2021 ICCV OCTOBER 11-17 VIRTUAL

BabelCalib: A Universal Approach to Calibrating Central Cameras

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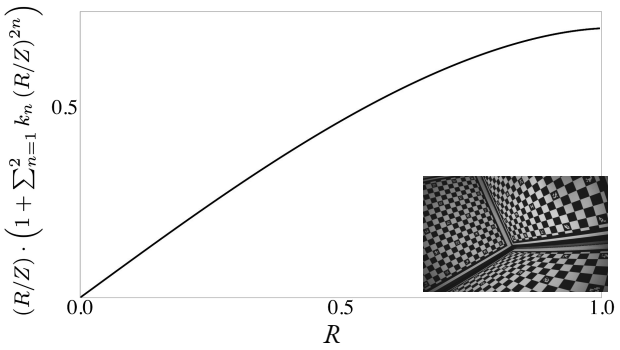
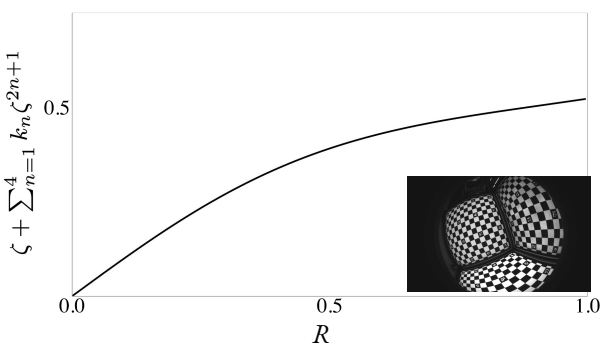
Camera Models & Initialization Problem

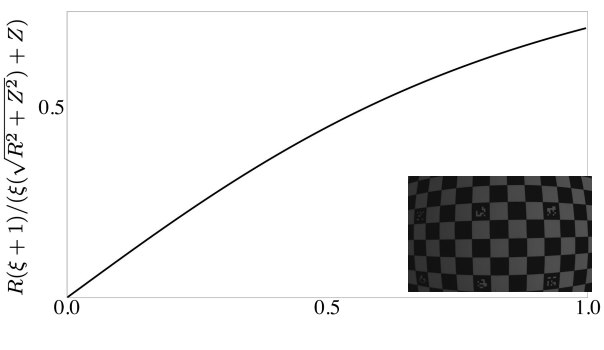
Brown-Conrady



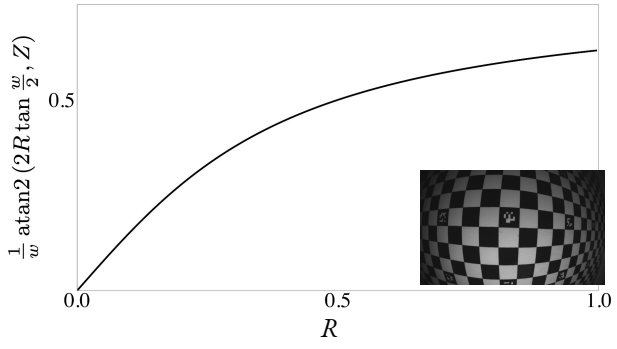
Kannala-Brandt



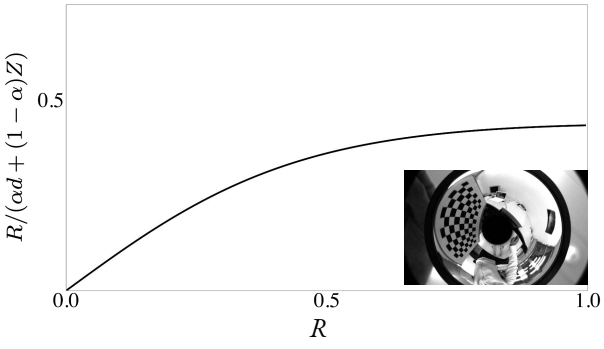
Unified Camera



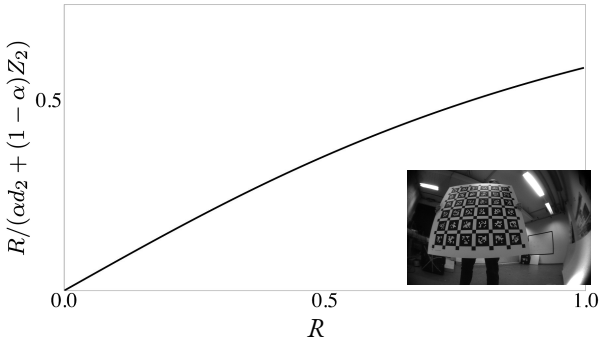
Field of View



Extended Unified Camera



Double Sphere



Minimal Solution?

Kannala-Brandt projection

$$r = \operatorname{atan2}(R, Z) \cdot \left(1 + \sum_{n=1}^{N} k_n (\operatorname{atan2}(R, Z))^{2n}\right)$$

r: projected point radius; $\operatorname{atan2}(R, Z)$: scene point radius; Z: scene point depth; k_n: parameters

Unified Camera projection

$$r = \frac{R(\xi + 1)}{\xi\sqrt{R^2 + Z^2} + Z}$$

ξ: parameter

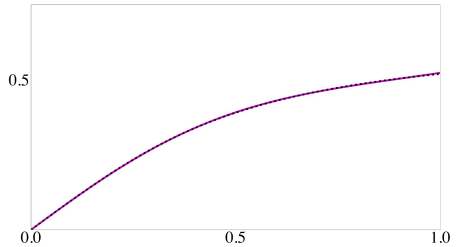
Brown-Conrady projection / distortion

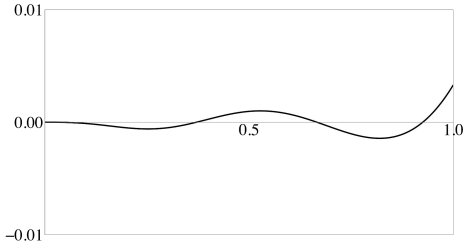
$$r = R/Z \cdot \left(1 + \sum_{n=1}^{N} k_n (R/Z)^{2n}\right)$$

k_n: parameters

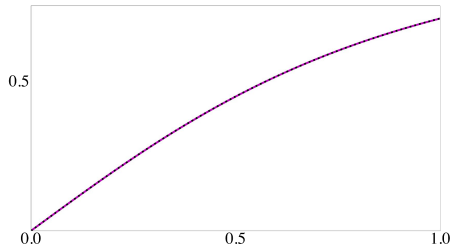
Fitting against Universal Division Back-Projection

