Increasing the Accuracy of Feature Evaluation Benchmarks Using Differential Evolution

Kai Cordes, Bodo Rosenhahn, Jörn Ostermann

Institut für Informationsverarbeitung
Leibniz Universität Hannover

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Feature Detection

- Requirement for many Computer Vision challenges
  - Object Recognition
  - Image Panoramas
  - Robot Navigation
  - Scene Reconstruction

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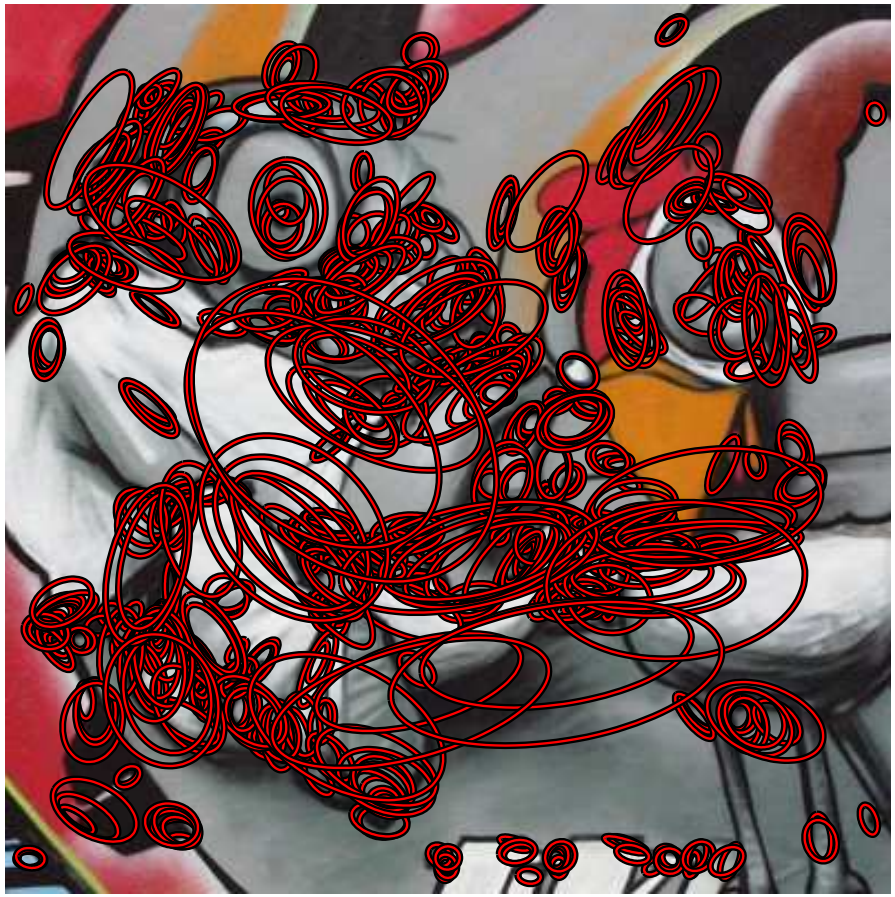
  - Scene Reconstruction
- Detect image structures invariant to:
  - brightness, rotation [*Harris* corners 1988]
  - scale [*Lindeberg* 1998], SIFT [*Lowe, Brown* 2002-2004]
  - affine transformation:
    - Edge-based regions (EBR) [*Tuytelaars, Van Gool* 1999]
    - Intensity extrema-based regions (IBR) [*Tuytelaars, Van Gool* 2000]
    - MSER [*Matas et al.* 2002]
    - Harris-Affine [*Mikolajczyk et al.* 2002]
    - Hessian-Affine [*Mikolajczyk et al.* 2004]

