

SURF-Face: Face Recognition Under Viewpoint Consistency Constraints

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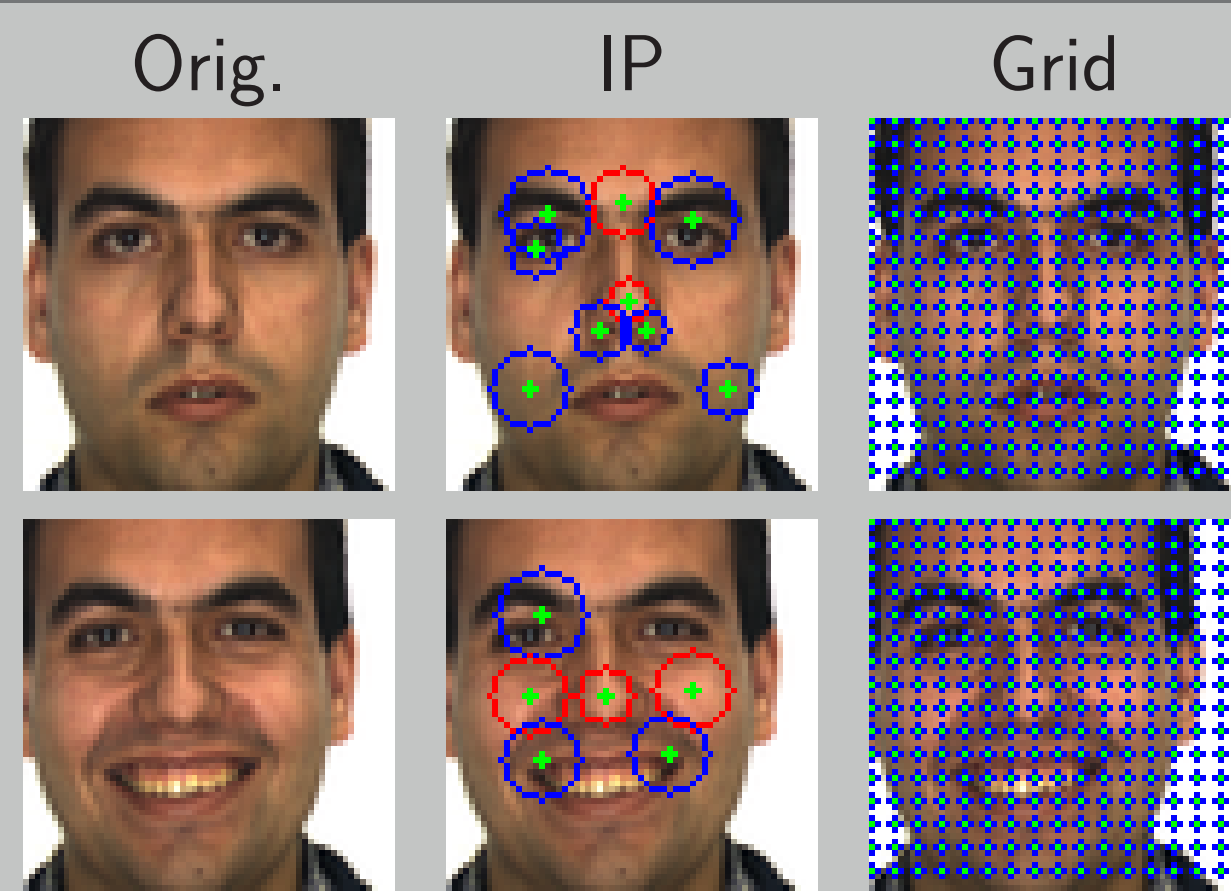


Introduction

- ▶ Most face recognition approaches are sensitive to registration errors
 - ▷ rely on a very good initial alignment and illumination
- ▶ We propose/analyze:
 - ▷ grid-based and dense extraction of local features
 - ▷ block-based matching accounting for different viewpoints and registration errors

Feature Extraction

- ▶ Interest point based feature extraction
 - ▷ SIFT or SURF interest point detector
 - ▷ leads to a **very sparse** description
- ▶ Grid-based feature extraction
 - ▷ overlaid regular grid
 - ▷ leads to a **dense** description



