BRISKS: Binary Features for Spherical Images on a Geodesic Grid

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Motivation

360 video and spherical/omnidirectional images now widely used:
- Virtual reality
- Omnidirectional SLAM/structure-from-motion
- Autonomous vehicles

Standard image processing/vision techniques adapted heuristically from planar images to spherical images

We extend a binary feature (BRISK) to spherical images in a way that respects spherical geometry

Problems with planar image representation

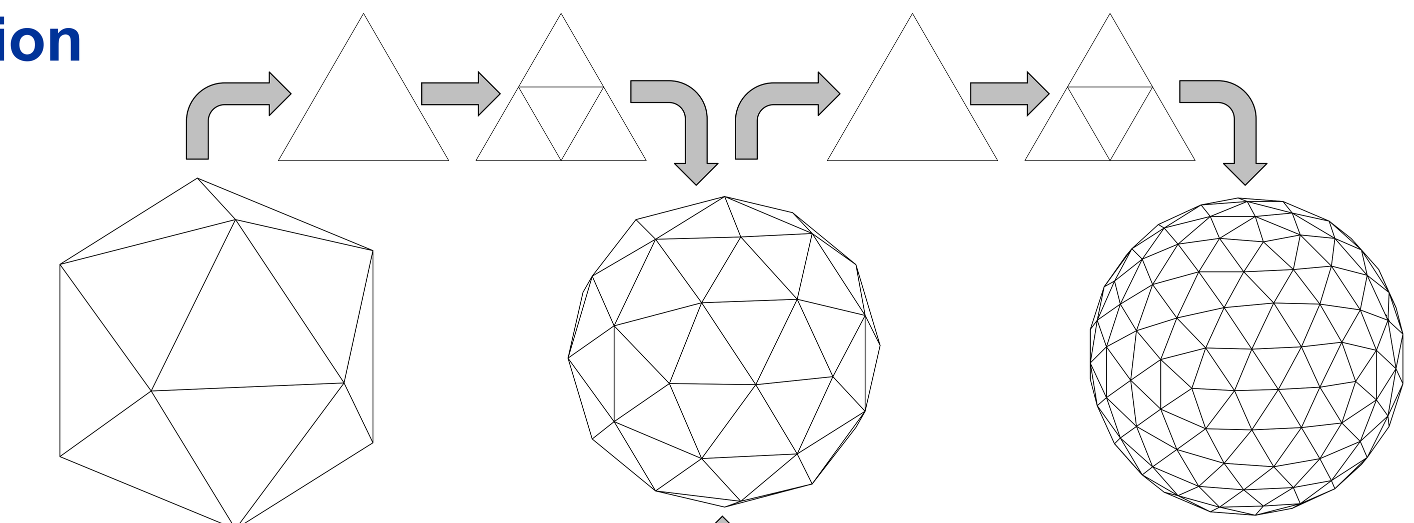
Standard spherical image representation is equirectangular projection:

Flattened planar images unsuitable for processing directly:

- Rotation-dependent distortion – particularly near the poles
- Introduces artificial boundaries
- Uneven sampling

Multiscale geodesic grid representation

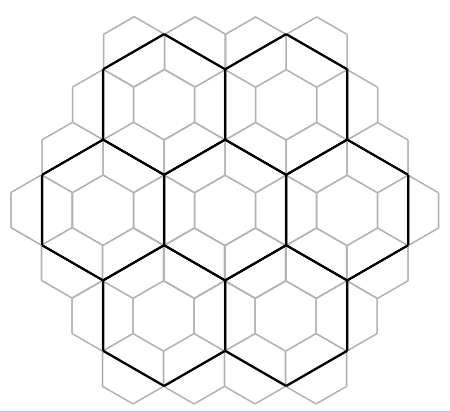
- We represent and store spherical images using a triangular subdivision mesh
- Subdivision scheme provides multiresolution representation
- Mesh stored in half-edge for constant time adjacency queries