Feature Detection

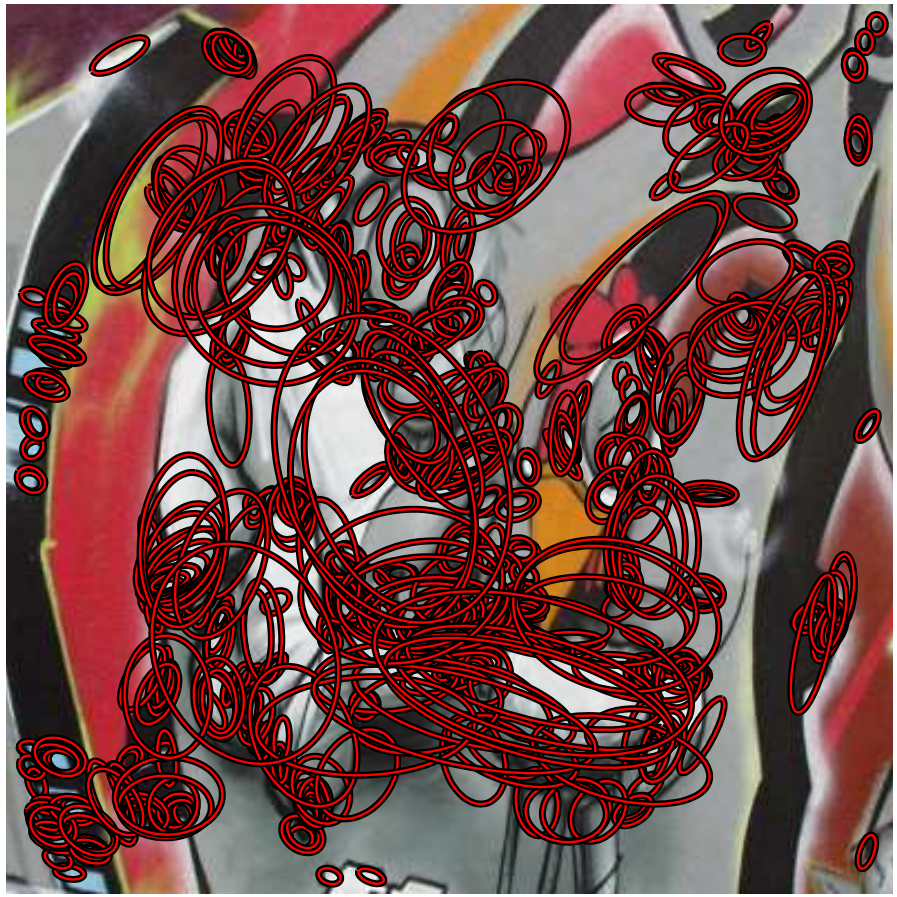
I_1

I_2

Feature Detection

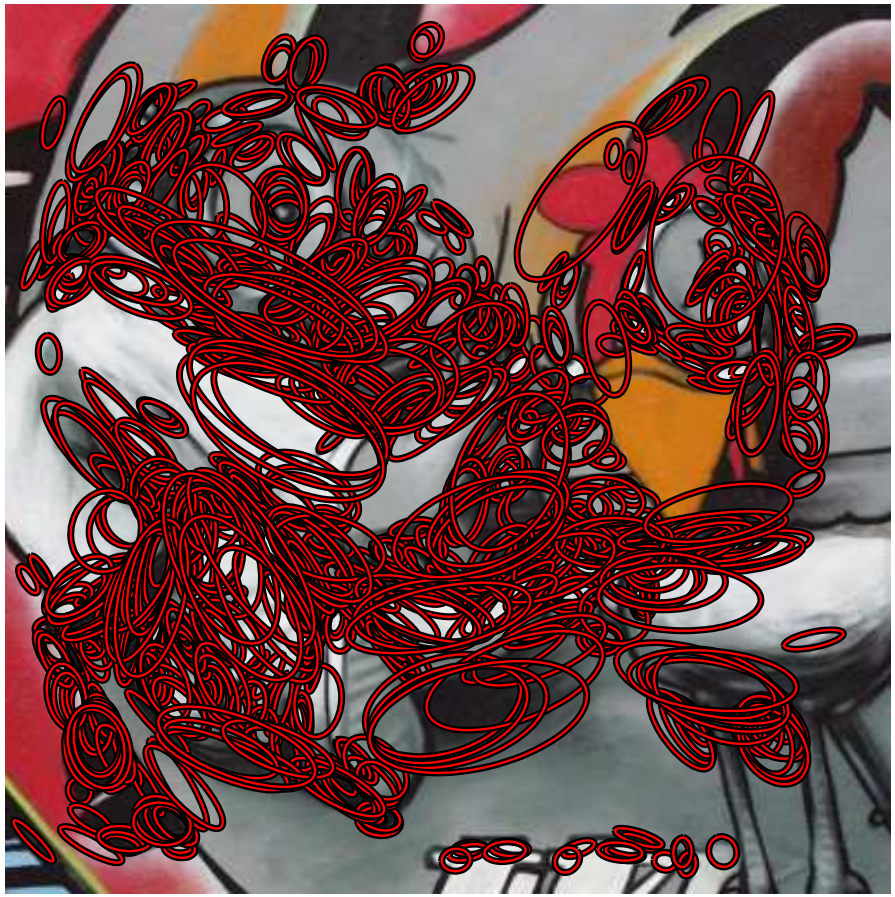


Harris-Affine - I_1

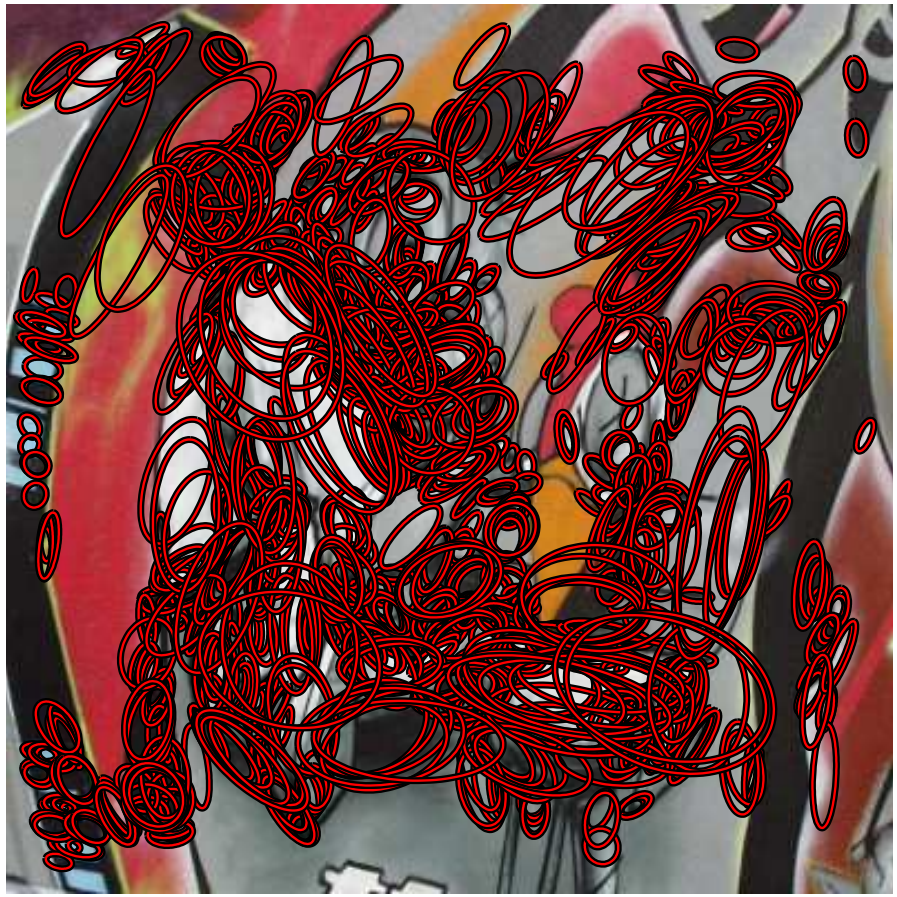


Harris-Affine - I_2

Feature Detection

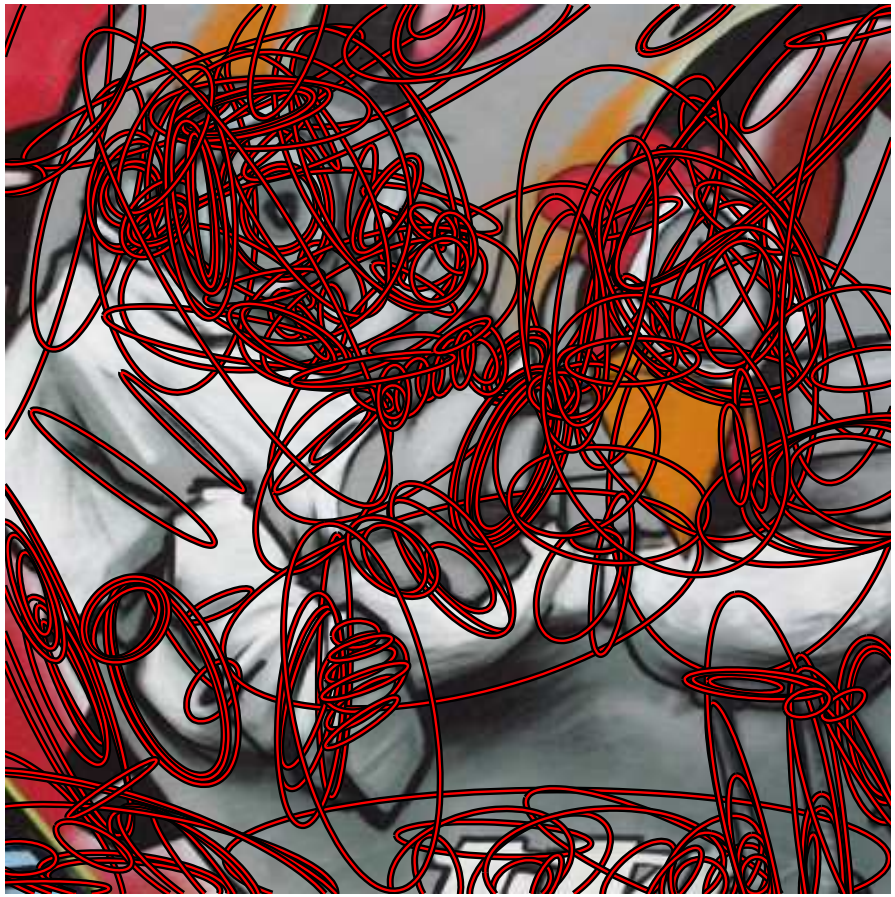


Hessian-Affine - I_1



Hessian-Affine - I_2

Feature Detection



MSER - I_1