Feature Description

- ▶ Scale Invariant Feature Transform (SIFT)
 - ▷ 128-dimensional descriptor, histogram of gradients, scale invariant
- ▶ Speeded Up Robust Features (SURF)
 - ▷ 64-dimensional descriptor, histogram of gradients, scale invariant
- ▶ face recognition: invariance w.r.t. rotation is often not necessary
 - ▷ rotation dependent upright-versions U-SIFT, U-SURF-64, U-SURF-128

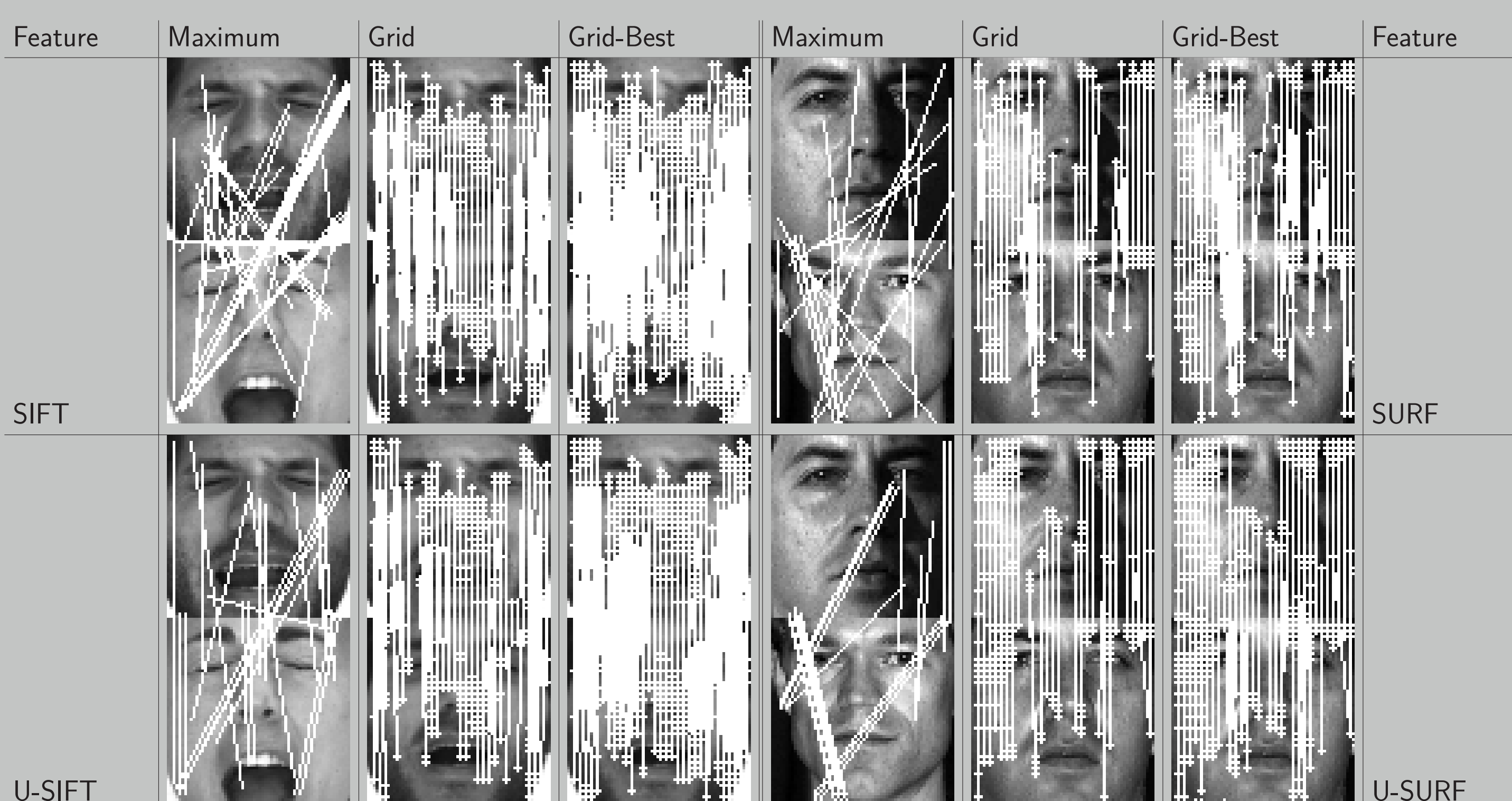
Feature Matching

- ▶ Recognition by Matching
 - ▷ nearest neighbor matching strategy
 - ▷ descriptor vectors extracted at keypoints in a test image \mathbf{X} are compared to all descriptor vectors extracted at keypoints from the reference images $\mathbf{Y}_n, n = 1, \dots, N$ by the Euclidean distance