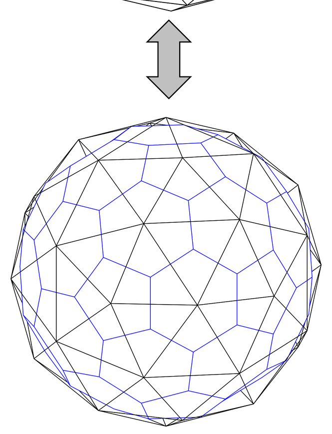


Possible image resolutions restricted to small set of possibilities:

No. subdivisions (s)	No. pixels ($= V_s$)	F_s
0	12	20
1	42	80
2	162	320
3	642	1,280
4	2,562	5,120
5	10,242	20,480
6	40,962	81,920
7	163,842	327,680
8	655,362	1,310,720
9	2,621,442	5,242,880

Visualisation of subdivision scheme in terms of hexagonal pixels:

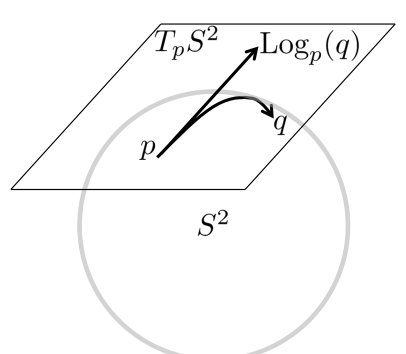




The dual polyhedron of the triangle mesh has hexagonal facets everywhere but at 12 points

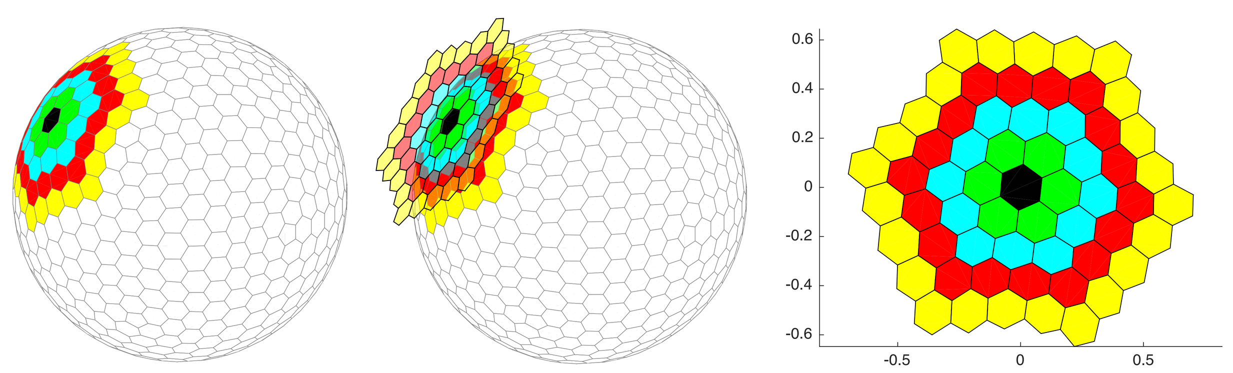
Colour per vertex in triangle mesh equivalent to hexagonal pixels

Local charts



The log map enables us to build a local chart in the tangent space around an interest point

Geodesic distances of pixels from interest point are preserved

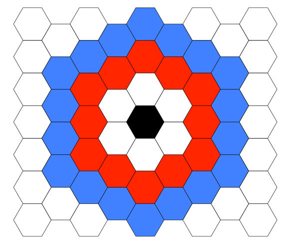


Interest point detection

- We detect FAST corners at octaves and intra-octaves
- Sub-pixel position refinement
- Continuous scale estimate