MSER - I_2

Feature Detection

Need for Comparison of Feature Detectors

Repeatability [*Mikolajczyk et al.* 2005]:

- How many Features from image $\mathtt{I}_1$ are also detected in image $\mathtt{I}_2$?
- Focus on detection, no Correspondence analysis

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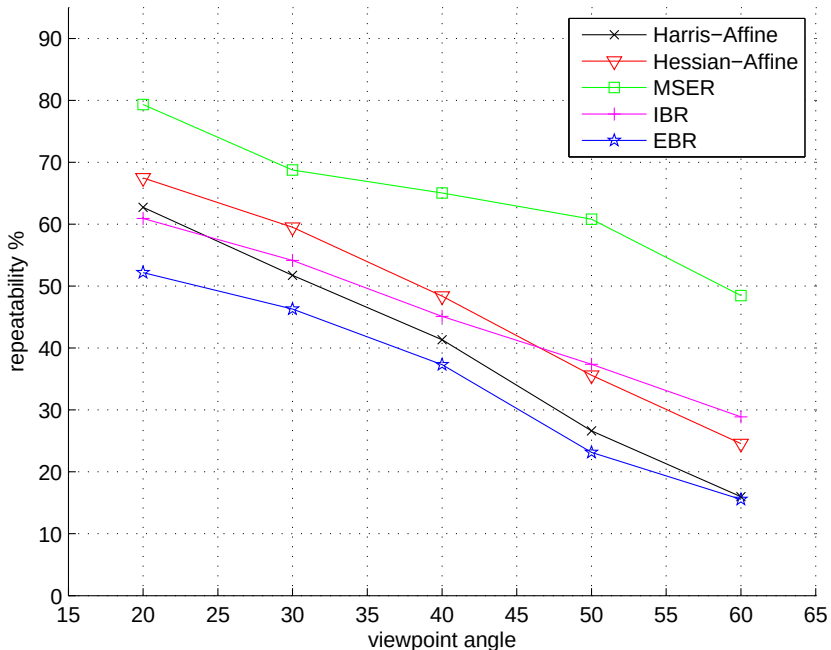

