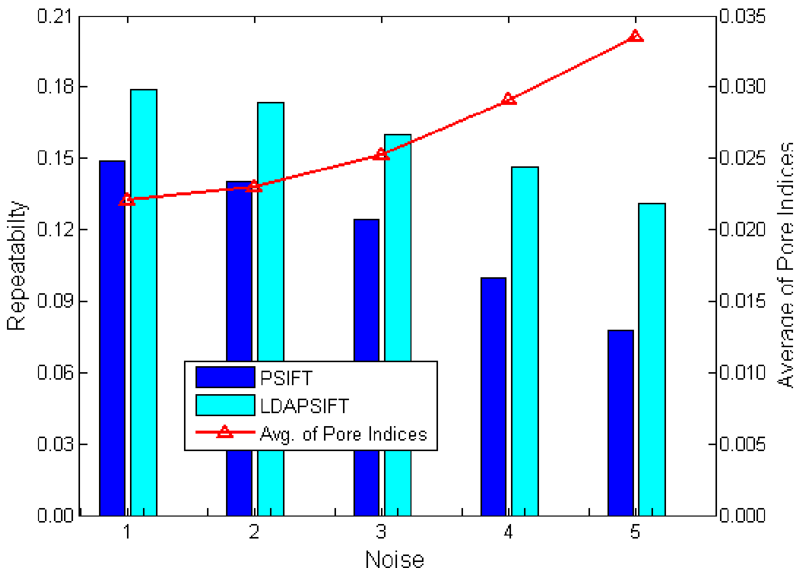
Table 3: Skin matching results.

Method	Avg. No. of inliers	Repeat -ability	No. of image pairs on which more than 20 inliers
LDAPSIFT	89.33	18.01%	102
PSIFT	73.86	14.89%	96
SIFT detector+PSIFT	25.94	5.95%	44
PSIFT detector+SIFT	8.65	1.74%	11
SIFT	3.66	0.79%	5