Subdivision scheme does not provide intra-octaves

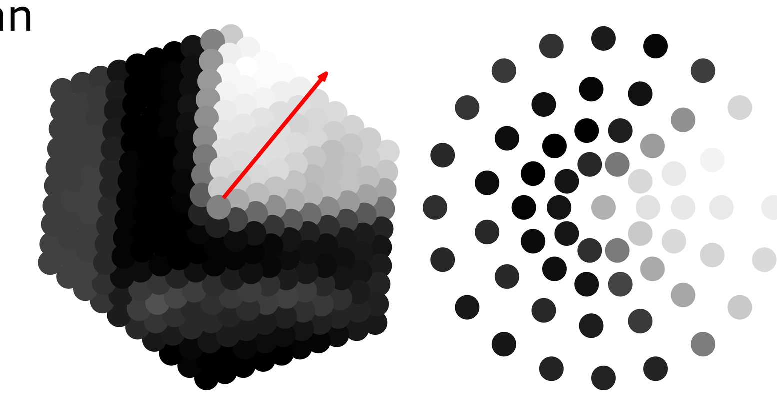
Detect by using AST pattern with 1.5x scale difference (red versus blue)



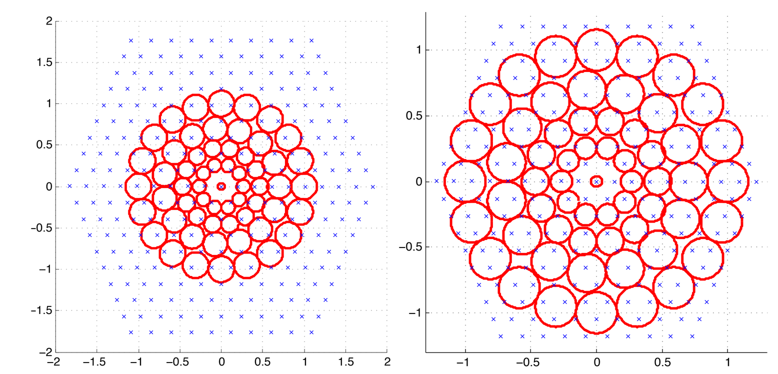
Example of a corner passing the spherical AST

Rotation-invariant descriptor extraction

From the 9-ring neighbourhood around an interest point:
- Approximate gradient direction using average from all "long range" pairs
- This defines characteristic direction
- Sampling pattern in tangent space rotated to characteristic direction
- Different sized sampling pattern for octave and intra-octave features



(a) Characteristic orientation. (b) Sampled intensities.



(a) Sampling octave feature. (b) Sampling intra-octave feature.

Experimental Results

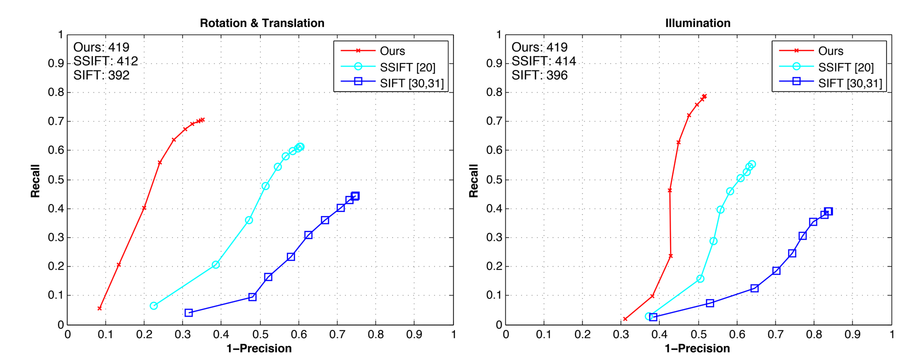
Synthetic (rendered) image dataset provides ground truth correspondence and controllable lighting:

Varying translation (ground truth depth on right)

