MORB: A MULTI-SCALE BINARY DESCRIPTOR

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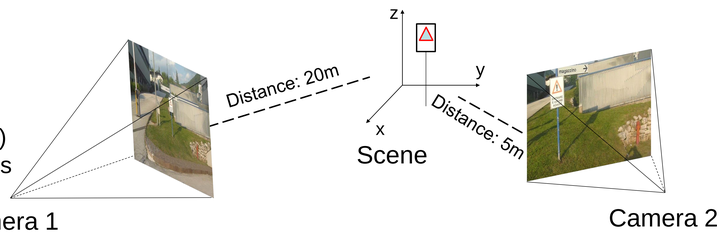
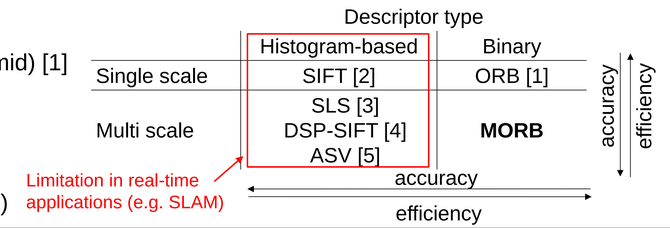
1. Introduction

- 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



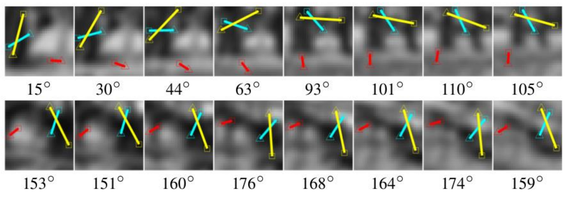
2. Related work

- 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)



3. Proposed approach: MORB

1. Multi-scale detection
   - Keypoint localisation for each scale (image pyramid) [1]
   - Cross-scale feature pruning to remove ambiguities
   - Sampling keypoint location for each scale
2. Orientation assignment (θ)
   - Intensity centroid method [1]
   - Independent estimation for each scale



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

3. Multi-scale ORB descriptor (MORB)
   - Rotated ORB sampling pattern $\boldsymbol{S}_\theta$ [1] for each scale
   - Set of binary descriptors $\boldsymbol{d_p} = [\boldsymbol{d}_{\boldsymbol{p},1}, \dots, \boldsymbol{d}_{\boldsymbol{p},S}]$
4. Cross-scale matching:
   - Nearest neighbor with a scale-aware Hamming distance

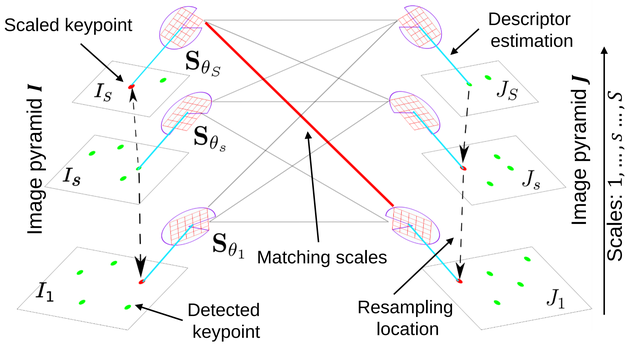
ORB descriptor at scale l of feature n

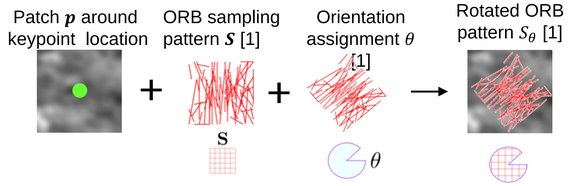
Hamming distance between feature m and feature n $\longrightarrow h_{m,n} = \min_{s,l \in \mathcal{S}} \boldsymbol{d}^m_{\boldsymbol{p},s} \oplus \boldsymbol{d}^n_{\boldsymbol{p},l}$

