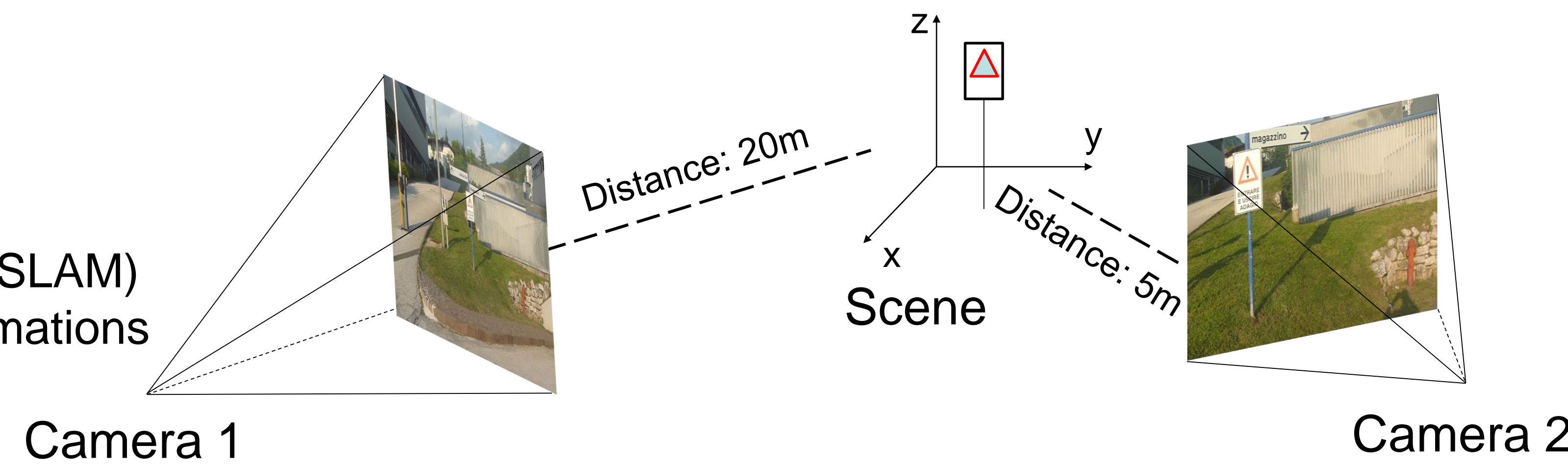


1. Introduction

- Matching local image features (keypoint location + descriptor) for
 - 3D reconstruction
 - Simultaneous Localisation and Mapping (SLAM)
- Challenges due to severe geometric transformations
 - Different scales
 - Different viewpoints



2. Related work

- Multi-scale keypoint localisation (detection)
 - Independent for each scale (image pyramid) [1]
 - Scale-invariant [2]
- Descriptor representation
 - Single scale (detection scale)
 - Multi scale (estimation across all scales)