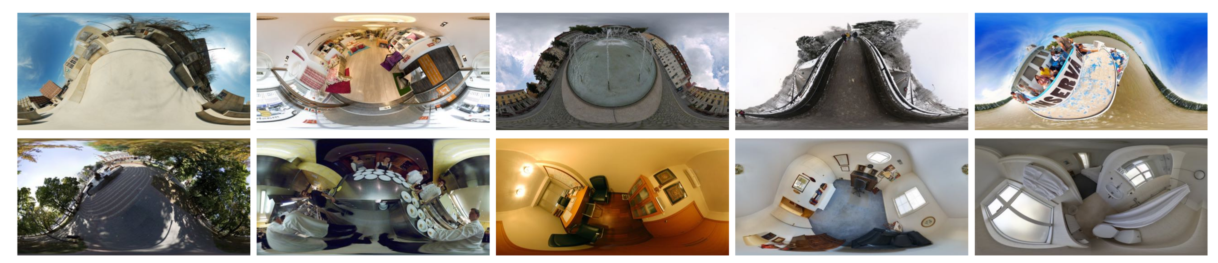
Varying illumination

	Rotation and Translation	Illumination
Ours	**0.93** (419)	**0.64** (414)
SSIFT [2]	0.65 (412)	0.49 (414)
SIFT [3], [4]	0.57 (392)	0.41 (396)

Repeatability (average number of detected features in brackets)

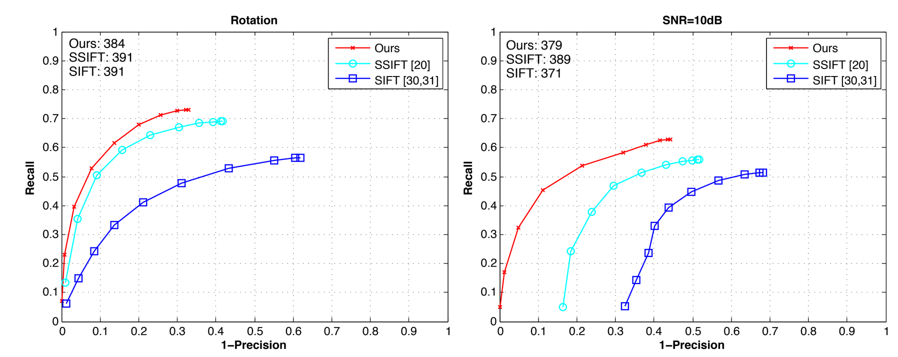


Real image dataset (SUN 360 [1]) used to test performance under rotation and noise



	Rotation	Noise 10dB	Noise 15dB	Noise 20dB
Ours	**0.94** (384)	**0.90** (379)	**0.93** (383)	**0.93** (385)
SSIFT [2]	0.86 (391)	0.76 (389)	0.79 (379)	0.83 (374)
SIFT [3], [4]	0.70 (391)	0.65 (371)	0.67 (378)	0.66 (384)

Repeatability (average number of detected features in brackets)



[1] J. Xiao, K. A. Ehinger, A. Oliva, and A. Torralba, "Recognizing scene viewpoint using panoramic place representation," in Proc. CVPR, 2012, pp. 2695–2702.
[2] J. Cruz-Mota, I. Bogdanova, B. Paquier, M. Bierlaire, and J.-P. Thiran, "Scale invariant feature transform on the sphere: Theory and applications," Int. J. Comput. Vis., vol. 98, no. 2, pp. 217–241, 2012.
[3] T. Goedeme, T. Tuytelaars, L. Van Gool, G. Vanacker, and M. Nuttin, "Omnidirectional sparse visual path following with occlusion-robust feature tracking," in Proc. OMNIVIS, 2005.
[4] D. Scaramuzza and R. Siegwart, "Appearance-guided monocular omni- directional visual odometry for outdoor ground vehicles," IEEE Trans. Robotic. Autom., vol. 24, no. 5, pp. 1015–1026, 2008.

Summary

- Lightweight, binary feature for spherical images
- All steps of the BRISK pipeline extended to sphere in natural way
- Performance exceeds naïve features on planar flattened images and SIFT on the sphere