SURF-Face: Face Recognition Under Viewpoint Consistency Constraints

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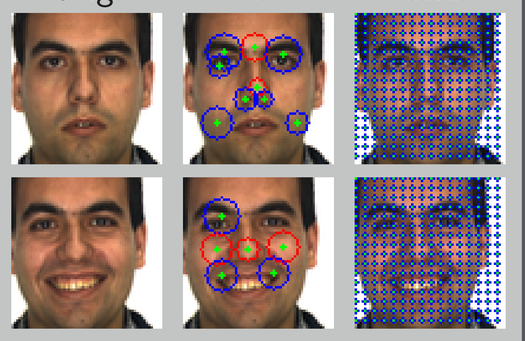
Introduction

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 X are compared to all descriptor vectors extracted at keypoints from the reference images $Y_n, n = 1, \cdots, N$ by the Euclidean distance
- decision rule:

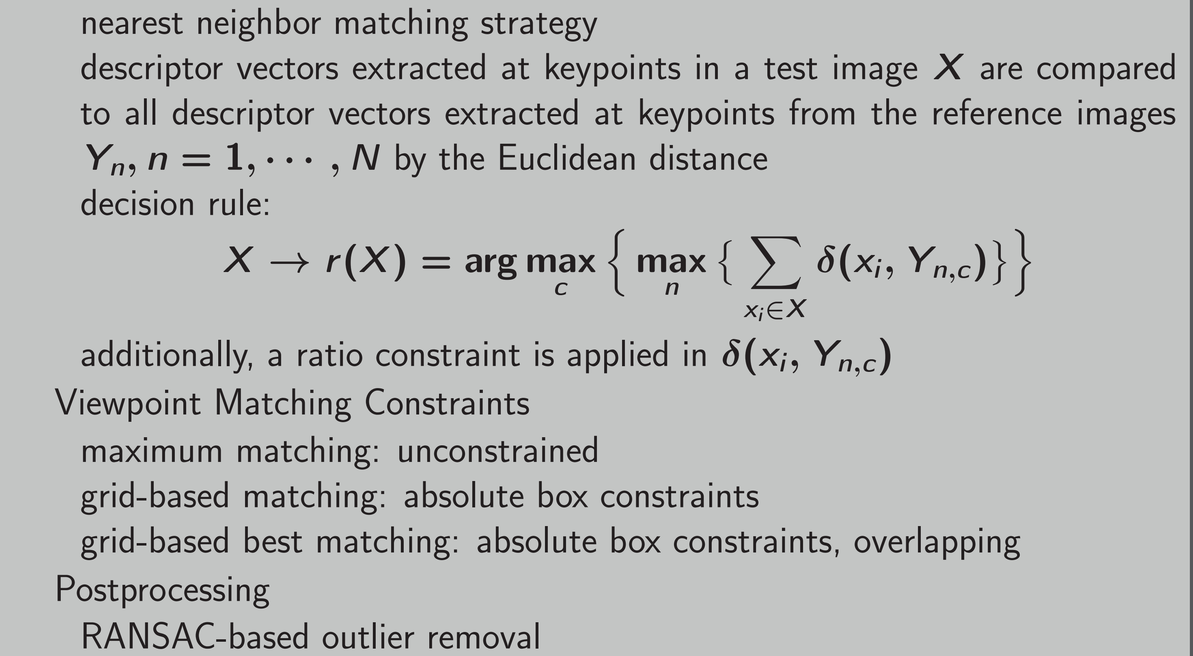
$$X \rightarrow r(X) = \arg\max_c \left\{ \max_n \left\{ \sum_{x_i \in X} \delta(x_i, Y_{n,c}) \right\} \right\}$$

- additionally, a ratio constraint is applied in $\delta(x_i, Y_{n,c})$

Viewpoint Matching Constraints
- maximum matching: unconstrained
- grid-based matching: absolute box constraints
- grid-based best matching: absolute box constraints, overlapping

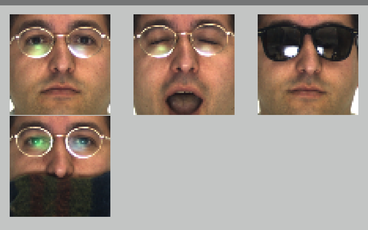
Postprocessing
- RANSAC-based outlier removal
- RANSAC-based system combination

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

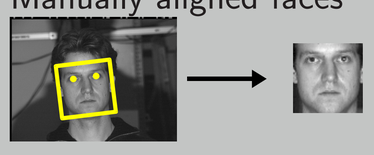
Descriptor	Extraction	# Features	Error Rates [%]		
			Maximum	Grid	Grid-Best
SURF-64	IPs	64 × 6.80 (avg.)	93.95	95.21	95.21
SIFT	IPs	128 × 723.17 (avg.)	43.47	99.33	99.33
SURF-64	64x64-2 grid	64 × 1024	13.41	4.12	7.82
SURF-128	64x64-2 grid	128 × 1024	12.45	3.68	3.24
SIFT	64x64-2 grid	128 × 1024	27.92	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 [%]					
	AR1scarf	*AR1sun*	*ARneutral*	*AR2scarf*	*AR2sun*	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