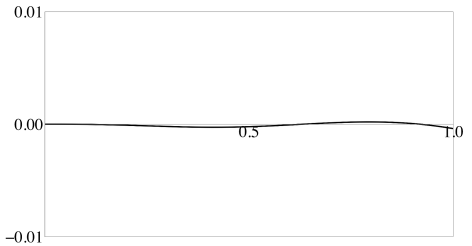
Kannala-Brandt projection



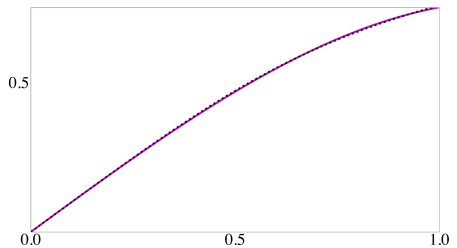


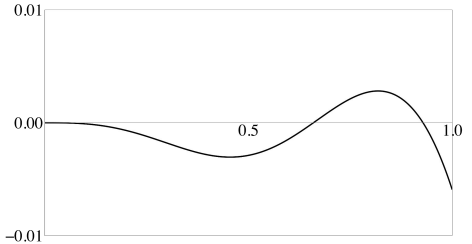
Unified Camera projection





Brown-Conrady projection / distortion

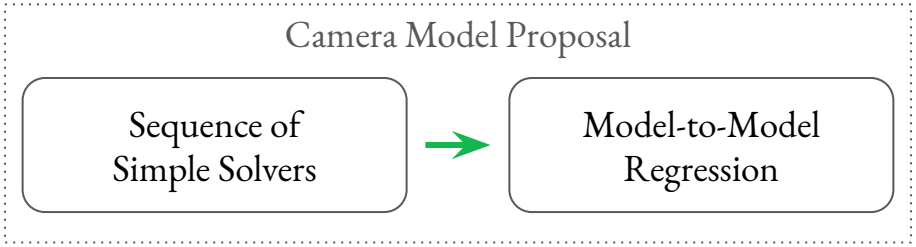




Functions

Residuals

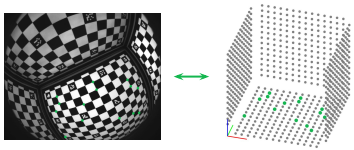
BabelCalib: Initial guess



BabelCalib: Initial guess

Camera Model Proposal

Sequence of Simple Solvers → Model-to-Model Regression



1. Radial Fundamental Matrix
2. Corner Correction
3. Center of Projection + Partial Pose
4. Division Model + Translation Depth

$$\mathbf{x} \otimes \mathbf{u}\,\mathrm{vec}(\mathbf{F}) = 0$$

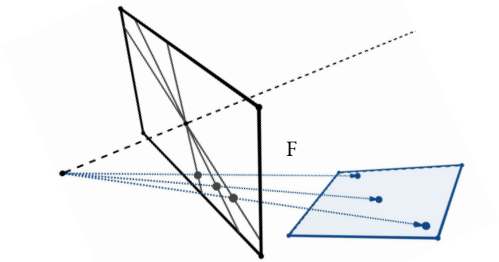
$$\mathbf{u}_i^* = \mathrm{proj}_{\mathbf{F}_r \mathbf{x}_i}(\mathbf{u}_i)$$

$$\zeta \mathbf{e} = \mathrm{null}\,\mathbf{F}^\top$$

$$(f_{21}, -f_{11}, r_{31})\,\mathbf{S}^2\,(f_{22}, -f_{12}, r_{32})^\top = 0$$

$$\|\mathbf{S}(f_{21}, -f_{11}, r_{31})^\top\|_2^2 = \|\mathbf{S}(f_{22}, -f_{12}, r_{32})^\top\|_2^2$$

$$g\,(\mathrm{diag}(f^{-1}, f^{-1}, 1)\mathbf{u}') \times \begin{pmatrix} x' \\ y' \\ z' + t_z \end{pmatrix} = 0$$



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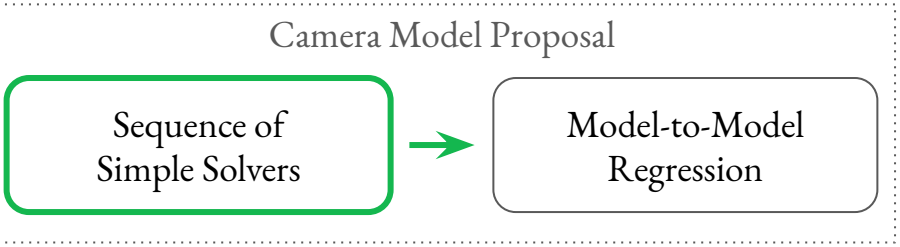

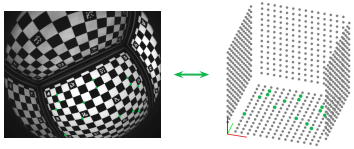

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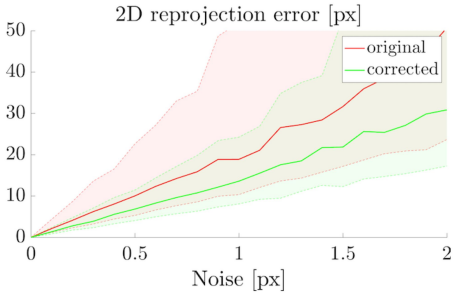

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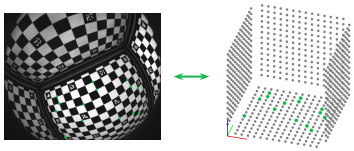

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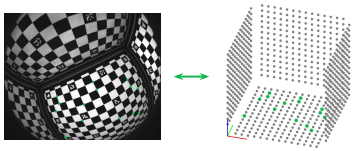

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Back-projection with division model

BabelCalib: Initial guess

Camera Model Proposal

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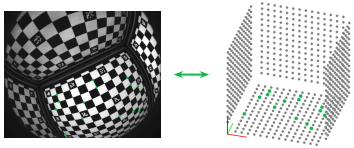

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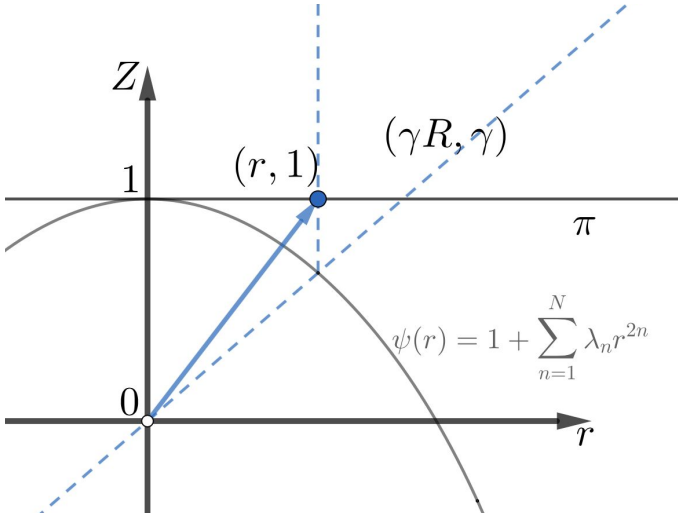