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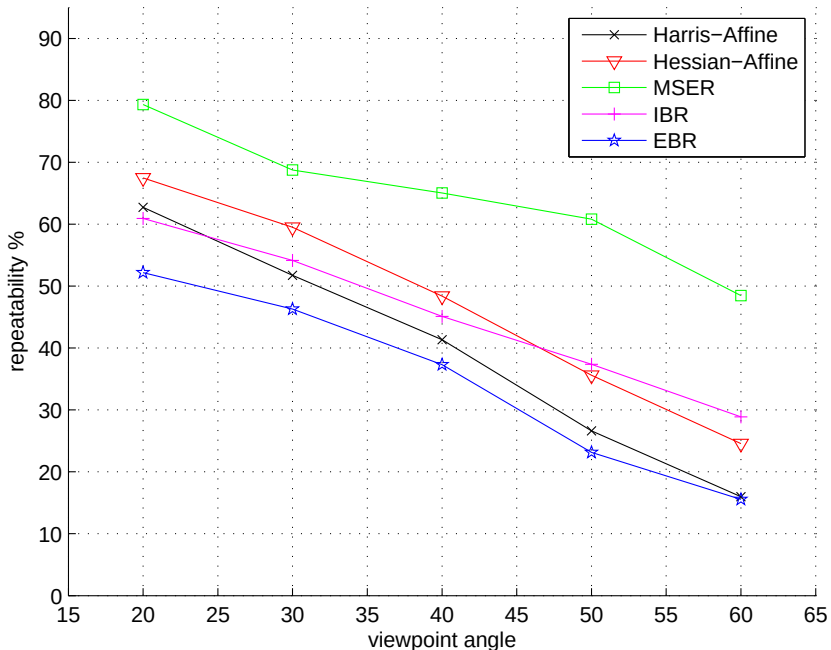
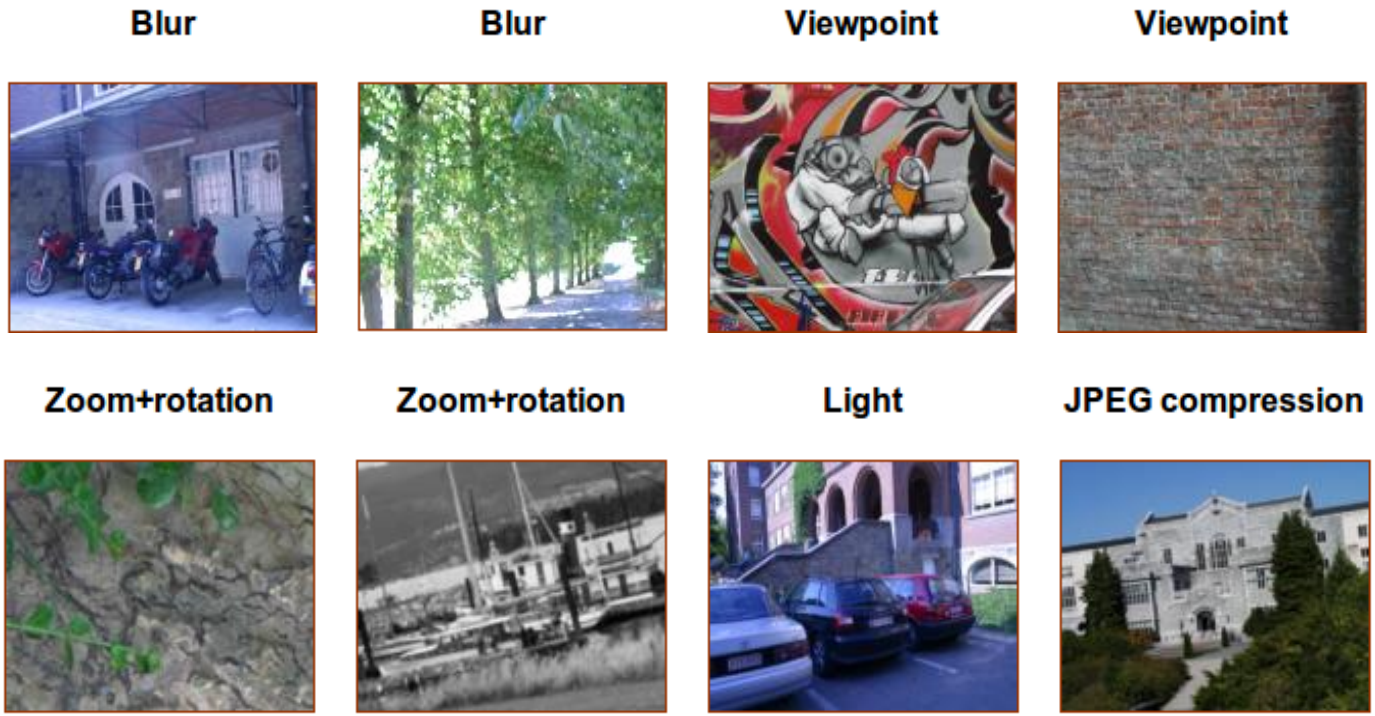


Important Requirements for Features:

- Stability (Object Recognition)
- Localization Accuracy (Scene Reconstruction)

Benchmark: Image Sets + Homography Matrices[1]



Impact of Evaluation Scheme:

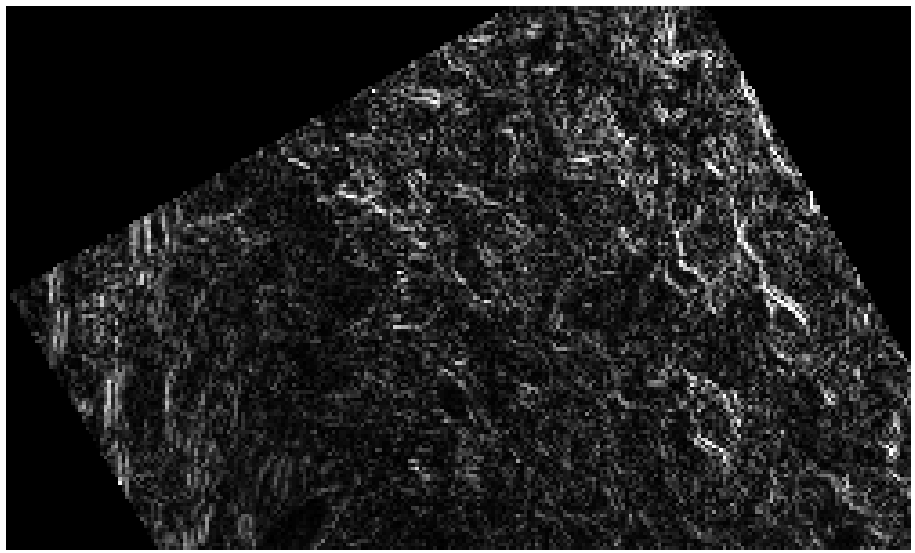
- A new detector has to be validated using this benchmark