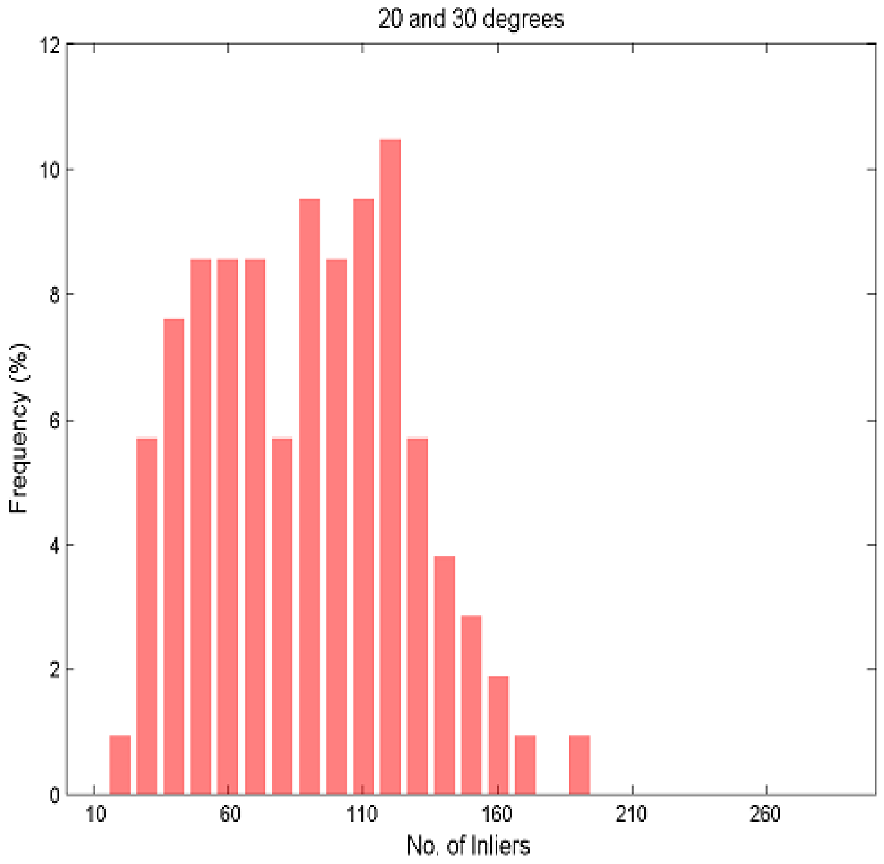
Experiments: Robustness Evaluation

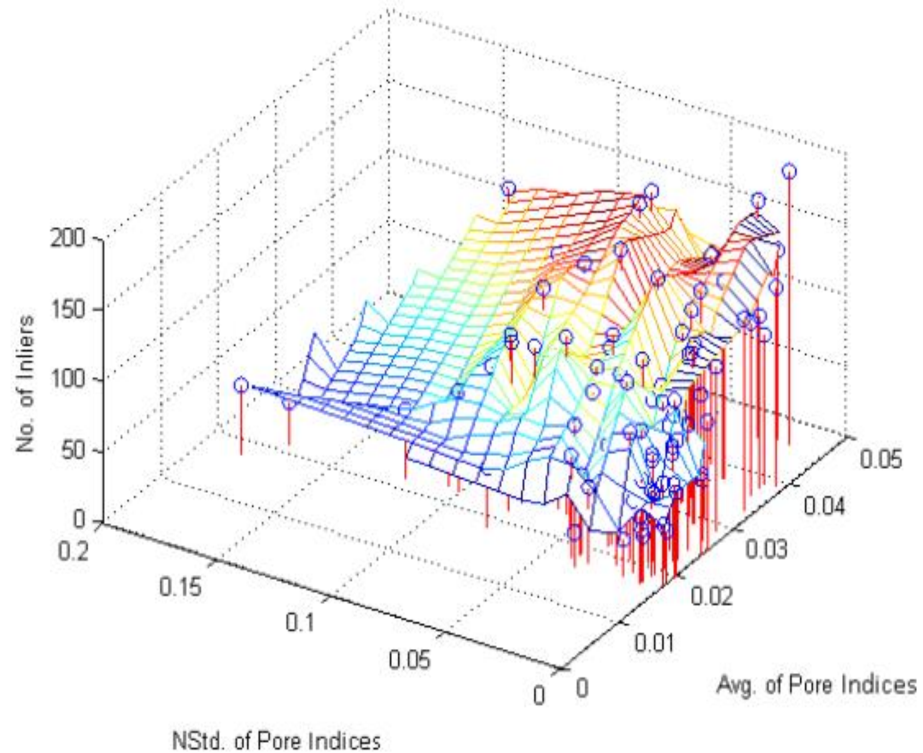






Matching Difficulty Analysis





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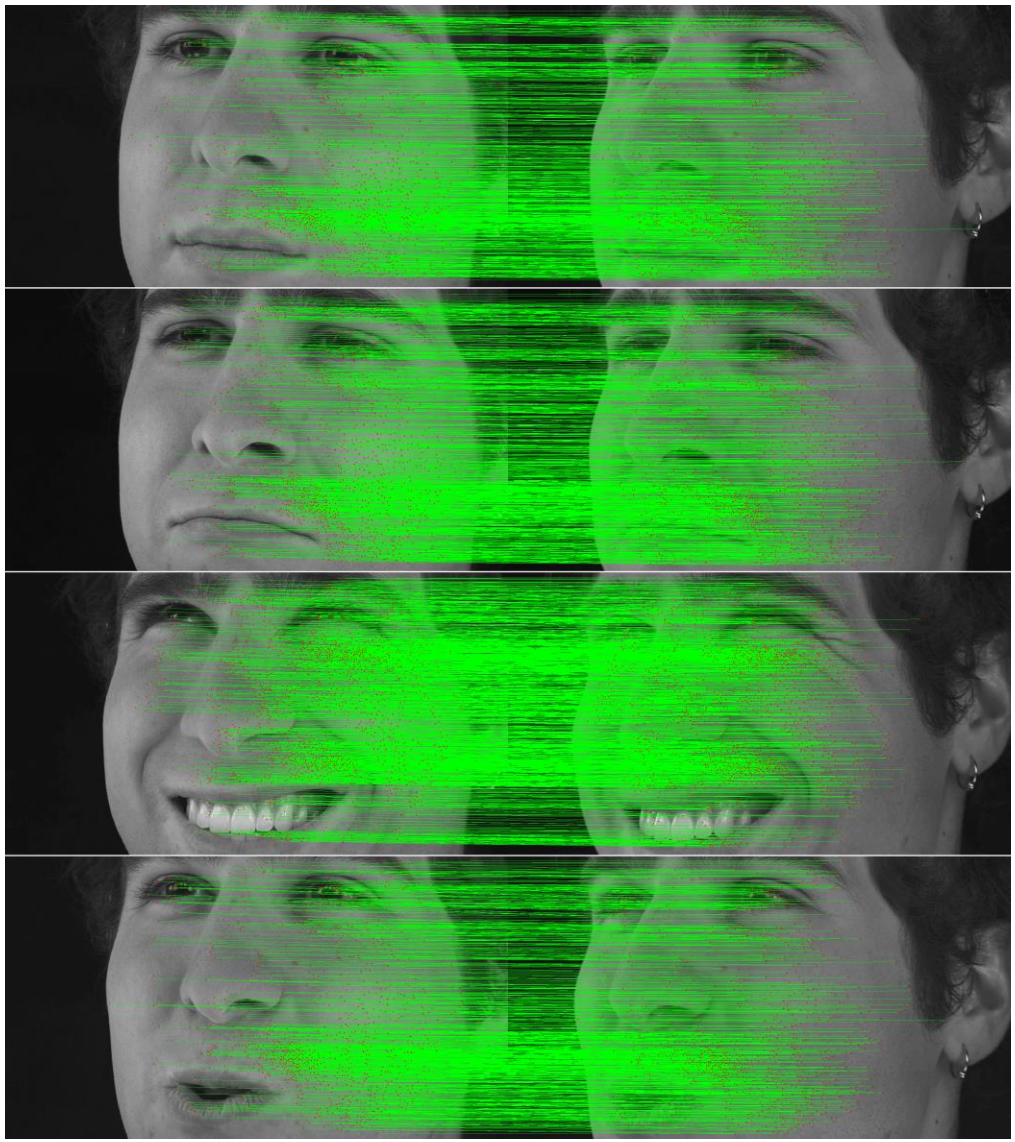
Candidate-constrained matching

- The region of candidates is constrained based on vertical coordinates or epipolar constraint.
  - The searching area is narrowed to 20% size of the whole face in the first matching.
  - In the 2^{nd} matching, based on primary facial features and the estimated epipolar constraint, the one is narrowed to 5% size.
- The scale of candidates should be similar.
  - $0.5 \leqslant |\sigma_2^j / \sigma_1^i| \leqslant 2$