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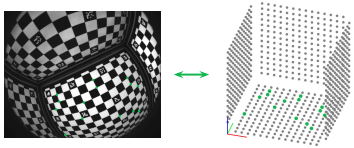

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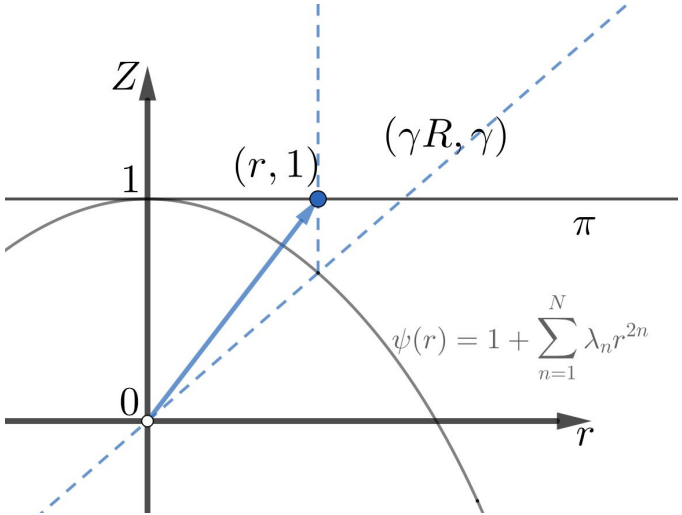


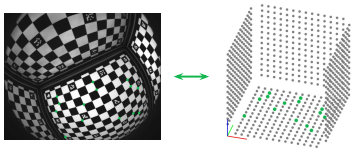
$$\sum_k (\phi_\theta(r_k, \psi(r_k)) - r_k)^2 \to \min_\theta$$

Fitting target projection model

BabelCalib Pipeline

Camera Model Proposal

Non-minimal Sampling → Sequence of Simple Solvers → Model-to-Model Regression → P3P + Refinement



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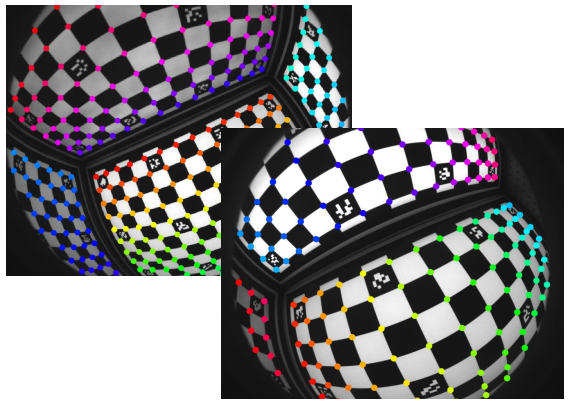

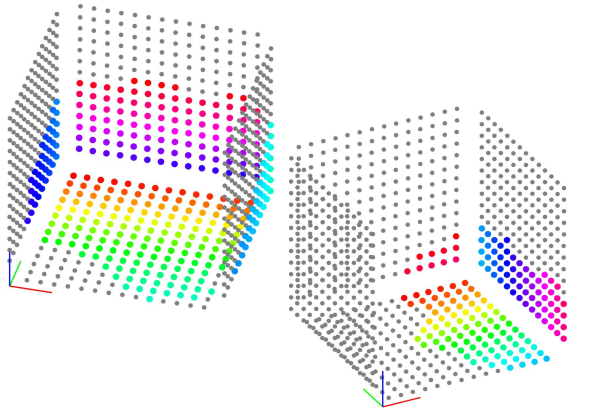

[Nakano et al. A Simple Direct Solution to the Perspective-Three-Point Problem. In BMVC 2019]

Evaluation: Data

Dataset	# cameras	# train + test img.	DFOV range	Max. img. size
Kalibr	8	140 + 60	110°—268°	1680 × 1680
OCamCalib	9	79 + 40	130°—266°	3840 × 2880
UZH-DAVIS	4	140 + 60	124°—148°	346 × 260
UZH-Snapdragon	4	140 + 60	144°—166°	640 × 480
OV-Corner	8	280 + 120	108°—109°	1280 × 800
OV-Cube	4	105 + 49	159°—183°	1280 × 800
OV-Plane	4	92 + 41	88°—187°	1280 × 800

[Usenko et al. The Double Sphere Camera Model. In 3DV 2018]
[Scaramuzza et al. A flexible technique for accurate omnidirectional camera calibration and structure from motion. In ICVS 2006]
[Delmerico et al. Are we ready for autonomous drone racing? the UZH-FPV drone racing dataset. In ICRA 2019]

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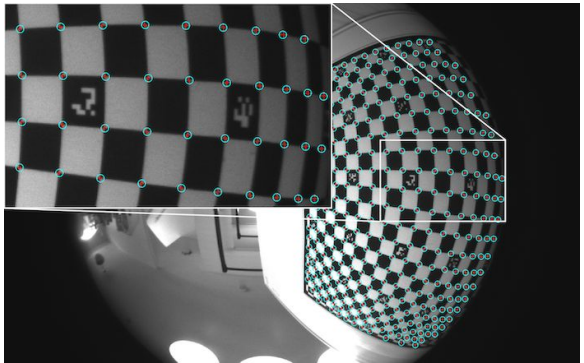
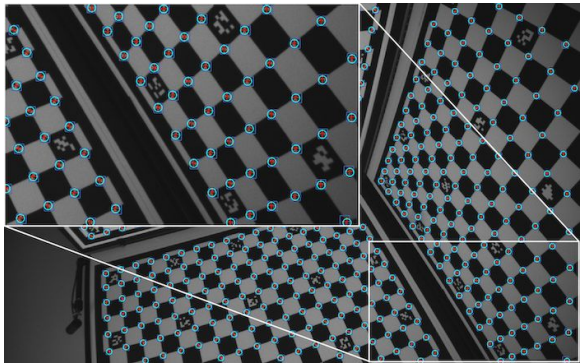
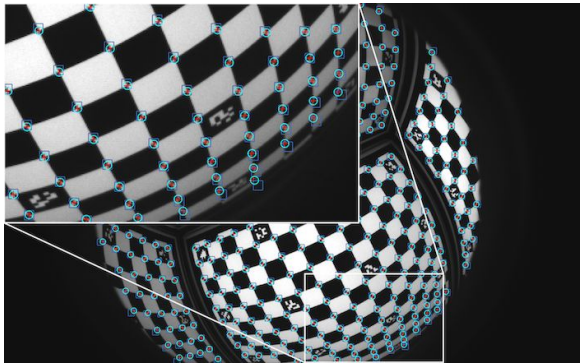
OV-Plane—130108MP, 0.478 px RMS