 - ▷ decision rule:

$$\mathbf{X} \rightarrow r(\mathbf{X}) = \arg \max_{\mathbf{c}} \left\{ \max_{\mathbf{n}} \left\{ \sum_{x_i \in \mathbf{X}} \delta(x_i, \mathbf{Y}_{n,c}) \right\} \right\}$$

- ▷ additionally, a ratio constraint is applied in $\delta(x_i, \mathbf{Y}_{n,c})$
- ▶ Viewpoint Matching Constraints
 - ▷ maximum matching: unconstrained
 - ▷ grid-based matching: absolute box constraints
 - ▷ grid-based best matching: absolute box constraints, overlapping
- ▶ Postprocessing
 - ▷ RANSAC-based outlier removal
 - ▷ RANSAC-based system combination

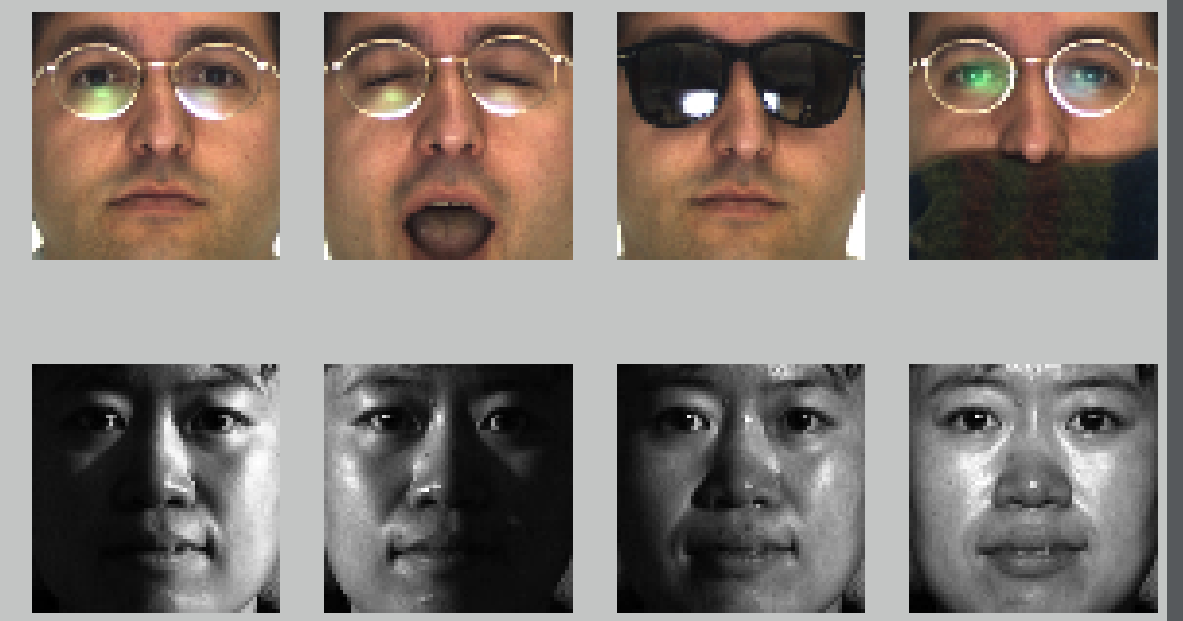
Matching Examples for the AR-Face and CMU-PIE Database