Face Matching Based on a Calibrated and Synchronized Dataset

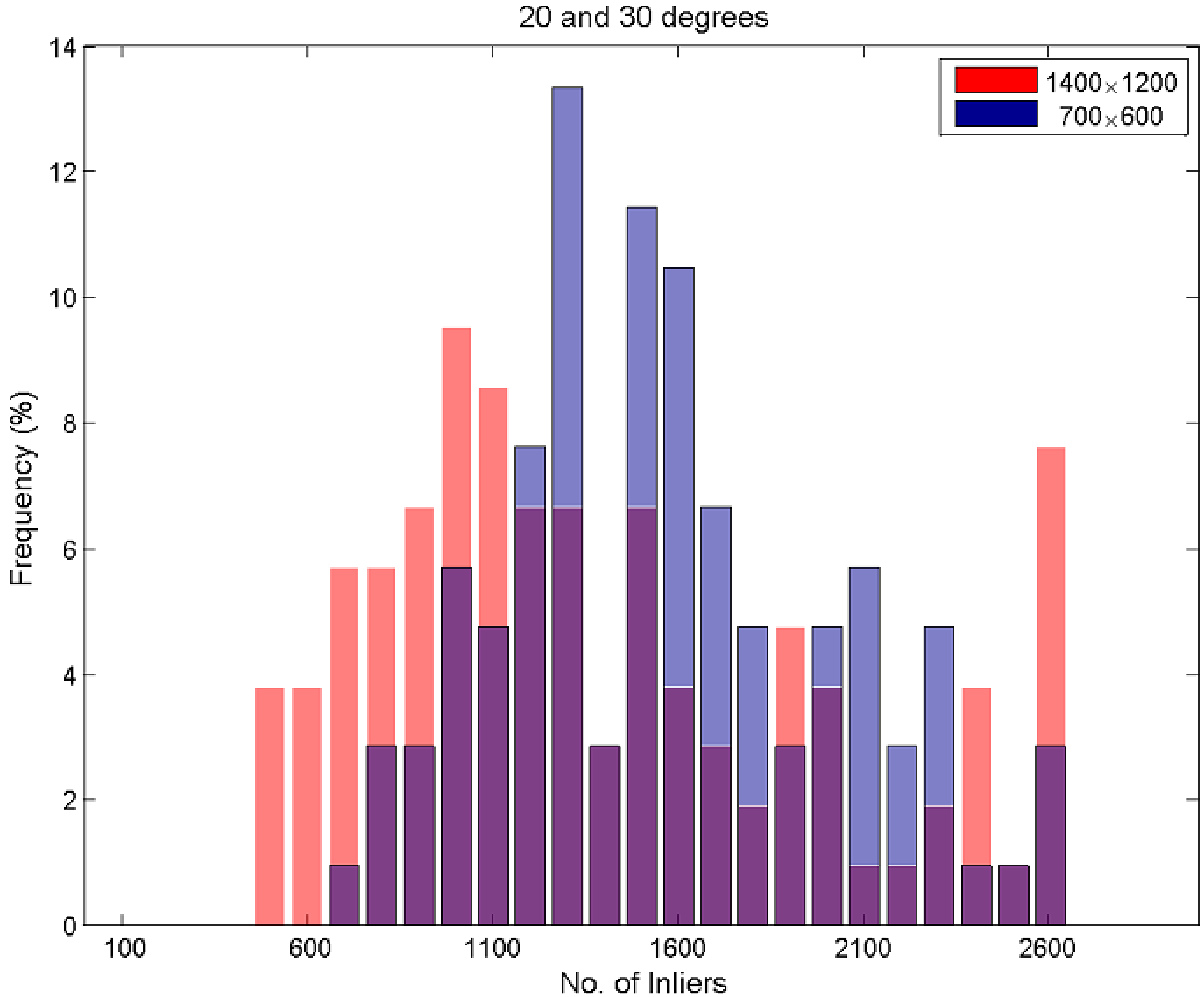


Face Matching Based on a Calibrated and Synchronized Dataset

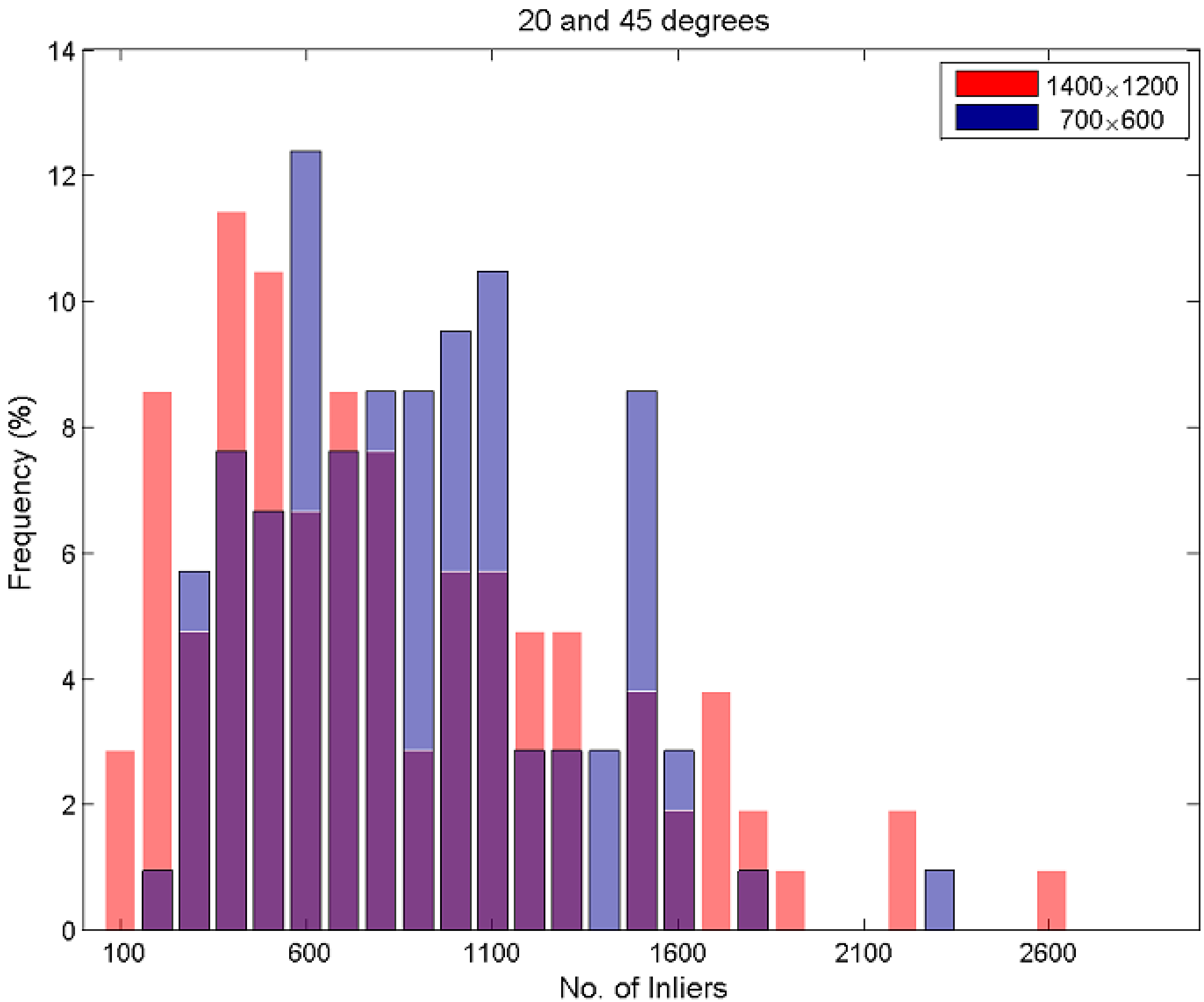
- The no. of inliers (Avg/Std) detected in each step of the matching process

Resolution	1,920 × 1,080		960 × 540	
Methods	Proposed	SIFT	Proposed	SIFT
Initial Matching	1026.4/ 189.5	177.7/ 37.5	1431.3/ 171.3	91.4/ 20.1
After RANSAC	691.4/ 121.6	107.8/ 30.1	920.5/ 90.0	51.6/ 14.9
Ground truth	688.2/ 122.1	107.4/ 30.1	915.1/ 90.0	50.8/ 15.0
2nd Matching	1390.2/ 238.7	N/A	1649.5/ 214.7	N/A
After 2nd RANSAC	1191.4/ 202.4	N/A	1377.6/ 146.0	N/A
Ground truth	1156.5/ 193.1	N/A	1338.8/ 139.3	N/A

