BabelCalib

A Universal Approach to Calibrating Central Cameras

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2021 ICCV OCTOBER 11-17 VIRTUAL

* partially supported by WASP funded by the Knut and Alice Wallenberg Foundation.
† part of this work was done when Y. Lochman and J. Pritts were at Facebook Reality Labs.

INTRO

- Models for wide FOV, fisheye & omni-directional cameras:
  - are highly nonlinear
  - require good initialization
- State of the art sometimes fails for these cases

Problem: requires tedious user-supplied initialization, or generating a minimal solver for each camera model

Need: easy-to-extend framework with universal initialization strategy

SIMPLIFIED PROJECTION EQUATIONS

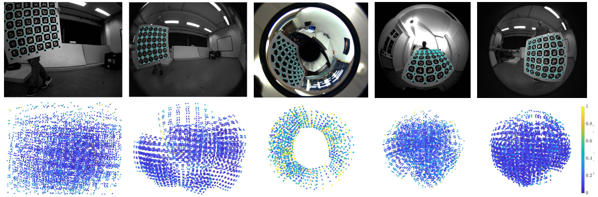
- Most projections — difficult solver generation

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

radius of an image point; radius of a scene point; depth of a scene point; target model parameters

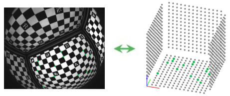
- Solvers are simple with known radii and depths
- Many models admit linear solvers
  - e.g., Kannala-Brandt, Brown-Conrady, Unified Camera

QUALITATIVE RESULTS



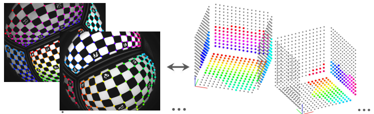
Reprojection errors [px]

BABELCALIB PIPELINE



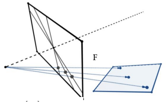
Camera Model Proposal

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



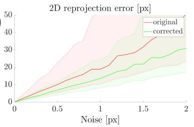
1. Radial Fundamental Matrix

- Non-minimal extension of 7pt method: $\mathbf{x} \otimes \mathbf{u}\, \mathrm{vec}(\mathtt{F}) = 0$



2. Corner Correction

- Jointly refine with F: $\mathbf{u}_i^* = \mathrm{proj}_{\mathtt{F}_r \mathbf{x}_i}(\mathbf{u}_i)$
- Substantially improves accuracy.



3. Center of Projection + Partial Pose

- Null space of refined F: $\zeta \mathbf{e} = \mathrm{null}\, \mathtt{F}^\top$
- Quadratic pose solver: $(f_{21}, -f_{11}, r_{31})\, \mathtt{S}^2\, (f_{22}, -f_{12}, r_{32})^\top = 0$, $\|\mathtt{S}(f_{21}, -f_{11}, r_{31})^\top\|_2^2 = \|\mathtt{S}(f_{22}, -f_{12}, r_{32})^\top\|_2^2$

4. Division Model + Translation Depth

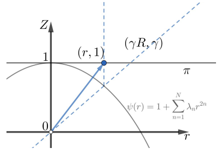
- Linear solver: $g\left(\mathrm{diag}(f^{-1}, f^{-1}, 1)\mathbf{u}'\right) \times \begin{pmatrix} x' \\ y' \\ z' + t_z \end{pmatrix} = 0$

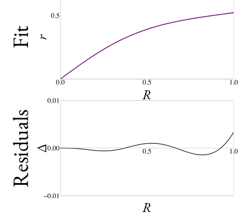
5. Fitting against Universal Division Back-Projection

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

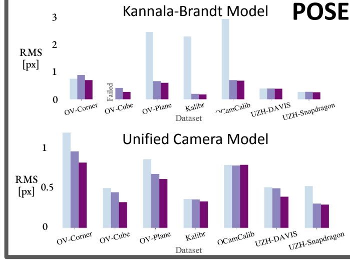
- Linear solutions for many target models

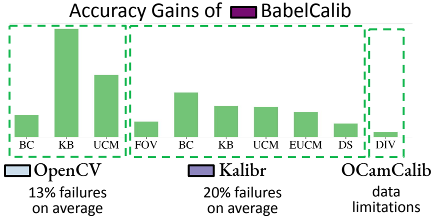
Back-projection with division model





POSE ESTIMATION RESULTS





BABELCALIB SUMMARY

- fully automatic approach
- no user-supplied initialization required
- supports all common projection models
- easy to extend with new models
- no catastrophic failures
- outperforms SOTA
- unaffected by displaced center