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Towards the Intrinsic Self-Calibration of a Vehicle-Mounted Omni-Directional Radially Symmetric Camera

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(a) Tracked scene points (b) Original lens distortion (ground plane) (c) Self-calibrated lens distortion (d) Lens distortion of another camera

Motivation

- Intrinsic calibration: lens distortion function and focal length
- Crucial for the use of omni-directional cameras in ADAS
- Usual approach: present pattern of known dimensions from different angles to the camera and compute the necessary parameters
- Automation is possible, but requires special hardware and a setup of known patterns

Method

- Estimate *lens distortion* parameters during unknown purely translational motion up to a scalar
- Estimate the scalar during an arbitrary but known motion
- Using radial lens distortion model by Scaramuzza: the z-component of a pixel's view ray is modeled by a radial polynomial $f(r)$ of degree 4

Lens distortion

- Follow points of static objects during purely translational motion
- Triplets of points from one motion curve set up

$$0 = det(w_1, w_2, w_3) = \begin{vmatrix} u_1 & u_2 & u_3 \\ v_1 & v_2 & v_3 \\ f(r_1) & f(r_2) & f(r_3) \end{vmatrix}$$

- This means any three view rays lie on a common plane
- Selecting particular view rays from the curves can stabilize the solution
- A reweighing scheme handles noise

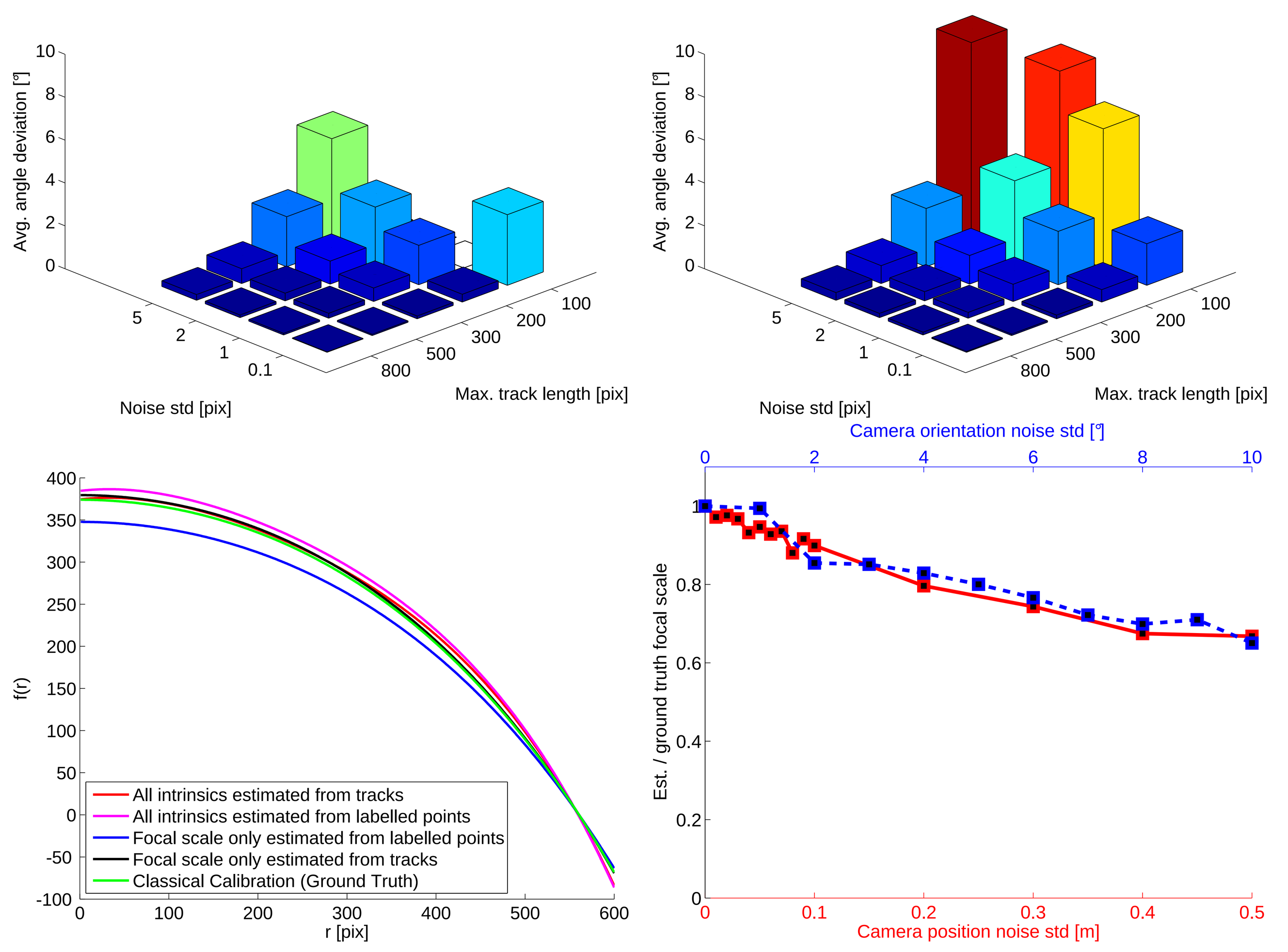
Resolving the focal ambiguity

- Epipolar constraint enforces camera centers from different time steps and a common scene point to lie on a plane
- Let R_i, t_i be camera orientations and positions, w_k view rays intersecting in the scene point
- This results in a set of quadratic equations

$$\begin{aligned} & 0 \\ =& det(R_k^T w_k, R_l^T w_l, t_k - t_l) \\ =& det(w_k^{uv}, R_k R_l^T w_l^{uv}, R_k(t_k - t_l)) \\ & + s \cdot det(w_k^f, R_k R_l^T w_l^{uv}, R_k(t_k - t_l)) \\ & + s \cdot det(w_k^{uv}, R_k R_l^T w_l^f, R_k(t_k - t_l)) \\ & + s^2 \cdot det(w_k^f, R_k R_l^T w_l^f, R_k(t_k - t_l)) \end{aligned}$$

Experiments

- Calibrate vehicle-mounted fisheye camera on a video sequence of 14s showing a drive-by on a parking deck
- Sequence consists of a curving maneuver (used for scale disambiguation) and a straight motion along a parking lot row (used for lens distortion determination)
- Compare manually labeled with automatically tracked points using NCC matching with templates of different scales and aspect ratios
- Motion must be known very accurately



Results

- Reweighing scheme can handle growing noise in pixel positioning
- Number and length of tracked curves is crucial
- Scalar disambiguation is very sensitive to noise

Scenario

- Initialize recently exchanged camera with default lens distortion
- Track and store passing scene points while using vehicle odometry and other positioning systems (SLAM) to measure displacement
- After gathering sufficiently many and long point tracks calibrate camera

Outlook

- Test method in different driving scenarios
- Examine SLAM aproach based on three fisheye cameras to calibrate a fourth

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