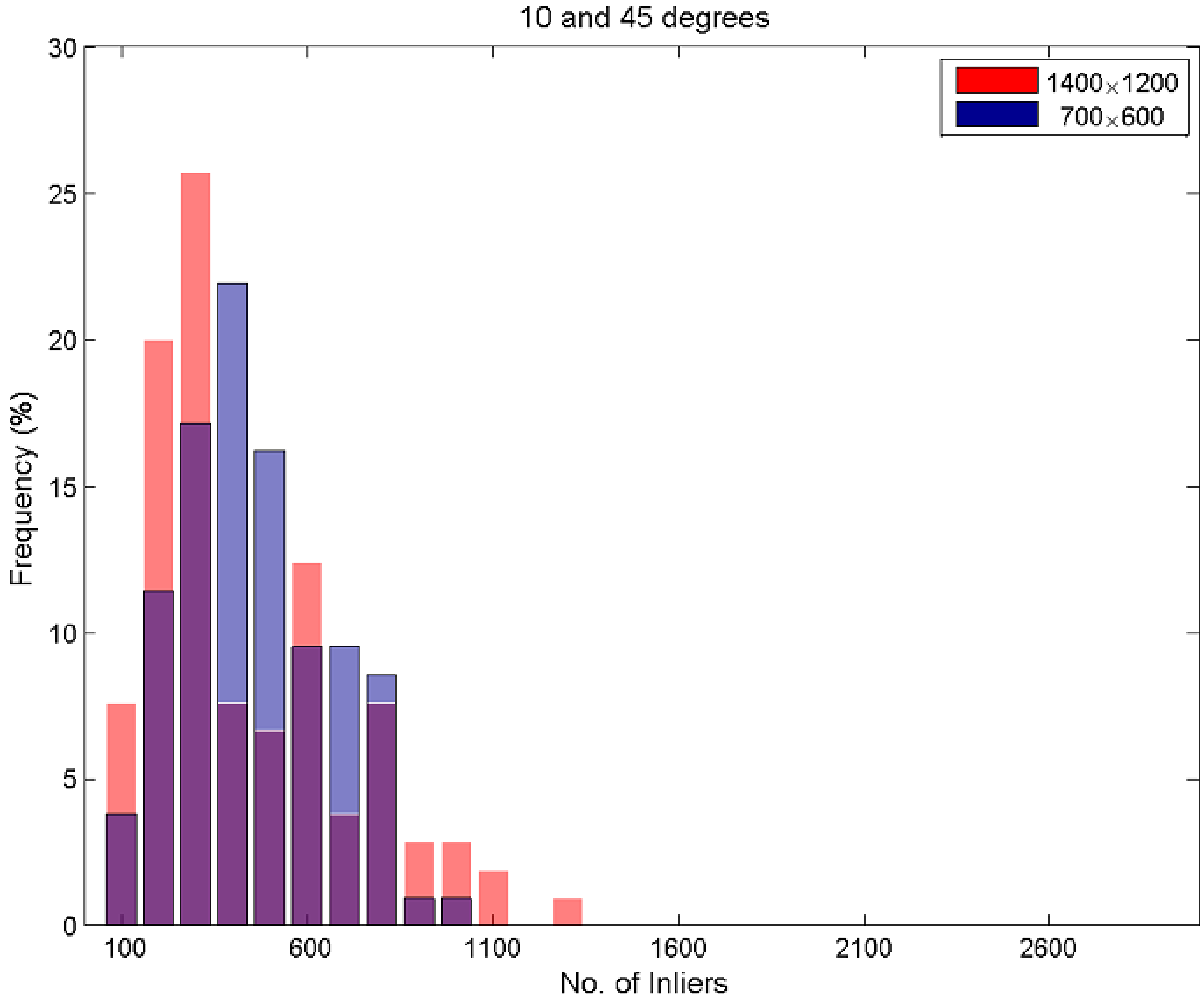
Face Matching Based on an Unsynchronized Dataset



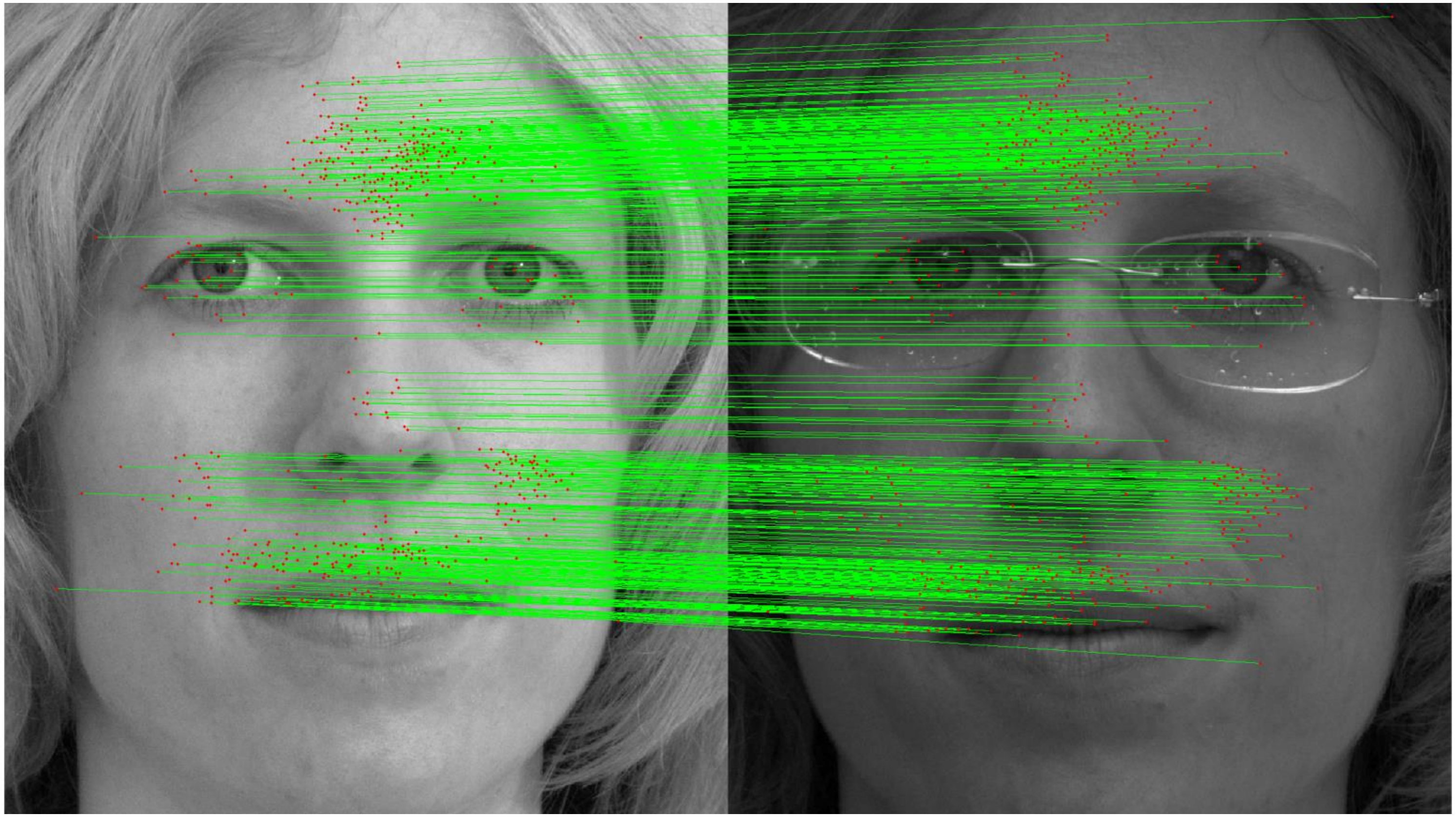
Face Matching Based on an Unsynchronized Dataset