- ▶ Matching results for the AR-Face (left) and the CMU-PIE database (right)
 - ▷ maximum matching show false classification examples
 - ▷ grid matchings show correct classification examples
 - ▷ upright descriptor versions reduce the number of false matches

Databases

- ▶ AR-Face
 - ▷ variations in illumination
 - ▷ many different facial expressions
- ▶ CMU-PIE
 - ▷ variations in illumination (frontal images from the illumination subset)



Results: Manually Aligned Faces

- ▶ AR-Face: 110 classes, 770 train, 770 test

Descriptor	Extraction	# Features	Error Rates [%]		
			Maximum	Grid	Grid-Best
SURF-64	IPs	64×5.6 (avg.)	80.64	84.15	84.15
SIFT	IPs	128×633.78 (avg.)	1.03	95.84	95.84
SURF-64	64x64-2 grid	64×1024	0.90	0.51	0.90
SURF-128	64x64-2 grid	128×1024	0.90	0.51	0.38
SIFT	64x64-2 grid	128×1024	11.03	0.90	0.64
U-SURF-64	64x64-2 grid	64×1024	0.90	1.03	0.64
U-SURF-128	64x64-2 grid	128×1024	1.55	1.29	1.03
U-SIFT	64x64-2 grid	128×1024	0.25	0.25	0.25

- ▶ CMU-PIE: 68 classes, 68 train ("one-shot" training), 1360 test

Descriptor	Extraction	# Features	Error Rates [%]		
			Maximum	Grid	Grid-Best
SURF-64	IPs	64×6.80 (avg.)	93.95	95.21	95.21
SIFT	IPs	128×723.17 (avg.)	43.47	99.33	99.33
SURF-64	64x64-2 grid	64×1024	13.41	4.12	7.82
SURF-128	64x64-2 grid	128×1024	12.45	3.68	3.24
SIFT	64x64-2 grid	128×1024	27.92	7.00	9.80
U-SURF-64	64x64-2 grid	64×1024	3.83	0.51	0.66
U-SURF-128	64x64-2 grid	128×1024	5.67	0.95	0.88
U-SIFT	64x64-2 grid	128×1024	16.28	1.40	6.41

Results: Unaligned Faces

- ▶ Automatically aligned by Viola & Jones

Descriptor	Error Rates [%]	
	AR-Face	CMU-PIE
SURF-64	5.97	15.32
SURF-128	5.71	11.42
SIFT	5.45	8.32
U-SURF-64	5.32	5.52
U-SURF-128	5.71	4.86
U-SIFT	4.15	8.99

- ▶ Manually aligned faces



- ▶ Unaligned faces



Results: Partially Occluded Faces

- ▶ AR-Face: 110 classes, 110 train ("one-shot" training), 550 test

Descriptor	Error Rates [%]					
	<i>AR1scarf</i>	<i>AR1sun</i>	<i>ARneutral</i>	<i>AR2scarf</i>	<i>AR2sun</i>	Avg.
SURF-64	2.72	30.00	0.00	4.54	47.27	16.90
SURF-128	1.81	23.63	0.00	3.63	40.90	13.99
SIFT	1.81	24.54	0.00	2.72	44.54	14.72
U-SURF-64	4.54	23.63	0.00	4.54	47.27	15.99
U-SURF-128	1.81	20.00	0.00	3.63	41.81	13.45
U-SIFT	1.81	20.90	0.00	1.81	38.18	12.54
U-SURF-128+R	1.81	19.09	0.00	3.63	43.63	13.63
U-SIFT+R	2.72	14.54	0.00	0.90	35.45	10.72
U-SURF-128+U-SIFT+R	0.90	16.36	0.00	2.72	32.72	10.54

Conclusions

- ▶ Grid-based local feature extraction instead of interest points
- ▶ Local descriptors:
 - ▷ upright descriptor versions achieved better results
 - ▷ SURF-128 better than SURF-64
- ▶ System robustness: manually aligned/unaligned/partially occluded faces
 - ▷ SURF more robust to illumination
 - ▷ SIFT more robust to changes in viewing conditions
- ▶ RANSAC-based system combination and outlier removal