Calibration Wizard

A Guidance System for Camera Calibration Based on Modelling Geometric and Corner Uncertainty

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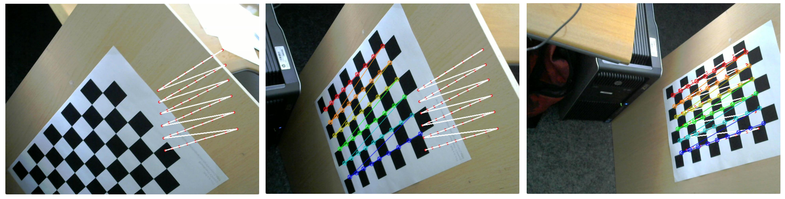
Motivation

Problems of most existing toolboxes for camera calibration:

- No detailed guidelines for taking images
- Not clear indicator of **calibration quality**
- ☹ **Unfriendly** to inexperienced users

Goal: Guide users to acquire **optimal poses** for calibration



Calculation of Optimal Next Pose

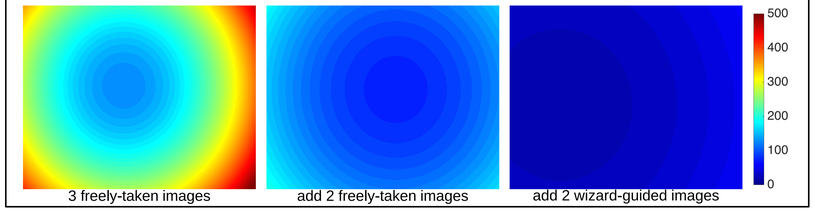
Θ : k intrinsic parameters Π_i: extrinsic parameters (pose), $i = 1 \cdots m$

$$\min \sum_{i,j} (x_{ij} - p_x(\Theta, \Pi_i, P_j))^2 + (y_{ij} - p_y(\Theta, \Pi_i, P_j))^2$$

$$J = \begin{pmatrix} A_1 & B_1 & 0 & \cdots & 0 & 0 \\ A_2 & 0 & B_2 & \vdots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & 0 \\ A_m & 0 & 0 & \cdots & B_m & 0 \\ \boldsymbol{A_{m+1}} & 0 & 0 & 0 & 0 & \boldsymbol{B_{m+1}} \end{pmatrix} \Rightarrow J^T J = \begin{pmatrix} U & W \\ W^T & V \end{pmatrix} \Rightarrow (J^T J)^{-1}$$

Upper-left $k \times k$ sub-matrix of $(J^T J)^{-1}$: $\sum = (U - WVW^T)^{-1}$ **covariance matrix** of Θ [1]

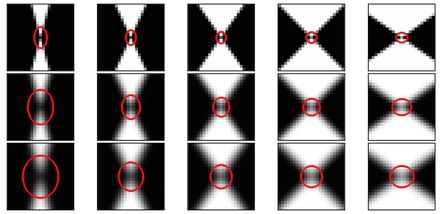
Global optimization over tr($\sum$) w.r.t. next pose $\boldsymbol{\Pi_{m+1}}$

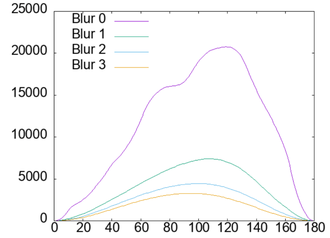


3 freely-taken images add 2 freely-taken images add 2 wizard-guided images

Corner Uncertainty

Problem: **Extreme camera poses** challenge corner detectors.
Solution: Consider corner uncertainty when **computing next pose**





- Estimate the **expected** autocorrelation matrices $\boldsymbol{C_{m+1}}$ of each corner point
- Express $\boldsymbol{C_{m+1}}$ as a function of opening angle and blur
- Incorporate into the calculation of $J^T J$ **=>** $J^T \mathrm{diag}(C_{11}, C_{12}, \cdots, \boldsymbol{C_{(m+1)n}}) J$

Comparison of Captured Images

Freely-taken images

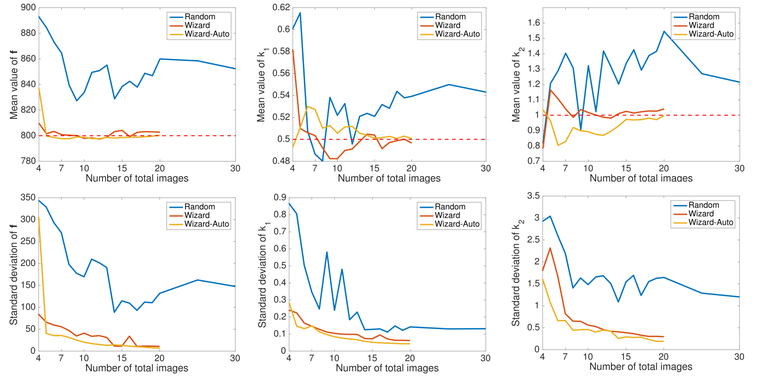
Wizard-guided images

References:
[1] Multiple View Geometry in Computer Vision, Hartley & Zisserman, 2003
[2] Towards Linear-time Incremental Structure from Motion, Wu, 3DV, 2013

ICCV 2019 Seoul, Korea

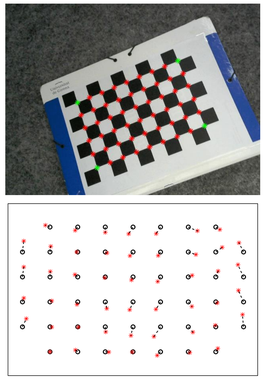
Synthetic Evaluation

Ground-truth: $f = 800, (u, v) = (320, 240), k_1 = 0.5, k_2 = 1$



Real-World Evaluation

Pose Estimation



	mean	std		mean	std
3-free	0.856	1.130	3-free + 4-wizard	0.862	1.155
20-free	0.802	1.115	3-free + 9-wizard	0.788	1.104
50-free	0.789	1.108	3-free + 12-wizard	**0.763**	**1.082**

Structure from Motion Test

VisualSfM [2]

	mean	std		mean	std
3-free	43.6	11.5	3-free + 2-wizard	17.4	10.8
7-free	30.5	11.7	3-free + 4-wizard	**14.4**	**9.1**
20-free	15.7	10.5			