Face Matching Based on an Unsynchronized Dataset



Face Matching Based on Twins Images



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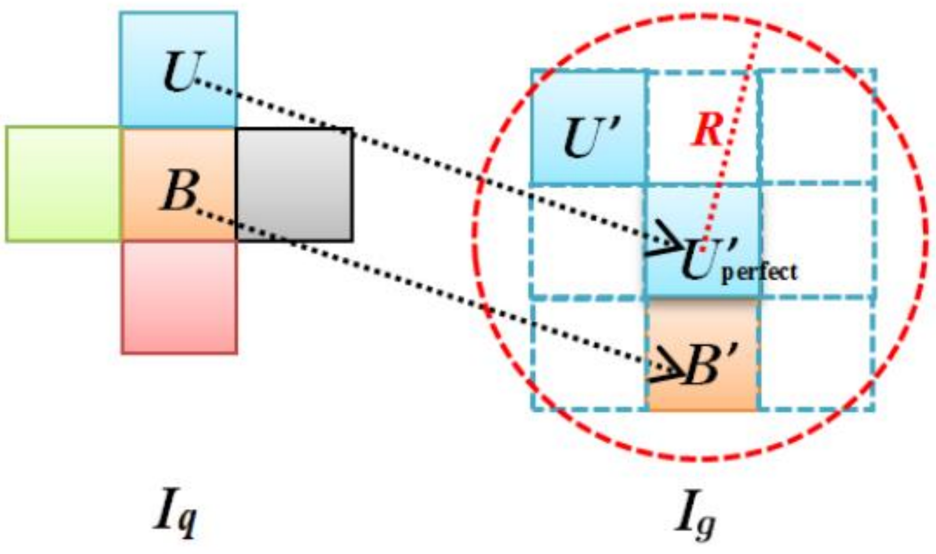
Feature dimension reduction

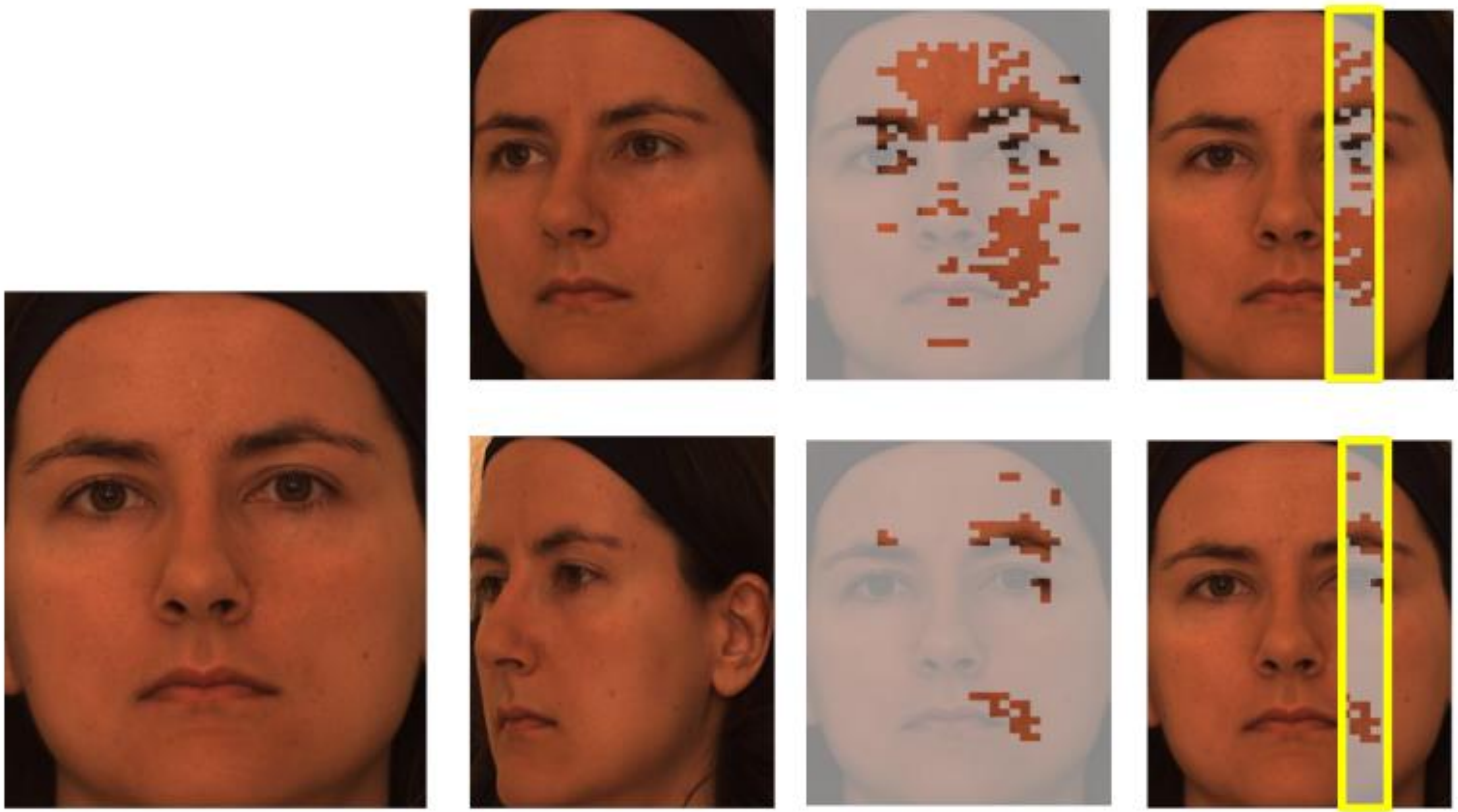
- Based on 16 face images from 4 subjects with different skin appearances
- Extract about 90,000 patches, 41x41 size
- Calculate horizontal and vertical gradient, so each training vector is 2x39x39=3,042 elements
- Then, PCA is applied
- The 72 leading eigen-vectors are used to form the projection matrix (3,042x72)
- The PSIFT is 512d, and the PPCASIFT is only 72d

Robust fitting

- RANSAC is not suitable for expression variance.
- Transfer the keypoint correspondences to block-based correspondences.
- The line connecting two correctly matched blocks *BB*' in the two face images should be approximately parallel to the other lines *UU*' of the corresponding neighboring blocks.