[1] http://www.robots.ox.ac.uk/~vgg/research/affine/

Benchmark: Bark Sequence

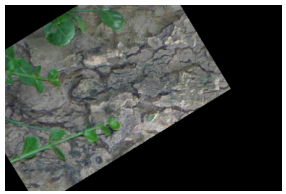
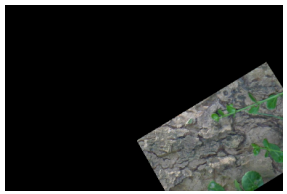
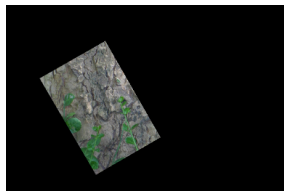
I_1 I_2 I_3 I_4 I_5 I_6

Mapping of I_1 to I_4



Difference to I_4

Benchmark: Bark Sequence

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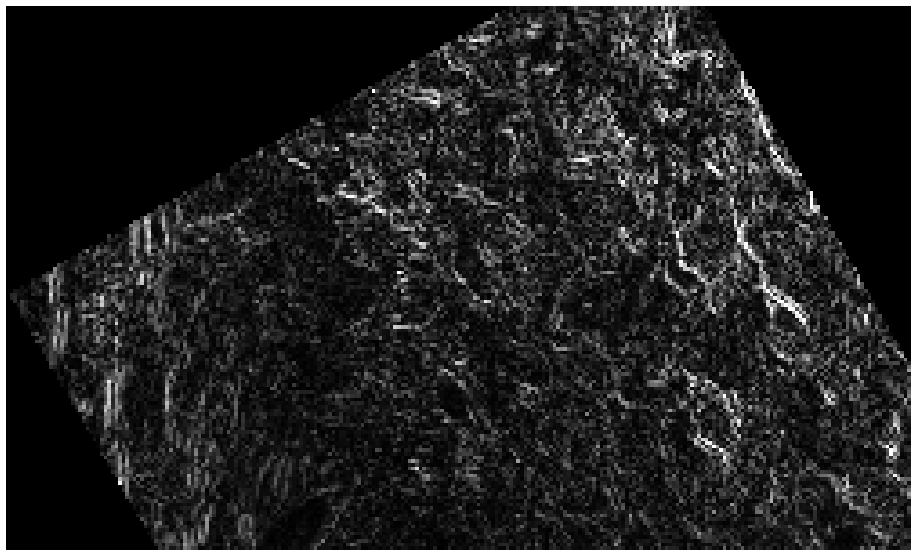

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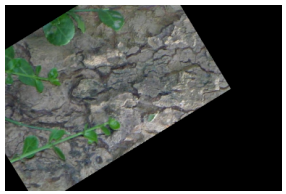
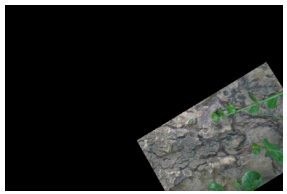
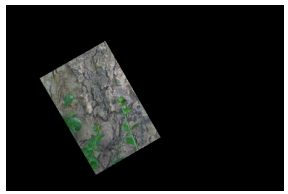