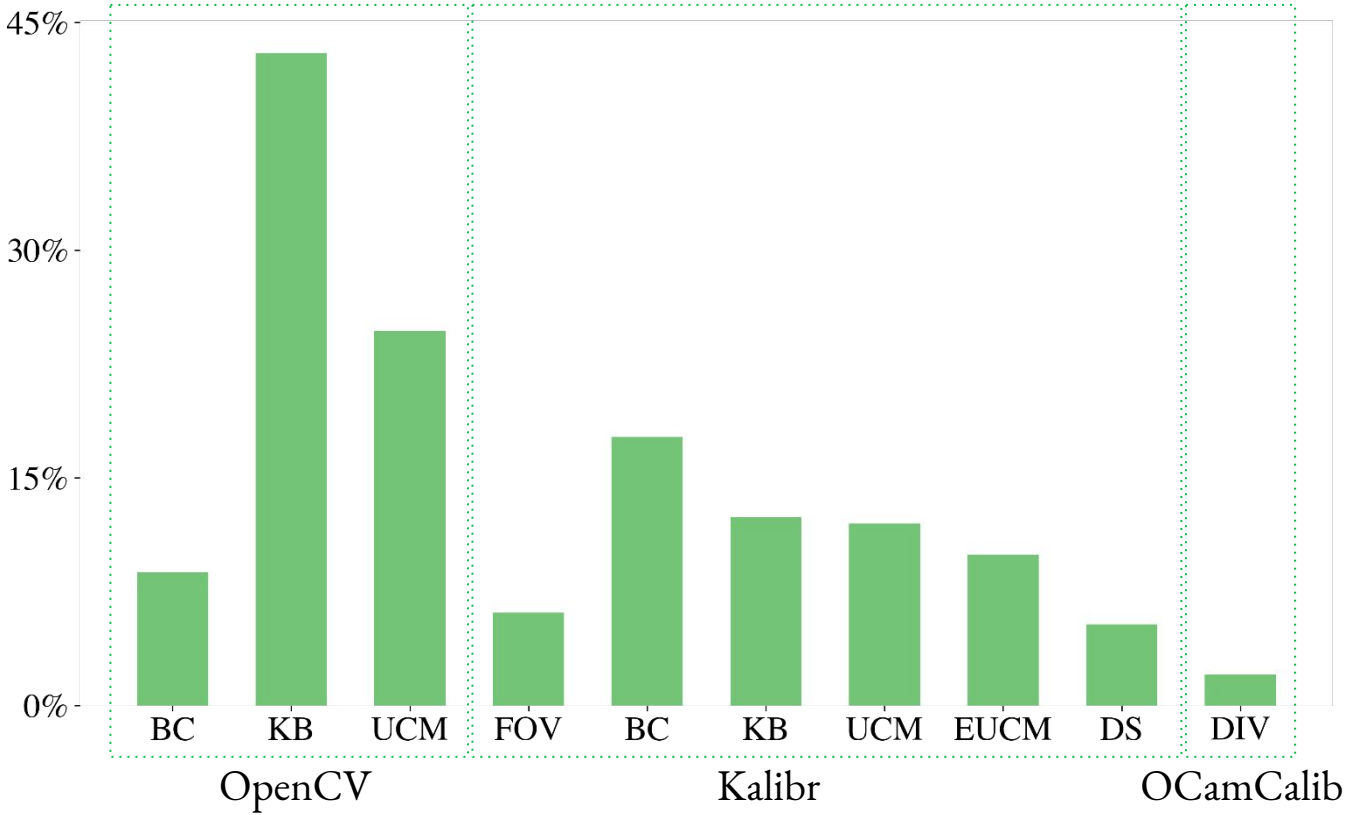
OV-Corner—Cam4, 0.770 px RMS



OV-Cube—Cam1, 0.268 px RMS



Accuracy Gains of BabelCalib



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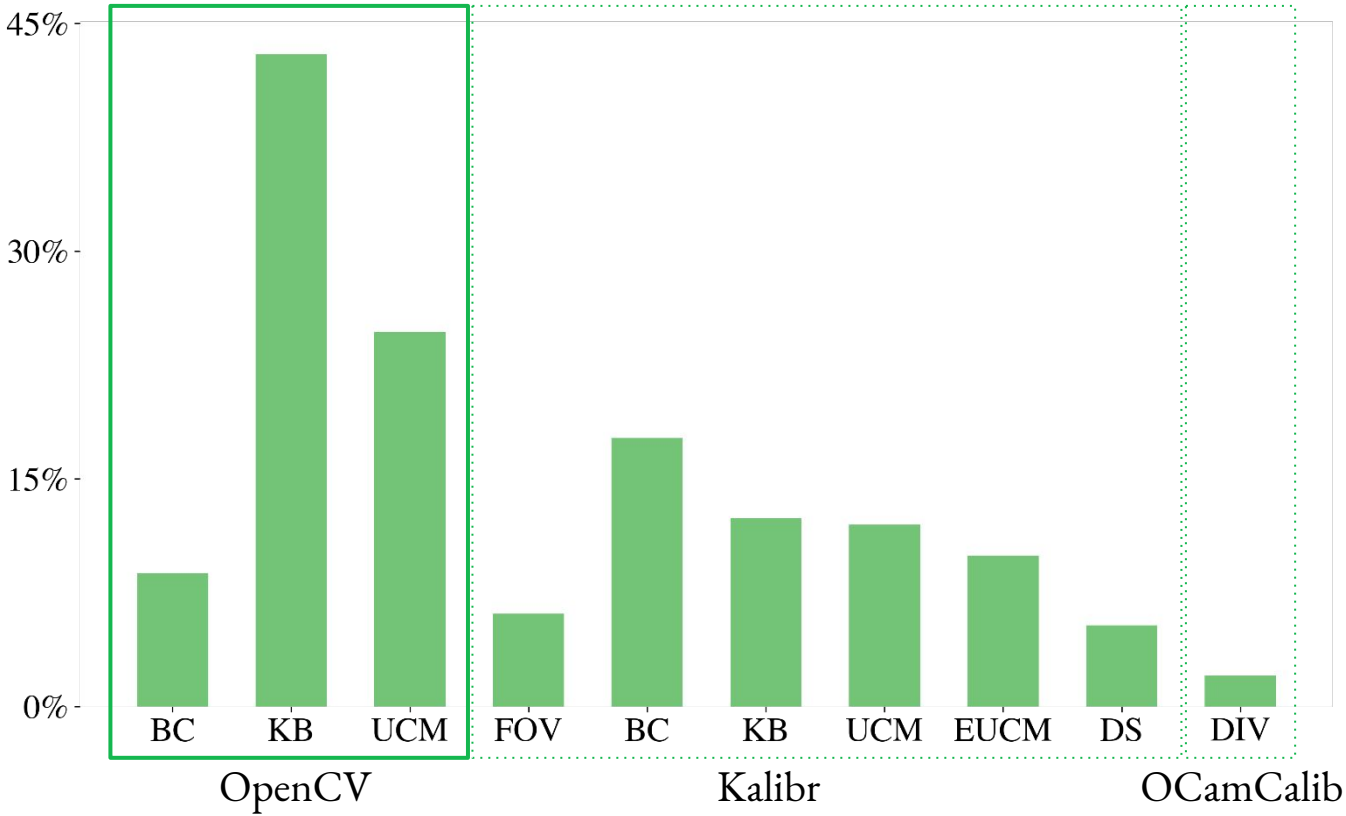