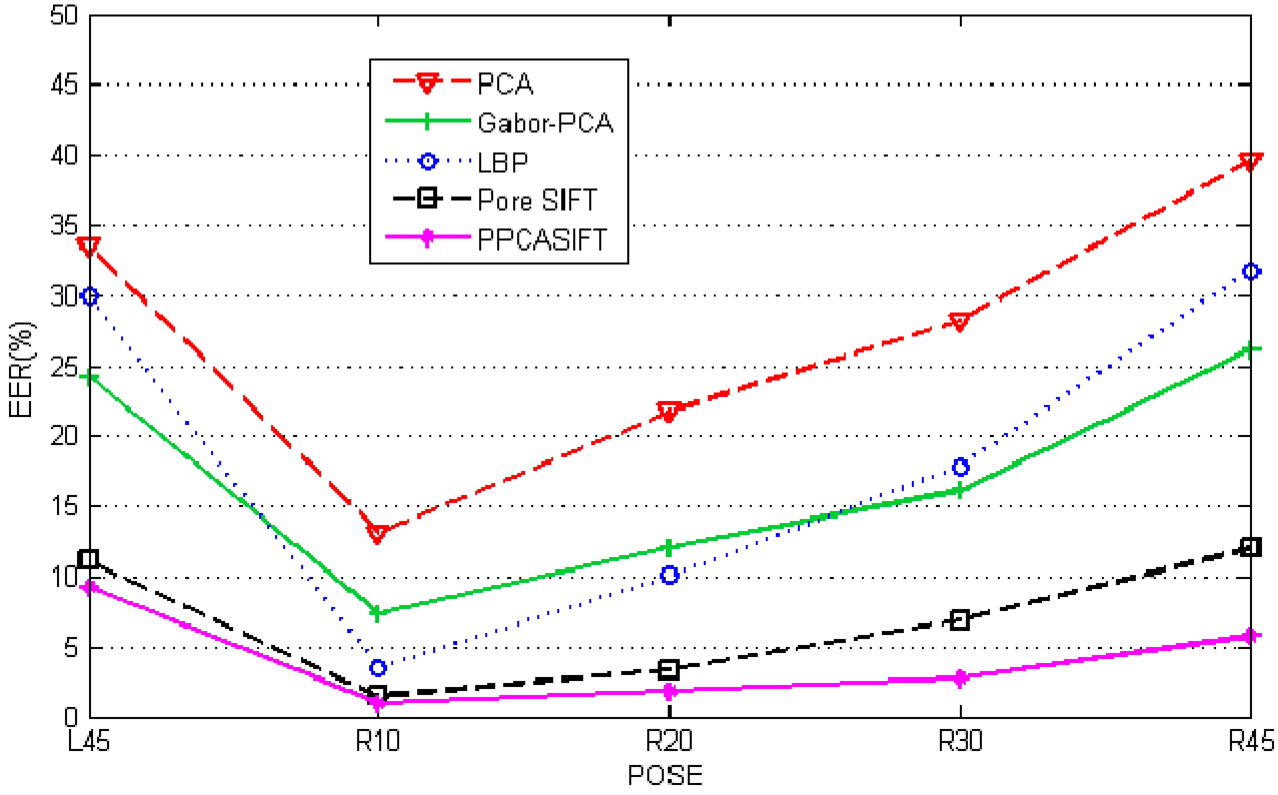


Similarity measurement



Face verification with pose variations

- Bosphorus dataset, 105 subjects, 1 as gallery other 5 poses as testing per subject