I_2


I_3


I_4


I_5


I_6


Mapping of I_1 to I_4, New


Difference to I_4, New

Benchmark: Graffiti Sequence

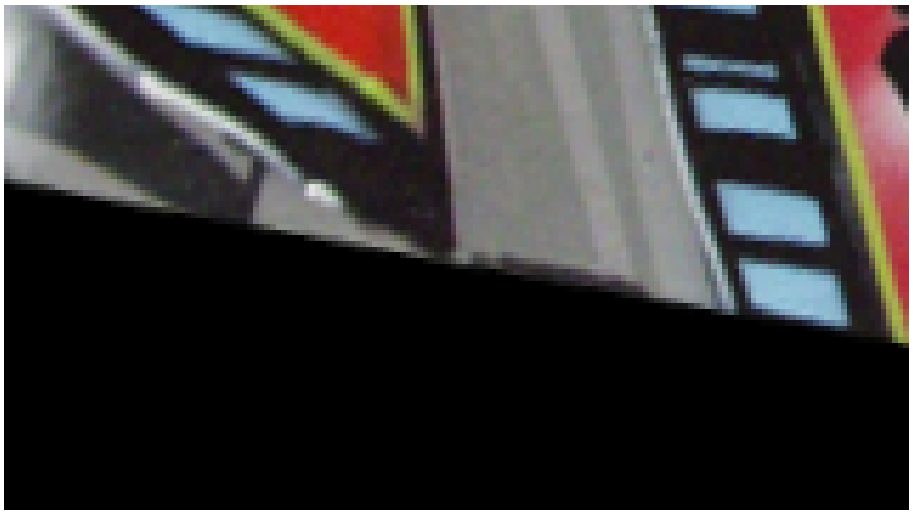
I_1 I_2 I_3 I_4 I_5 I_6

Mapping of I_1 to I_3

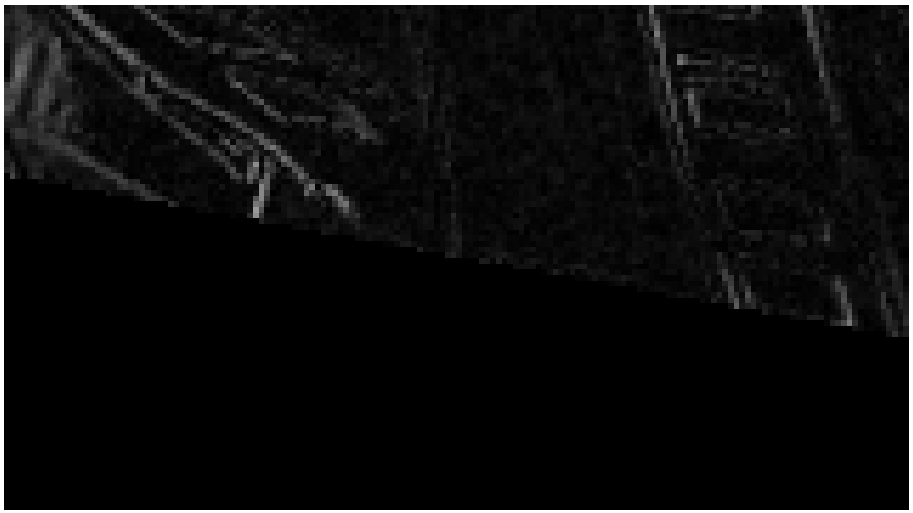
Difference to I_3

Benchmark: Graffiti Sequence

I_1 I_2 I_3 I_4 I_5 I_6



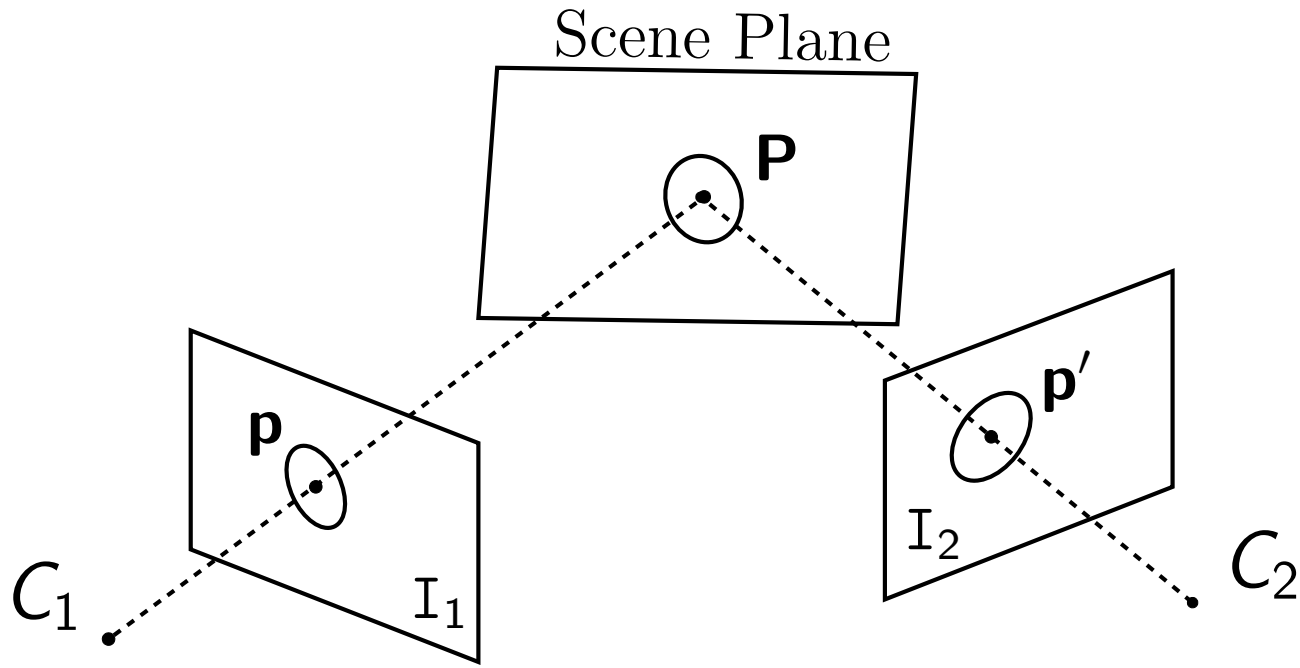
Mapping of I_1 to I_3, New



Difference to I_3, New

Outline

Homography Estimation



For each point pair $\mathbf{p}, \mathbf{p}'$

$$\mathtt{H} \cdot \mathbf{p} = \mathbf{p}' \qquad (1)$$

RGB values should be identical

$$\mathtt{I}_1(\mathtt{H} \cdot \mathbf{p}) = \mathtt{I}_2(\mathbf{p}') \qquad (2)$$

Cost Function

Strategy:

- Minimize pixel differences:

$$E_{\mathrm{H}} = \frac{1}{J} \sum_{j=1}^{J} ||\mathrm{I}_1(\mathrm{H} \cdot \mathbf{p}_j) - \mathrm{I}_2(\mathbf{p}'_j)|| \rightarrow MIN \tag{3}$$

- 8 parameters: $\mathrm{H} = \begin{pmatrix} h_1 & h_2 & h_3 \\ h_4 & h_5 & h_6 \\ h_7 & h_8 & 1 \end{pmatrix}$

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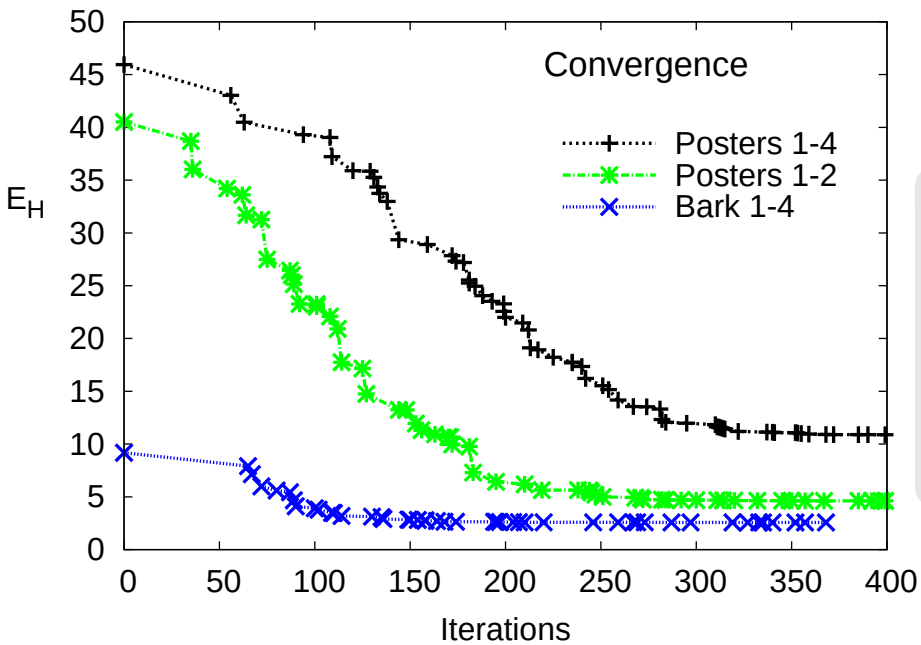
- Feature independent cost function
- Many local minima
- Differential Evolution (DE) for minimization