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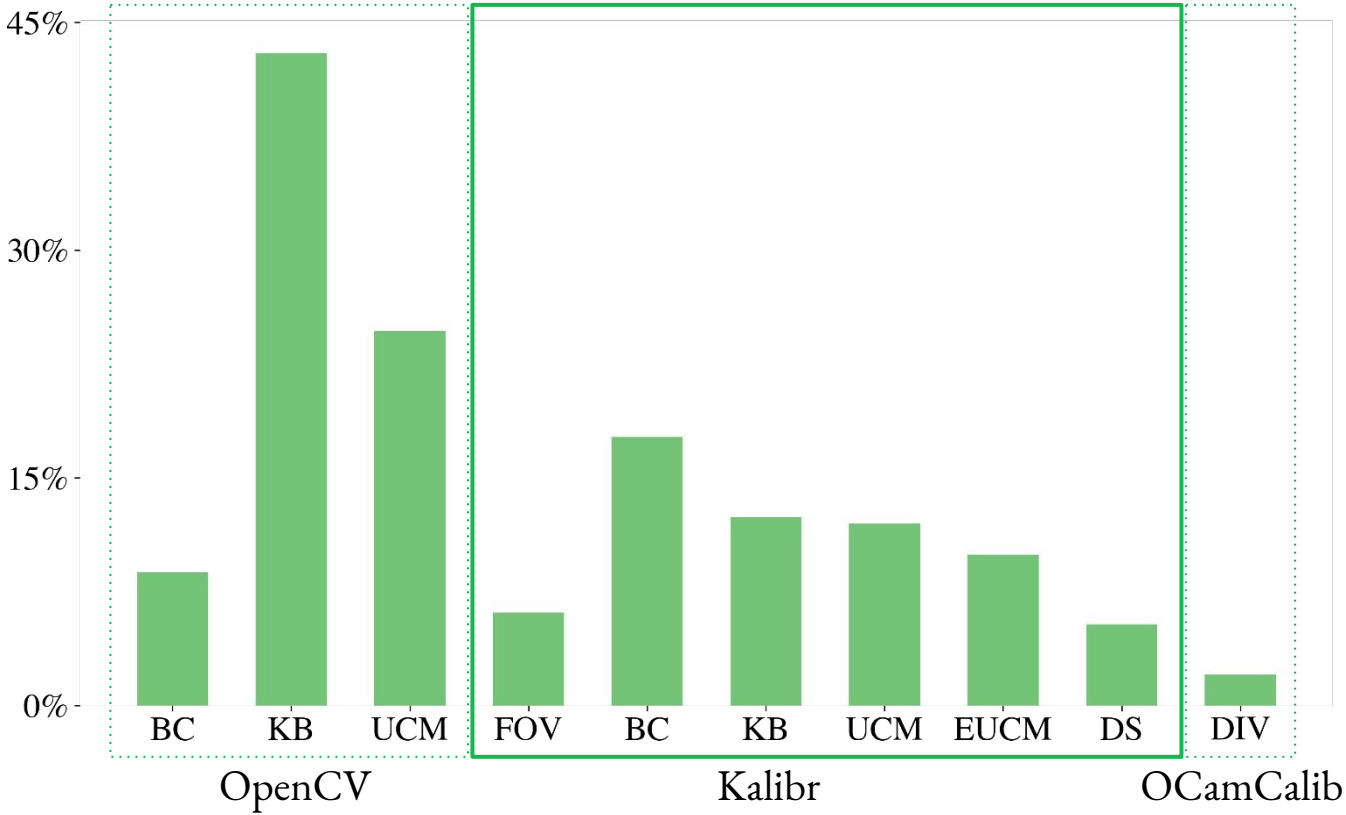

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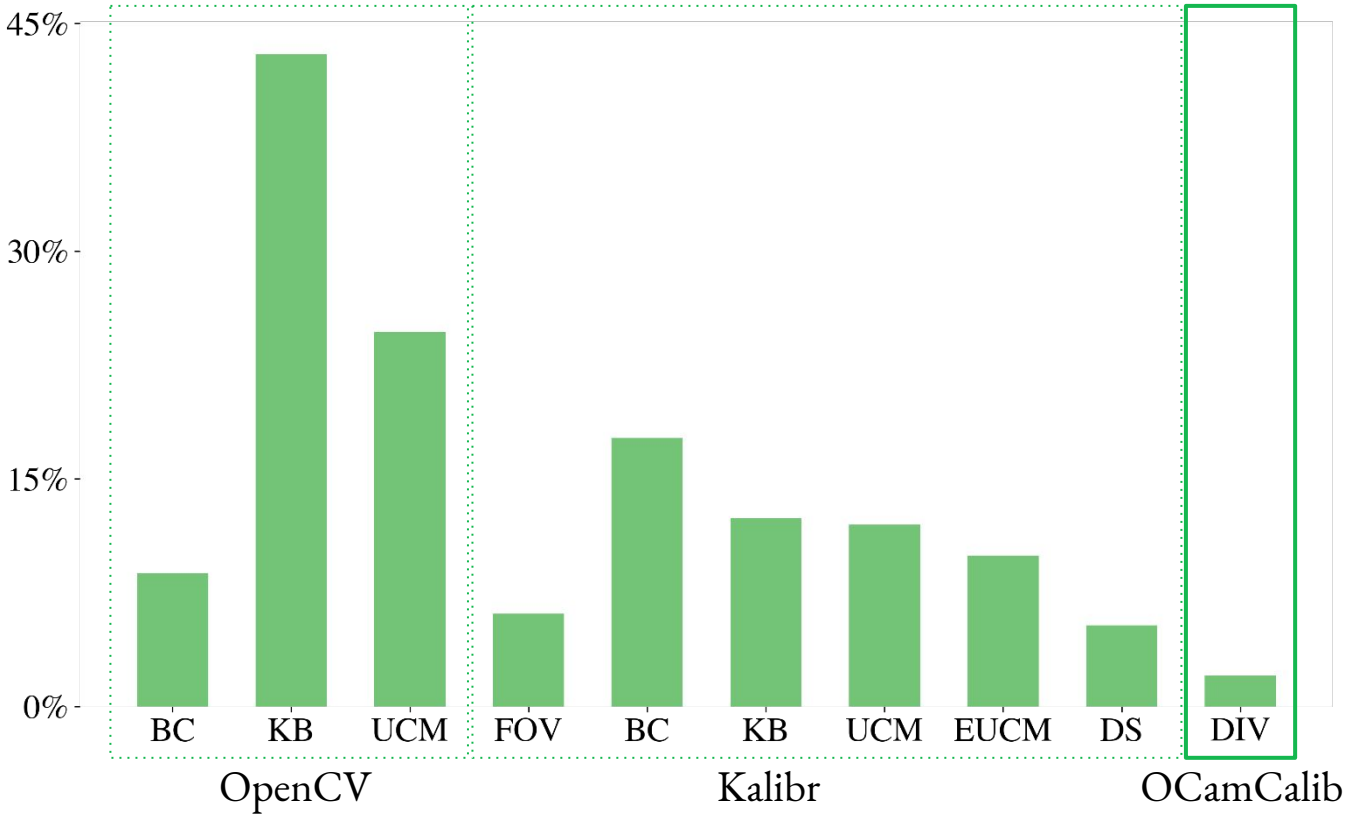