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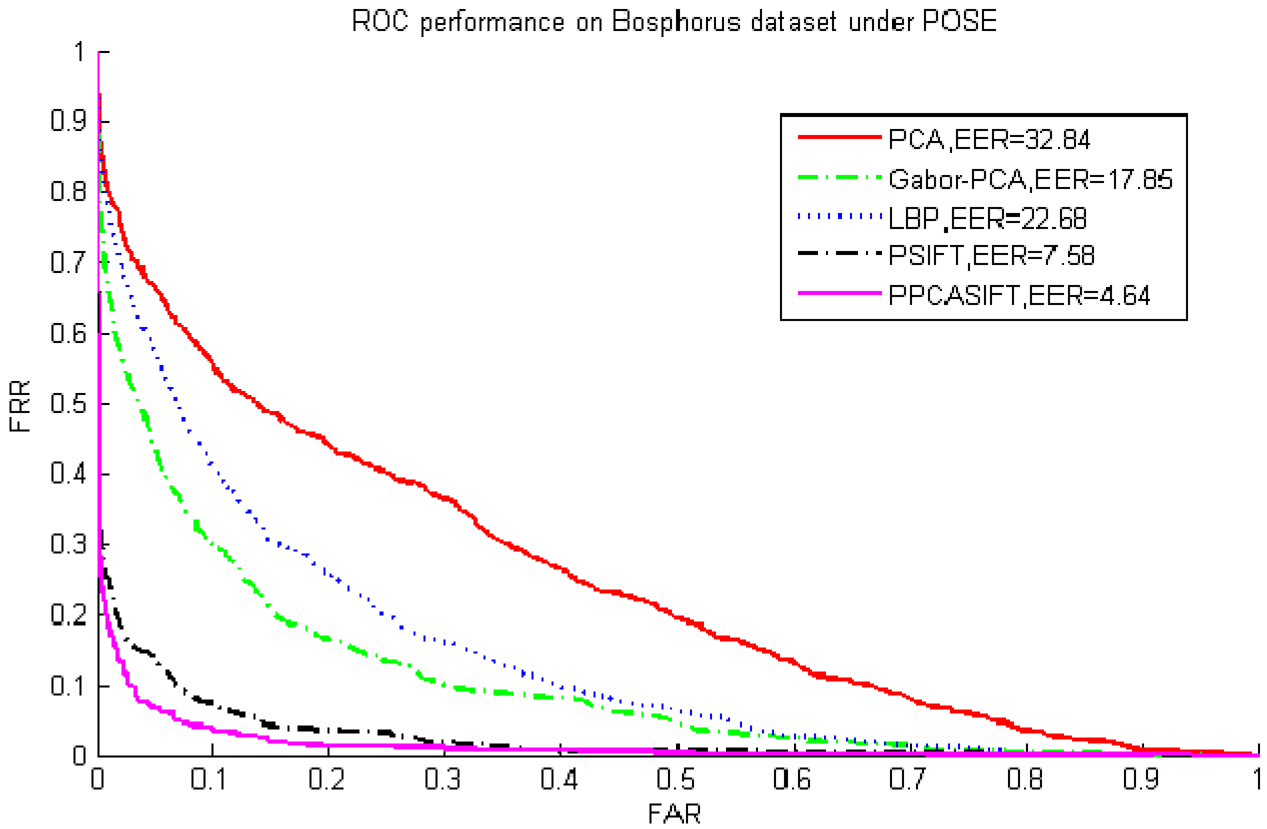
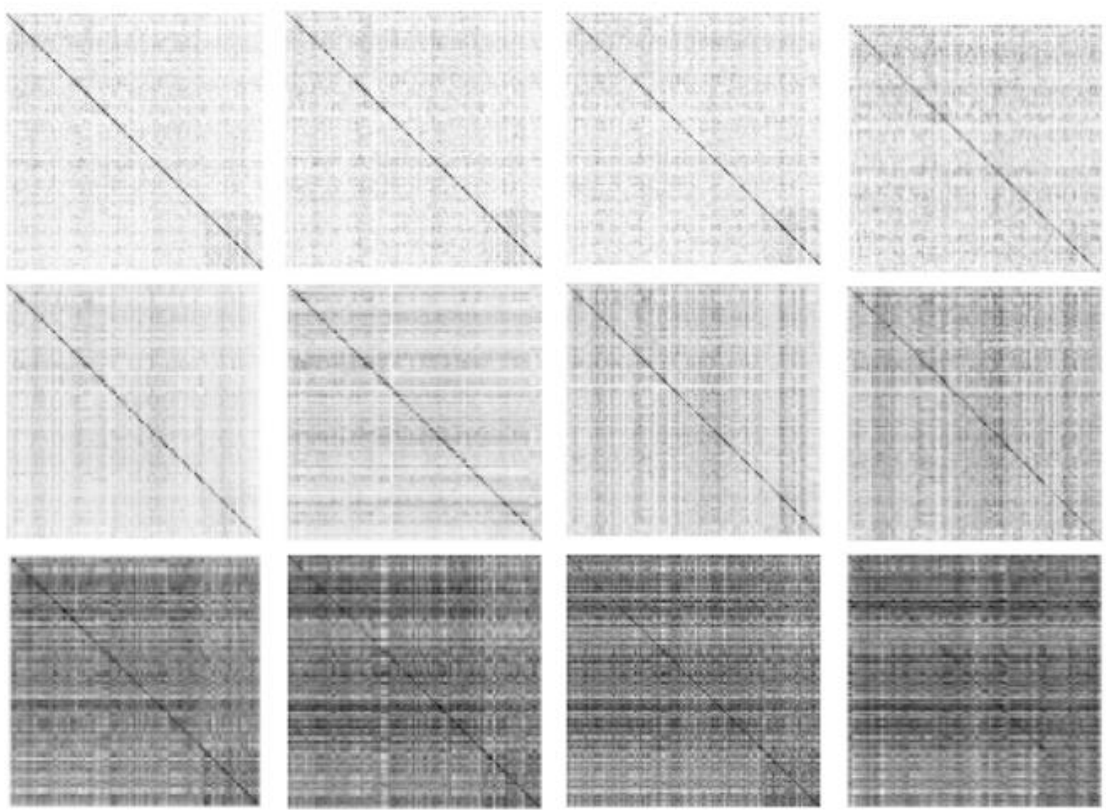