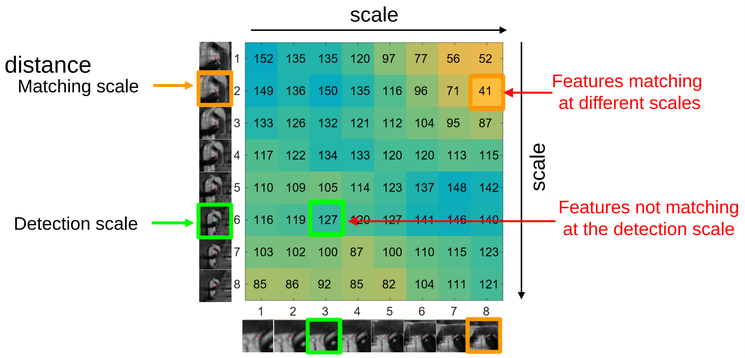
XOR operator + counting

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

MORB multi-scale descriptor and cross-scale matching







4. Experimental results

Datasets

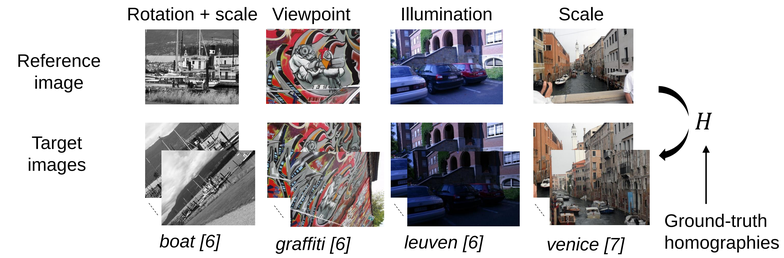
- Planar image sets with geometric/photometric changes
- Oxford ACRD [6]
- Heinly's dataset [7]

Performance measures

- Matching score [7]: $\frac{\#\ correct\ matches}{\#\ features}$
- Precision: $\frac{\#\ correct\ matches}{\#\ total\ matches}$
- Recall: $\frac{\#\ correct\ matches}{\#\ total\ true\ matches}$
- F-score: $2\frac{Precision \times Recall}{Precision + Recall}$
- 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



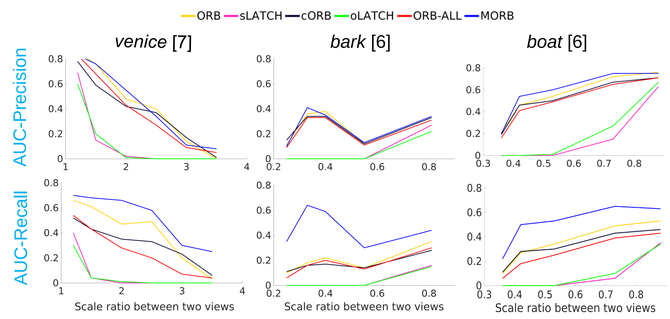
Example of method rankings with different measure curves

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

AUC (ranking)

Method rankings not preserved

Results



	ORB	sLATCH	cORB	oLATCH	ORB-ALL	MORB	
AUC-F-score	.19	.11	.17	.10	.16	**.22**	*graffiti*
	.25	.21	.22	.16	.23	**.35**	*wall*
	.56	**.68**	.49	.51	.49	*.61*	*leuven*
	.39	.29	.34	.28	.36	**.47**	Oxford avg. [6]
Matching score	**.17**	.10	.13	.10	.11	*.15*	*graffiti*
	.18	.20	.16	.14	.15	**.24**	*wall*
	.35	**.51**	.31	.32	.28	*.35*	*leuven*
	.28	.23	.25	.23	.24	**.30**	Oxford avg. [6]

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.
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[8] Levi, G. and Hassner, T., "LATCH: Learned Arrangements of Three Patch Codes," in WACV, 2016.