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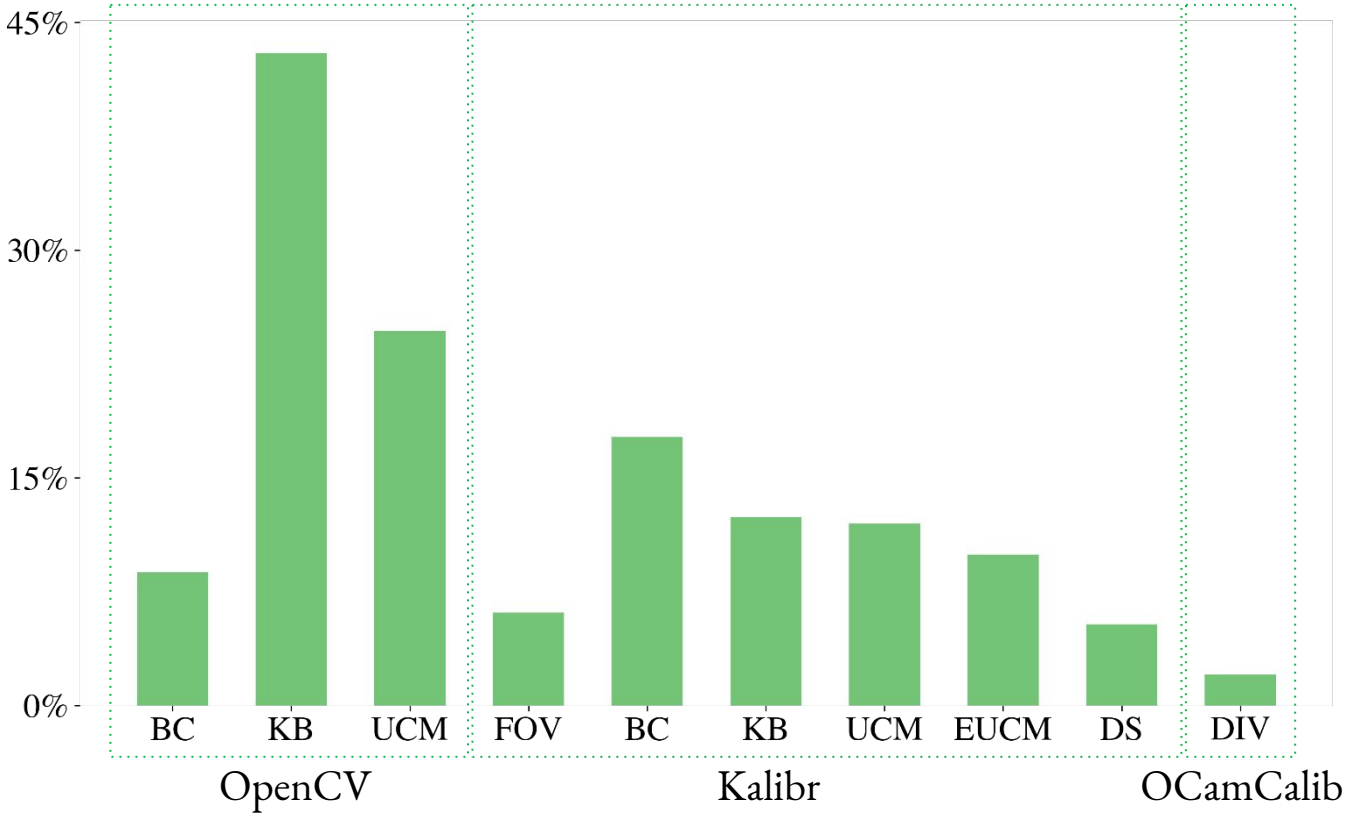