Optimization

- DE/rand/1/bin (classic DE)
- $NP = 100$, $CR = 0.9$, $F = 0.9$
- Approximate solution $\rightarrow$ Search space center



- Computation time: < 400 iterations (2 h)

$\rightarrow$ Not critical for benchmark generation

Results





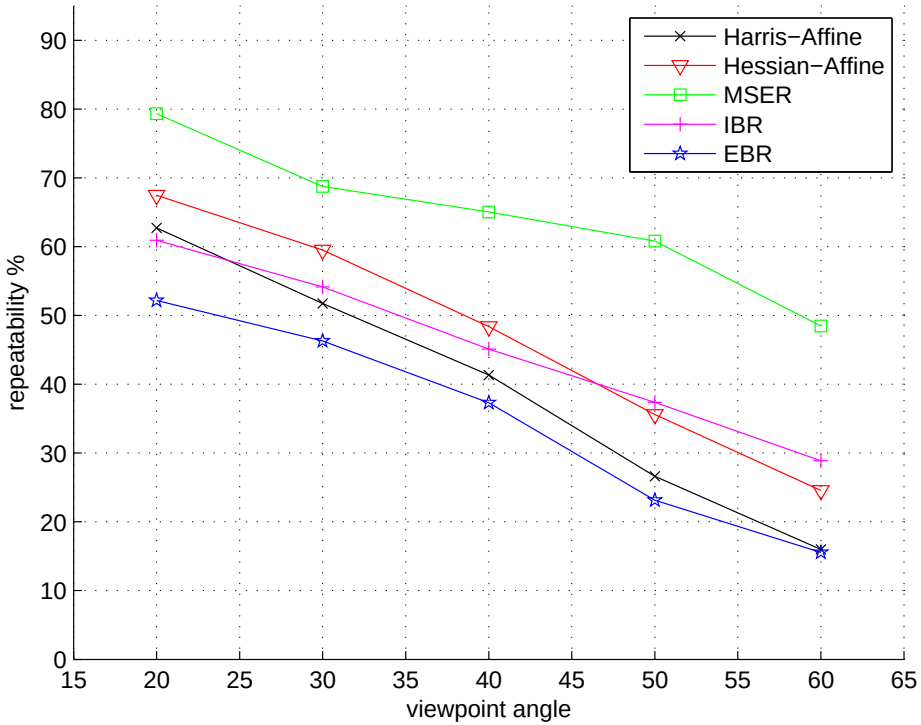

Image Pair I^{graf}	1-2	1-3	1-4	1-5	1-6
E_H^{old}	11.16	16.36	20.44	24.47	29.16
E_H^{new}	4.62	8.71	14.95	19.94	24.30

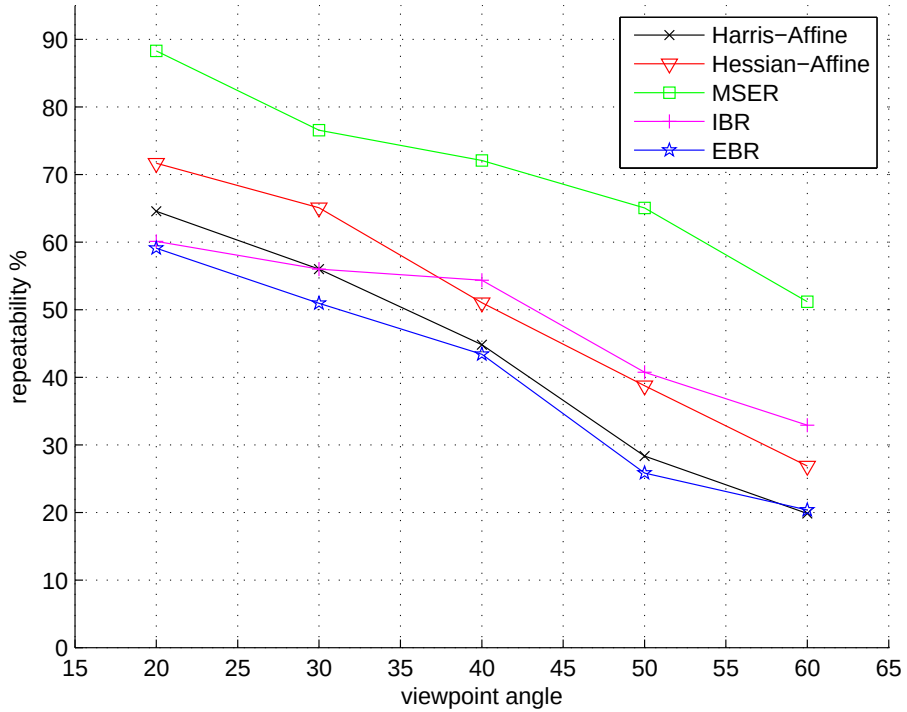




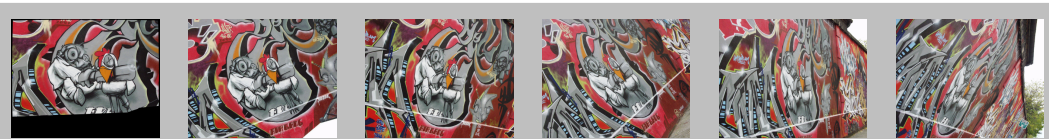

Image Pair I^{bark}	1-2	1-3	1-4	1-5	1-6
E_H^{old}	11.20	13.36	9.19	6.98	10.29
E_H^{new}	10.14	10.04	2.57	3.21	3.34