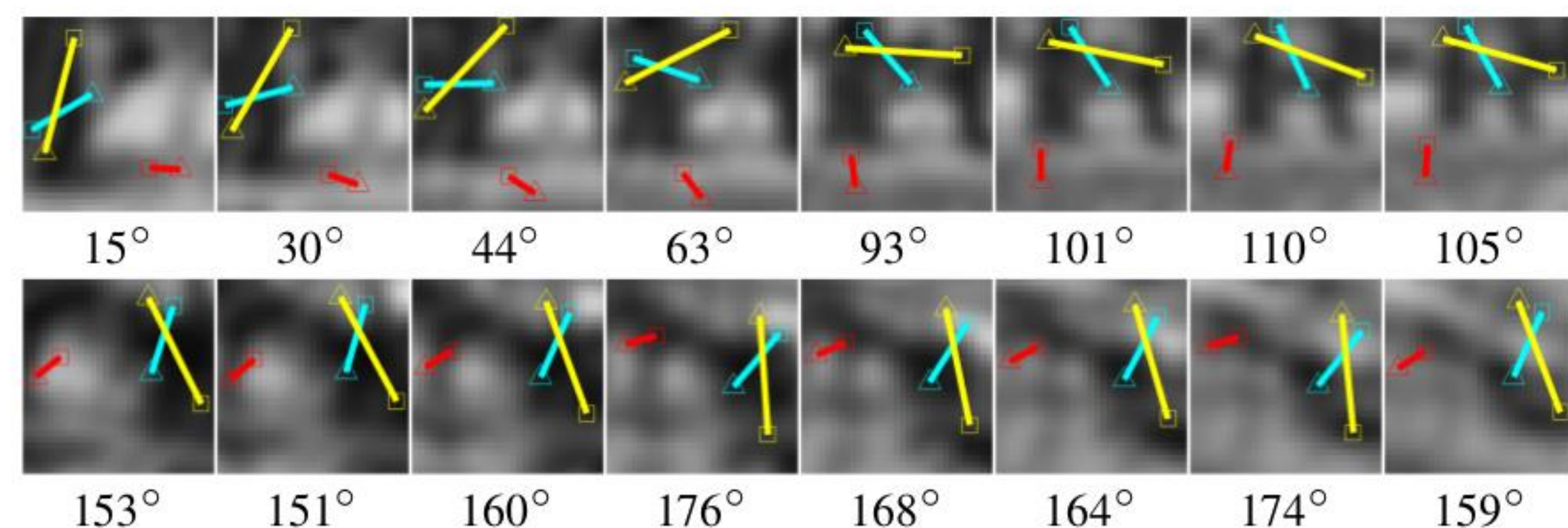
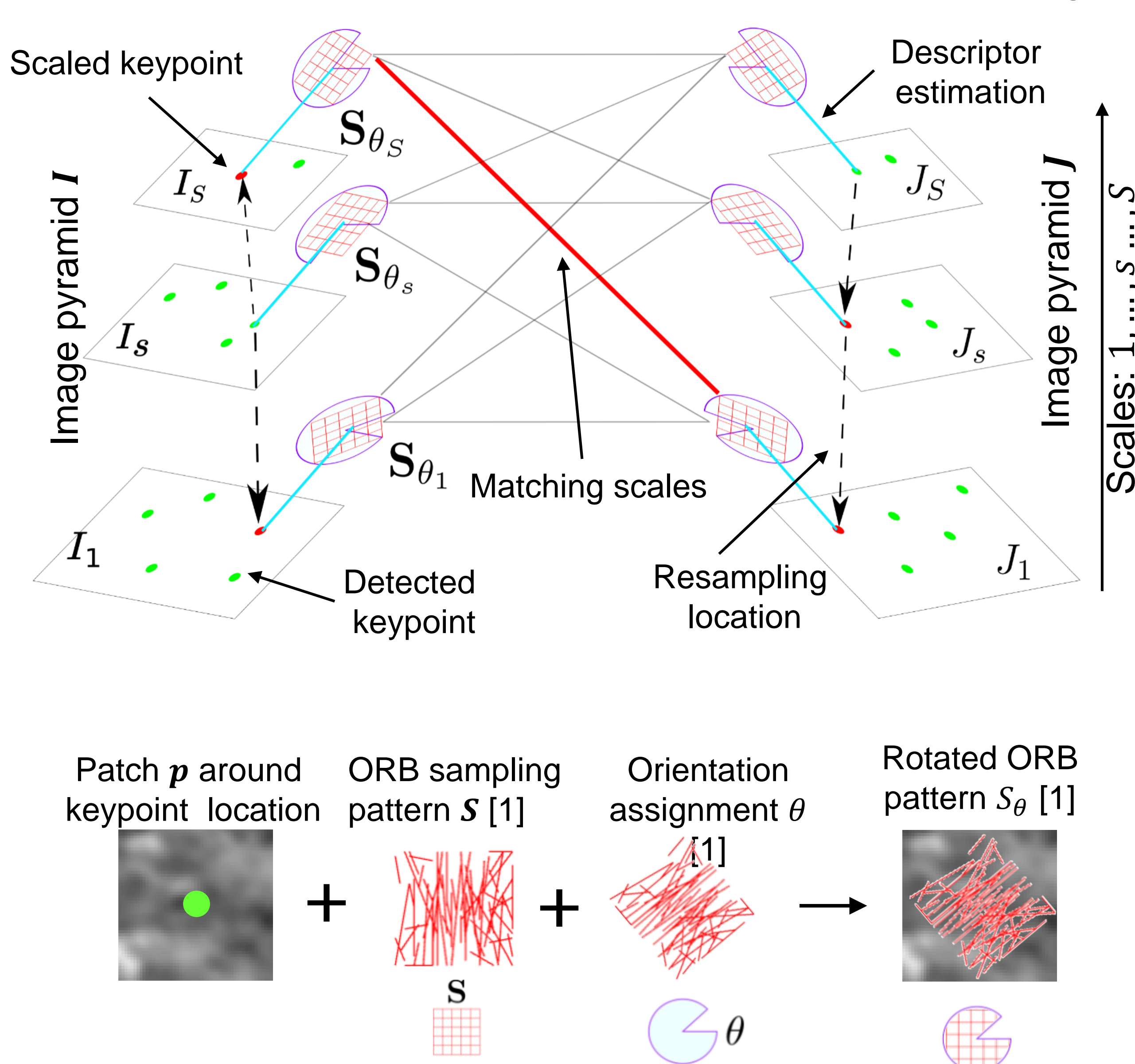
		Descriptor type		accuracy	efficiency
		Histogram-based	Binary		
Single scale		SIFT [2]	ORB [1]		
Multi scale		SLS [3] DSP-SIFT [4] ASV [5]	MORB		