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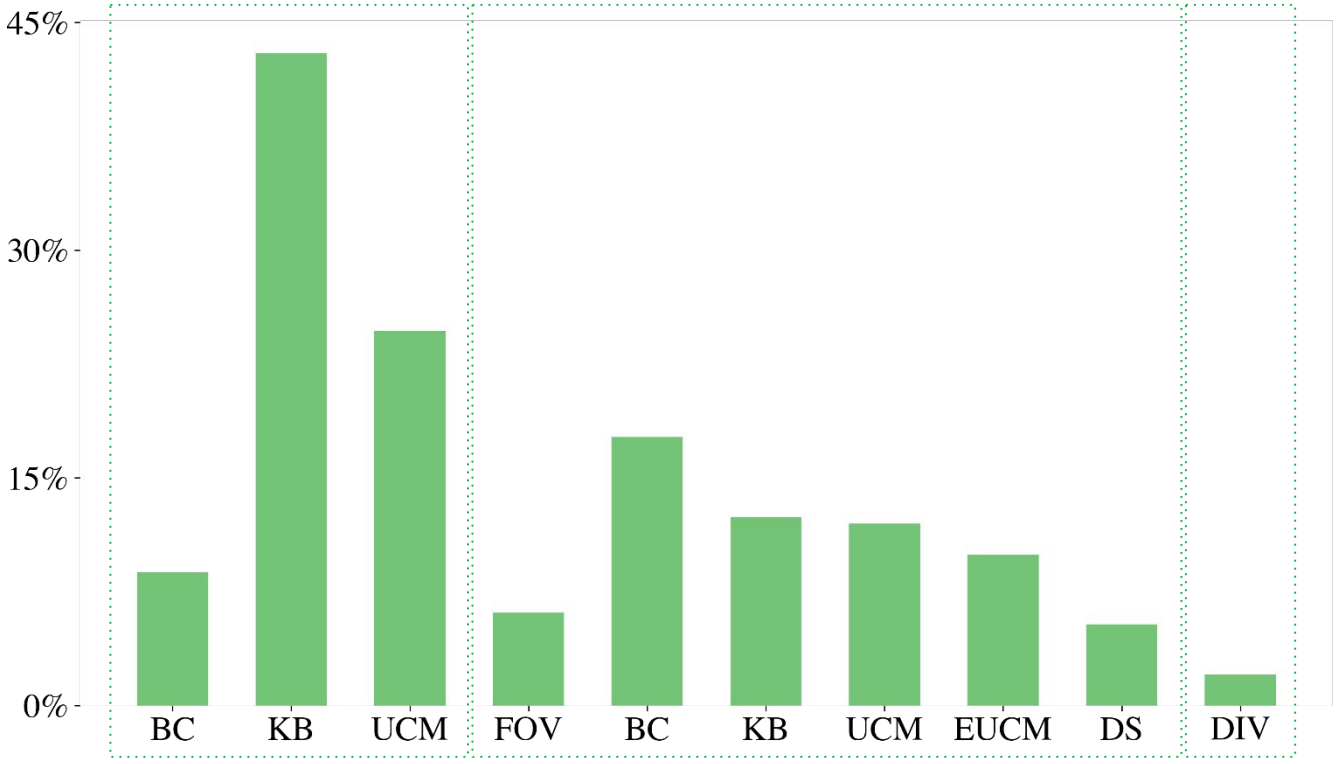
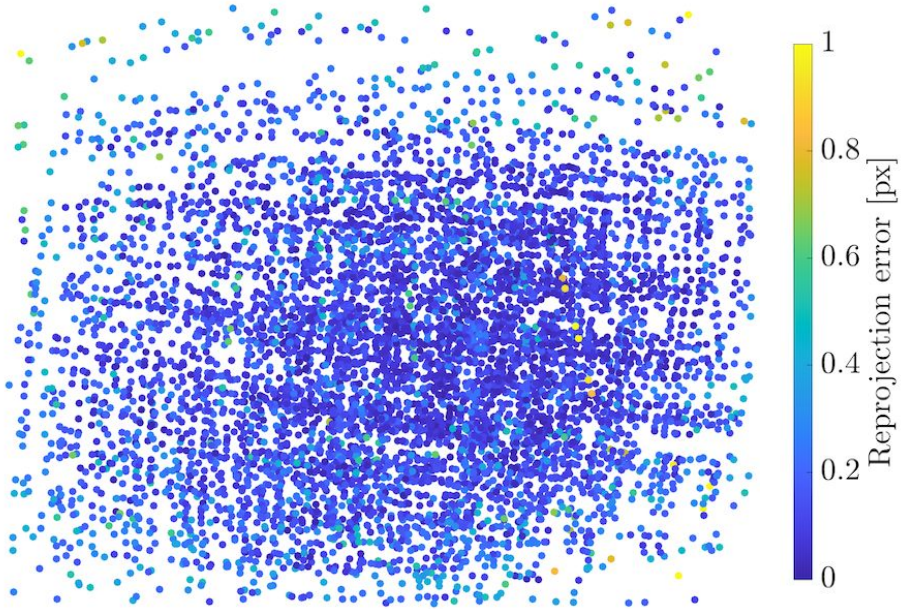


Qualitative Results



Calibration data: [Usenko et al. The Double Sphere Camera Model. In 3DV 2018]

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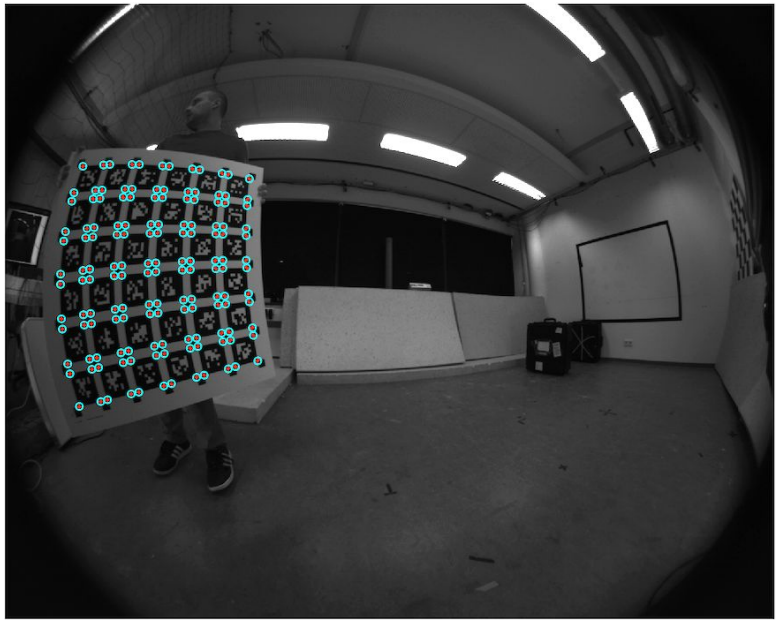