Results



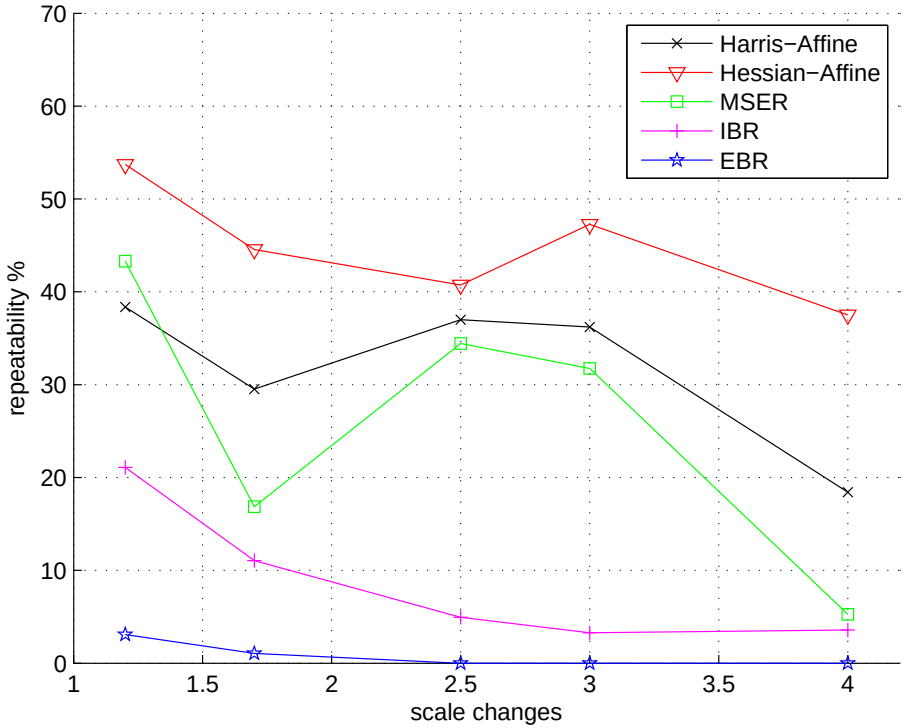


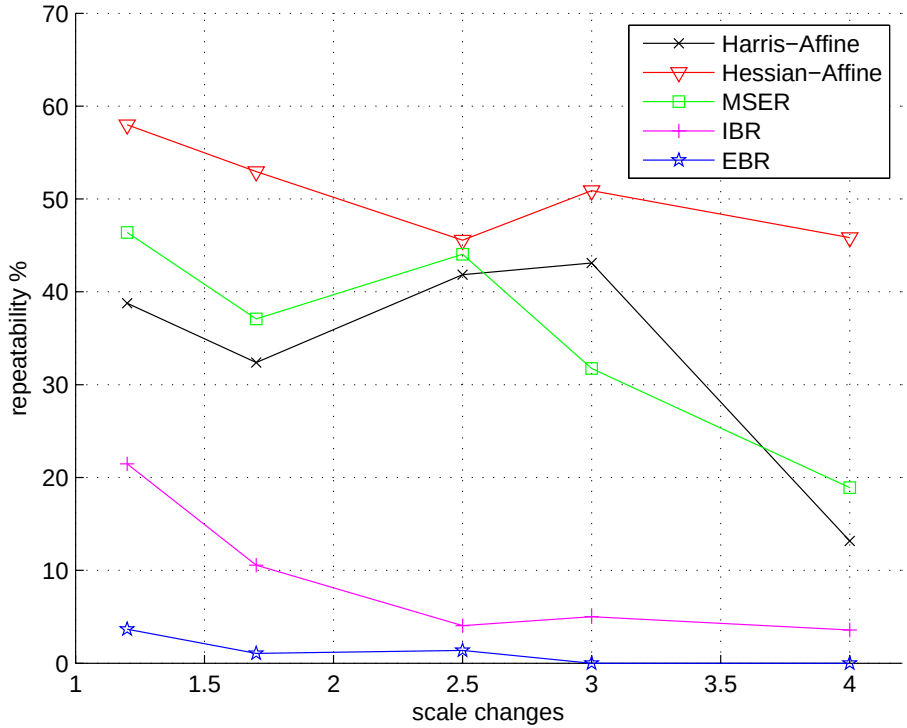
Graffiti Sequence



⇒ MSER and IBR repeatability scores increased by up to 9%

Results





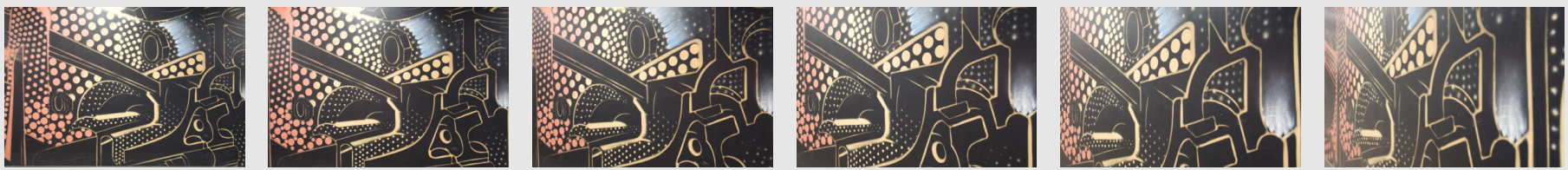
Bark Sequence

⇒ MSER repeatability score increased by up to 20%

Generate new Benchmark Data with Low Error

Grace

Underground



Posters

Conclusion

Summary:

- Increased accuracy for Feature Benchmark
- Constructed new, highly-accurate Benchmark data
- Evaluation data available at project page:
  `www.tnt.uni-hannover.de/project/feature_evaluation/`

Future Work:

- Increase performance to use DE concept for CV tasks
  - enhanced DE variants
  - coarse-to-fine approach
  - determination of appropriate search space boundaries