Limitation in real-time applications (e.g. SLAM) → accuracy ↑ efficiency ↓

3. Proposed approach: MORB

- Multi-scale detection
 - Keypoint localisation for each scale (image pyramid) [1]
 - Cross-scale feature pruning to remove ambiguities
 - Sampling keypoint location for each scale
- Orientation assignment (θ)
 - Intensity centroid method [1]
 - Independent estimation for each scale
- Multi-scale ORB descriptor (MORB)
 - Rotated ORB sampling pattern S_θ [1] for each scale
 - Set of binary descriptors $d_p = [d_{p,1}, \dots, d_{p,s}]$
- Cross-scale matching:
 - Nearest neighbor with a scale-aware Hamming distance

MORB multi-scale descriptor and cross-scale matching



Orientation estimation across scales for a matching pair: example with 3 rods of the ORB sampling pattern [1]

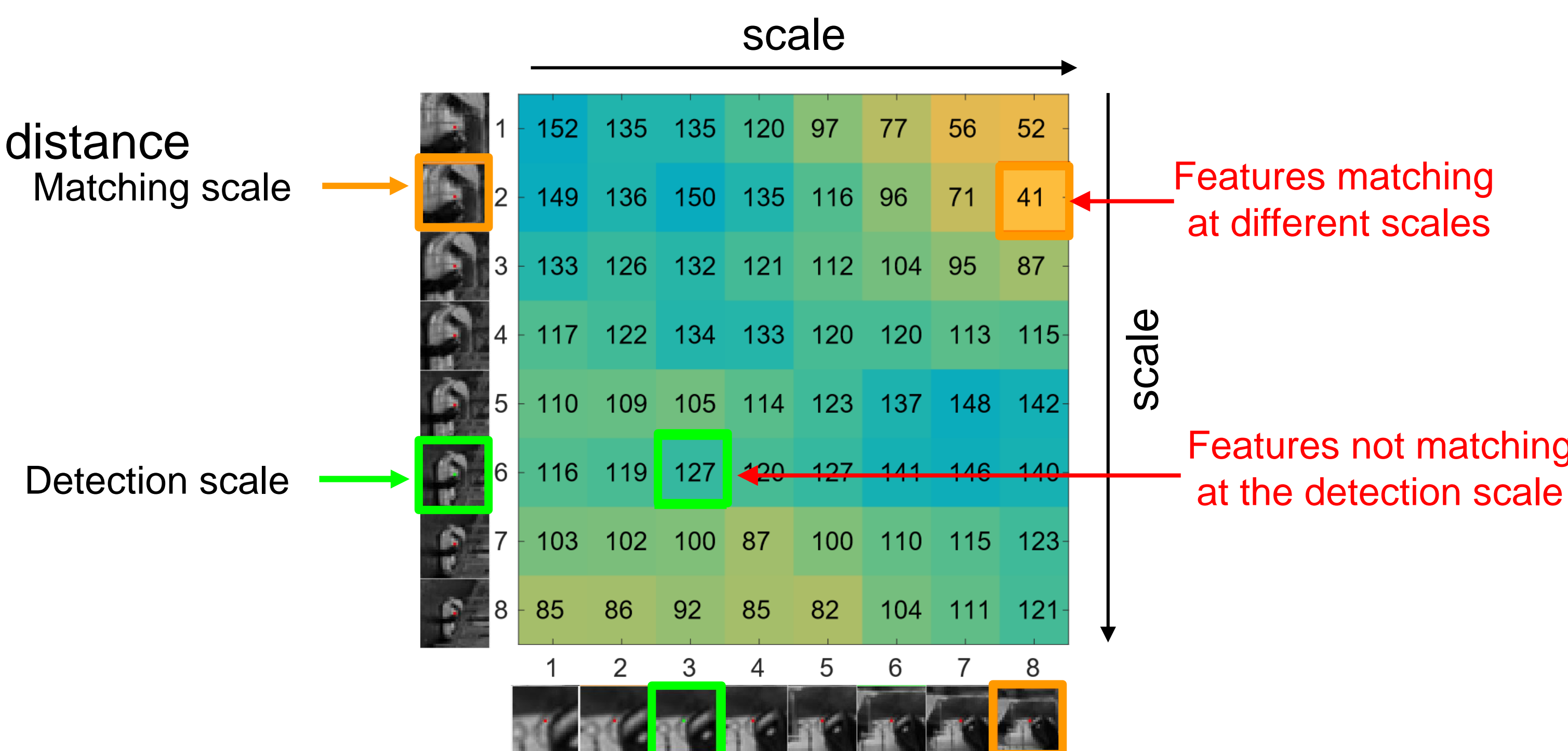
- Multi-scale ORB descriptor (MORB)
 - Rotated ORB sampling pattern S_θ [1] for each scale
 - Set of binary descriptors $d_p = [d_{p,1}, \dots, d_{p,s}]$