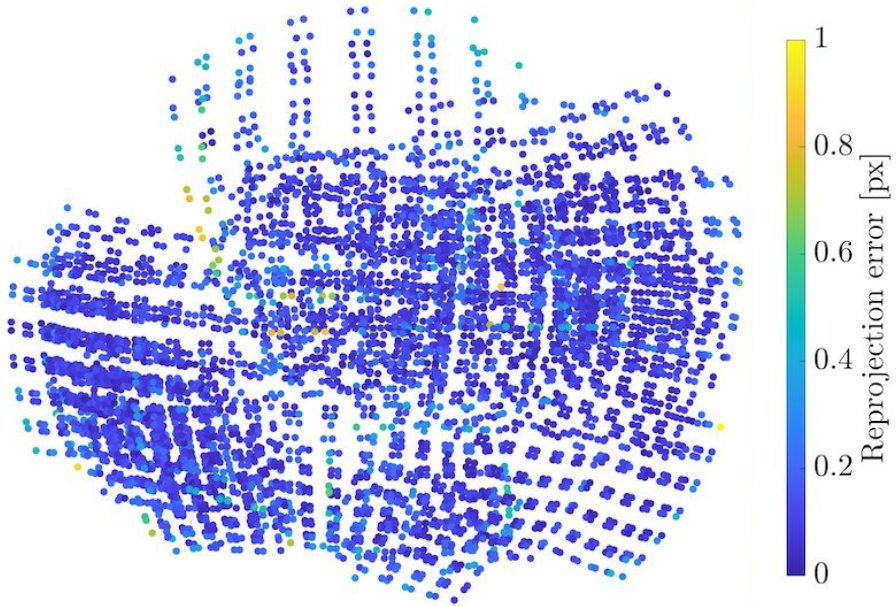

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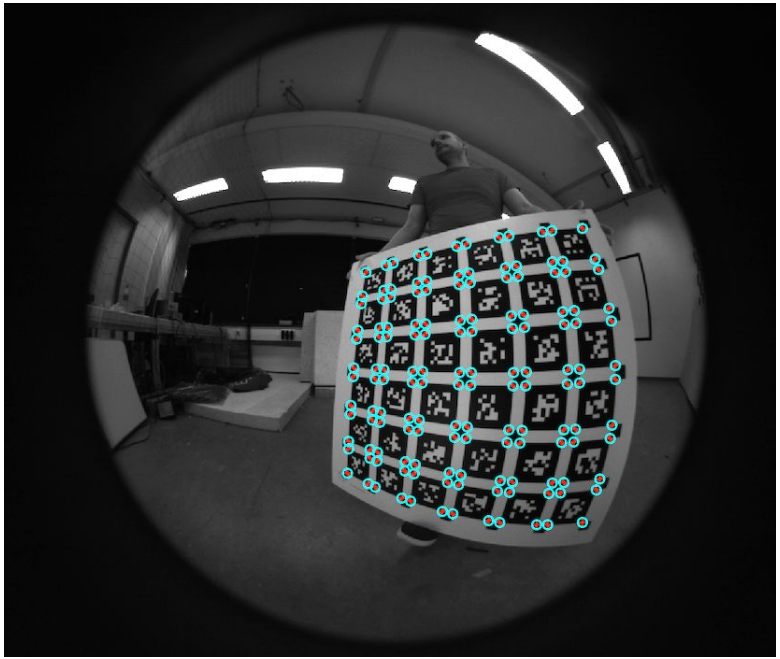

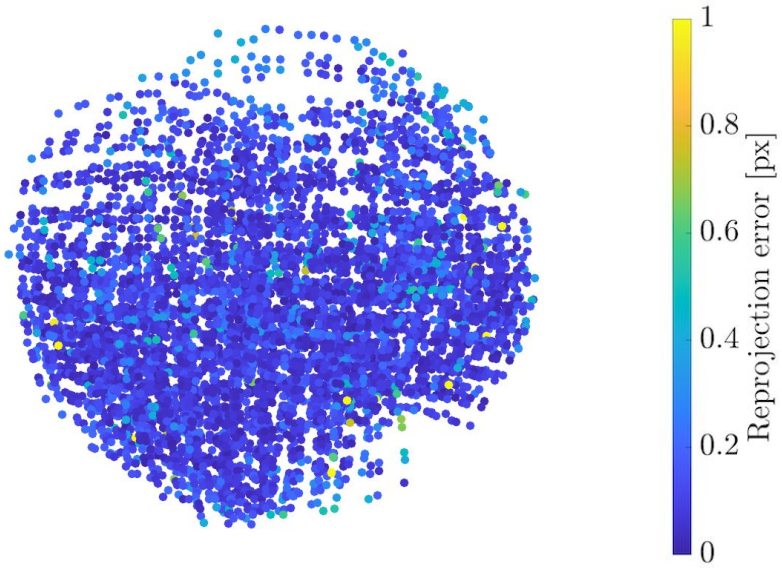

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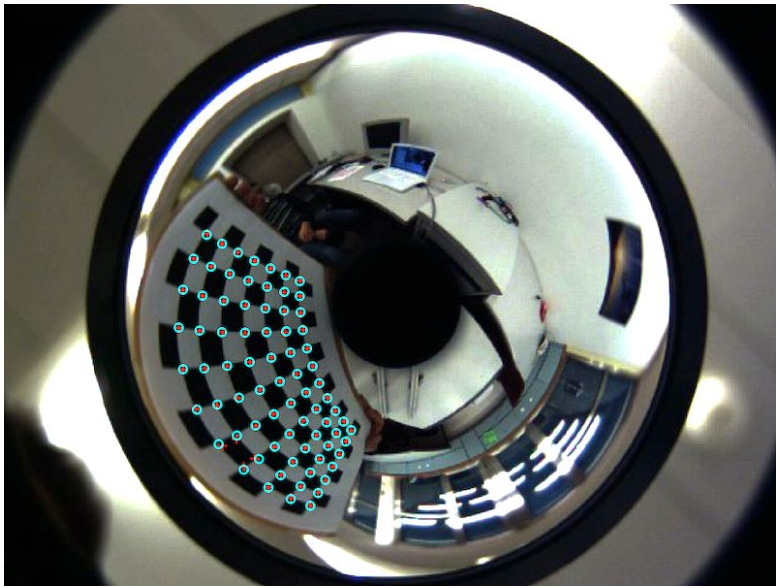

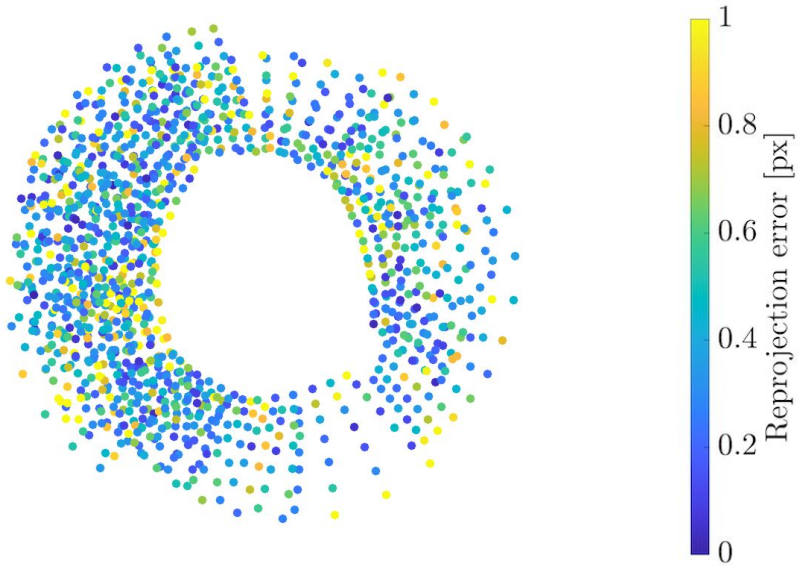

Calibration data: [Scaramuzza et al. A flexible technique for accurate omnidirectional camera calibration and structure from motion. In ICVS 2006]

BabelCalib Summary

- fully automatic approach to calibrate central cameras
- no user initialization required
- supports all commonly used central projection models
- easy to add new models
- achieves significant accuracy gains over the state of the art
- no catastrophic failures
- unaffected by displaced center of projection

CHALMERS UNIVERSITY OF TECHNOLOGY

FACEBOOK REALITY LABS

УКРАЇНСЬКИЙ КАТОЛИЦЬКИЙ УНІВЕРСИТЕТ

2021 ICCV OCTOBER 11-17 VIRTUAL

BabelCalib: A Universal Approach to Calibrating Central Cameras

Paper, code and data are available at the project page:

https://ylochman.github.io/babelcalib