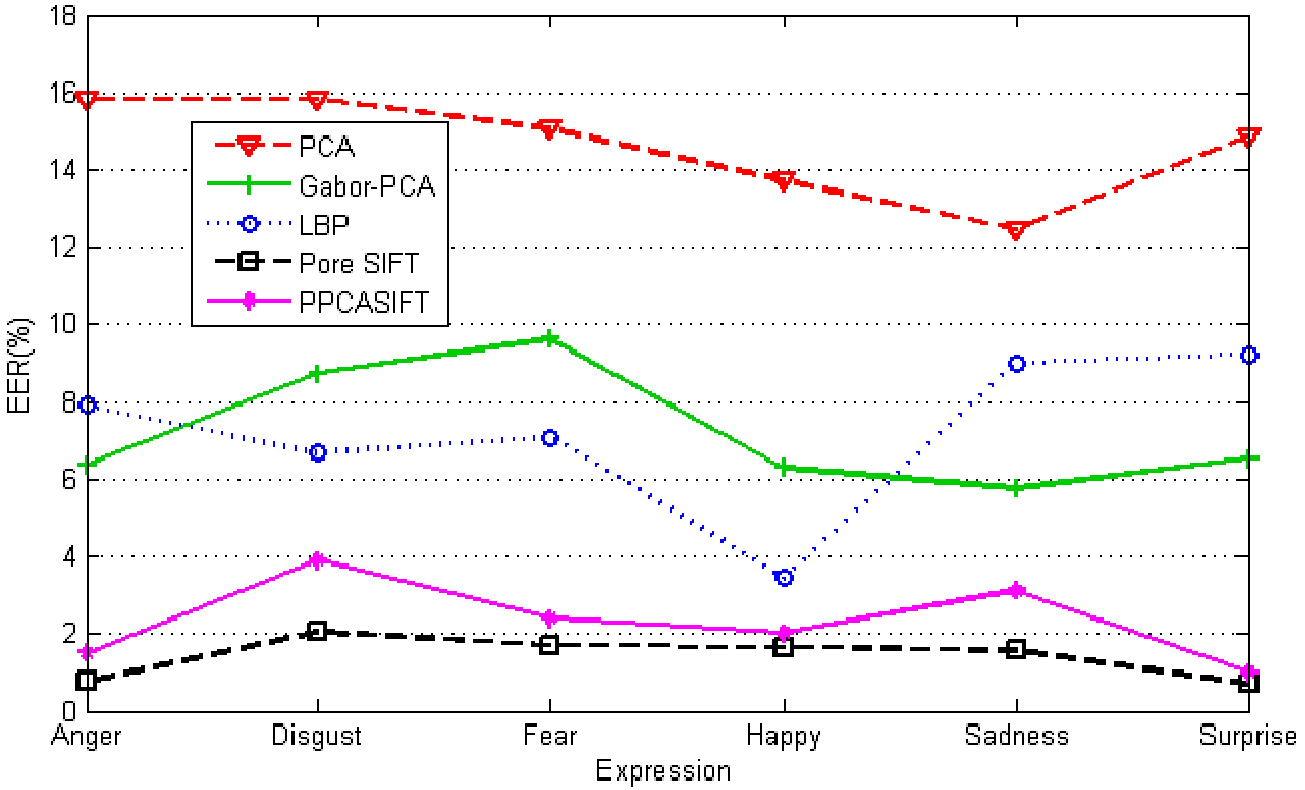
Face verification with pose variations



Distance matrices

Face verification under different expressions

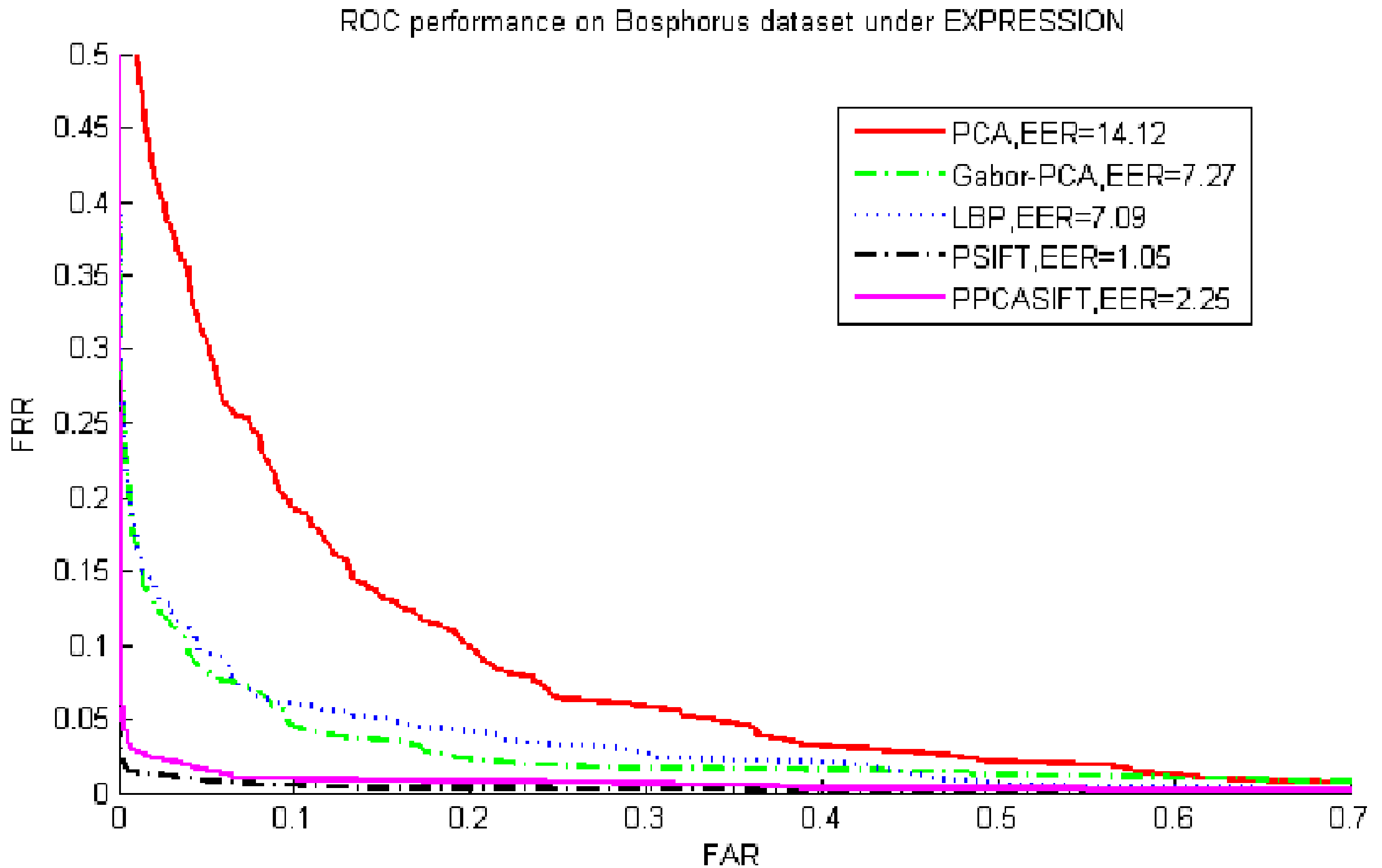
- Bosphorus dataset, 105 subjects, 1 as gallery other 6 emotions as testing per subject



EER of comparing methods under different expressions.

Face verification under different expressions

- Bosphorus dataset, 105 subjects, 1 as gallery other 6 emotions as testing per subject



Face verification on face images captured at different time sessions

- FRGC v2, 362 subjects, 9,844 images, 1 gallery per subject
- Captured time from 0 to 430 days

Table 5.2: EER(%) of different face-verification methods

T-All	14.24	2.83	5.09	**0.91**	1.29
FRGC-0-2W	15.6	4.21	8.28	2.01	3.3
FRGC-3-10W	27.11	9.67	12.87	4.25	6.75
FRGC-11-18W	33.63	12.05	16.23	6.32	8.21
FRGC-19-26W	28.94	9.62	14.2	5.6	7.7
FRGC-Aft26W	28.75	14.26	18.09	8.11	10.55
FRGC-All	27.57	10.02	14.12	**5.51**	7.36

Alignment errors

(a)

(b)

σ of $(\Delta x, \Delta y)$	Equal Error Rate(%)				
	PCA	Gabor+PCA	LBP	PSIFT	PPCASIFT
0	14.12	7.27	7.61	**0.77**	1.94
10	15.23	7.35	7.89	**0.73**	2.20
20	19.49	9.38	13.88	**0.87**	2.12
30	21.86	14.06	21.98	**0.79**	2.59
40	24.90	16.97	25.22	**0.63**	2.30
50	29.13	22.97	31.06	**0.97**	2.60

Computational cost

- Each query (using 64bit Matlab R2010b on Intel Core i7 3.5GHz, 4 cores , 8 threads, 8GB RAM system).
  - PSIFT 1.42s
  - PPCASIFT 0.03s

Conclusions

- Contributions of this thesis
  - A new framework has been proposed for pore-scale facial feature extraction.
  - Reliable matching can be established based on uncalibrated face images.
  - Pore Index is proposed to analyze the relationship among the skin appearance, the image quality and the matching difficulty.
  - An alignment-robust and pose-invariant face verification method has been proposed using the HR information based on the pore-scale facial features.

Future work

- Better (distinctive, compact) features based on learning
- Skin feature as a new biometric measure
- Fusion of low-resolution features
- 3D face reconstruction

More Applications

- 电影动画
- 皮肤医疗图像
- 移动支付，刷脸支付，远程开户
- 防替考，入场认证
- 法庭证据，群体事件监控与取证
- 反恐，国家安全

Q & A