- Cross-scale matching:
 - Nearest neighbor with a scale-aware Hamming distance

Hamming distance between feature m and feature n → $h_{m,n} = \min_{s,l \in S} d_{p,s}^m \oplus d_{p,l}^n$

XOR operator + counting

Set of scales: $\{1, \dots, S\}$



4. Experimental results

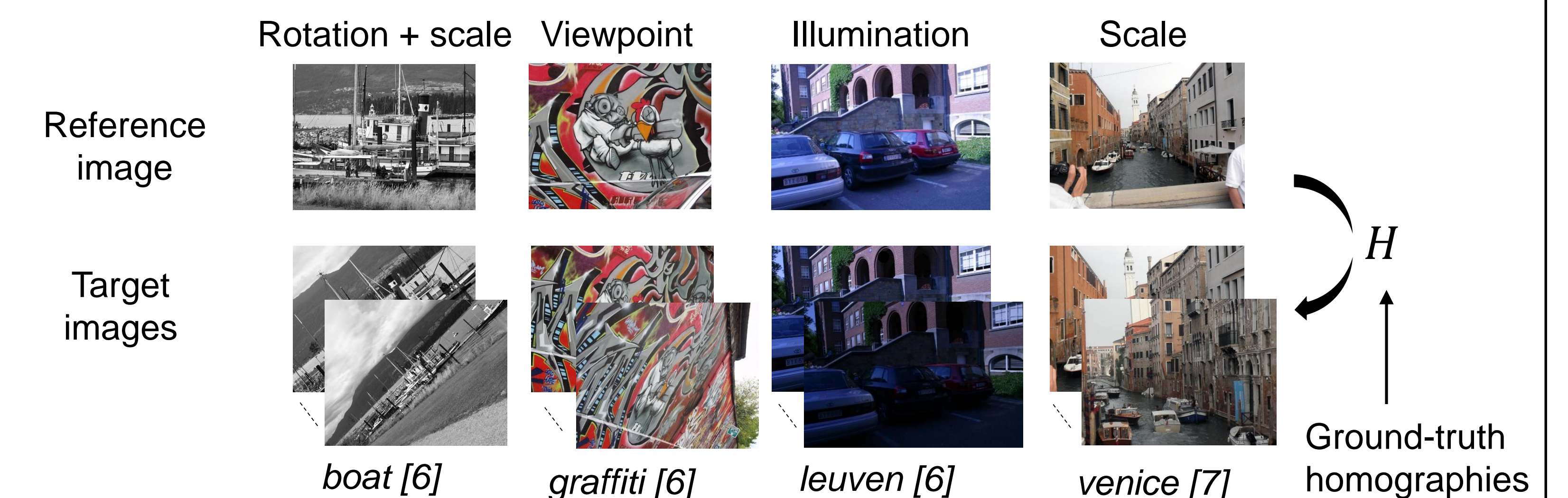
- Datasets**
- Planar image sets with geometric/photometric changes
 - Oxford ACRD [6]
 - Heinly's dataset [7]

Performance measures

- Matching score [7]: $\frac{\# \text{correct matches}}{\# \text{features}}$
- Precision: $\frac{\# \text{correct matches}}{\# \text{total matches}}$
- Recall: $\frac{\# \text{correct matches}}{\# \text{total true matches}}$
- F-score: $2 \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}$
- Area under curve (AUC) [4] by varying Hamming distance threshold [6]

Comparisons (detector/descriptor)

- ORB [1] / ORB [1] (ORB)
- SIFT [2] / LATCH [8] (sLATCH)
- MORB / ORB [1] (cORB)
- MORB / LATCH [8] (oLATCH)
- MORB / independent ORB [1] (ORB-ALL)
- Nearest neighbor similarity matching

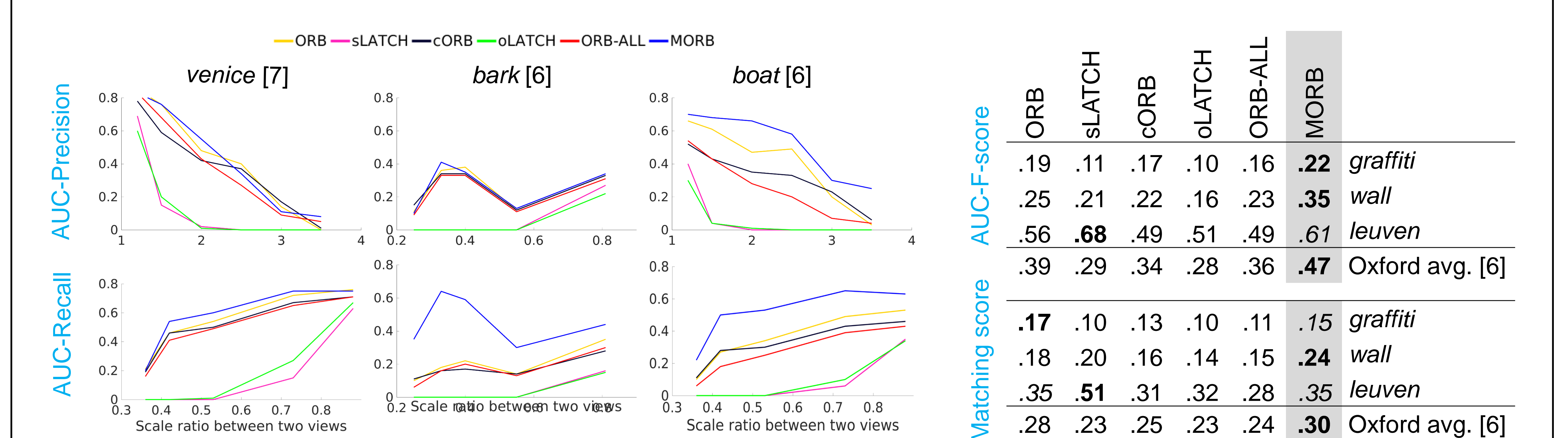


Example of method rankings with different measure curves

	ORB	sLATCH	MORB	
	.76 (1)	.63 (3)	.75 (2)	AUC-Precision
	.53 (2)	.35 (3)	.63 (1)	AUC-Recall
	.15 (2)	.19 (1)	.13 (3)	AUC-Recall vs 1-precision
	.58 (2)	.36 (3)	.66 (1)	AUC-F-score

Method rankings not preserved

Results



References

[1] Rublee, E. et al., "ORB: an efficient alternative to SIFT and SURF," in ICCV, 2011.
 [2] Lowe, D.G., "Distinctive image features from scale-invariant keypoints," in IJCV, 2004.
 [3] Hassner, T. et al., "Sifting through scales," in TPAMI, 2017.
 [4] Dong, J. and Soatto, S., "Domain-size pooling in local descriptors: DSP-SIFT," in CVPR, 2015.
 [5] Yang, T.-Y., et al., "Accumulated Stability Voting: A Robust Descriptor from Descriptors of Multiple Scales," in CVPR, 2016.
 [6] Mikolajczyk, K. and Schmid, C., "A Performance Evaluation of Local Descriptors," in TPAMI, 2005.
 [7] Heinly, J. et al., "Comparative Evaluation of Binary Features", in ECCV, 2012.
 [8] Levi, G. and Hassner, T., "LATCH: Learned Arrangements of Three Patch Codes," in WACV, 2016.