A Novel Hybrid Camera System with Depth and Fisheye Cameras

Motivation

Most consumer RGB-D cameras have a field of view (FoV) too small for certain applications. On the other hand, there are many cameras (such as fisheye cameras) which are able to capture color images with a large FoV, but lacking the 3D information.

New hybrid system with fisheye and depth cameras to overcome the limitations, having:

• Depth certainty and scale
• Wide field of view (>180 deg)

This system needs to be calibrated, but the methods from the literature cannot be used for such complex configuration. In this work, we present a new method for depth-fisheye calibration. Experiments show its accuracy with real images.

Camera models

• Scaramuzza’s model for the fisheye camera [1].
  • This makes our method valid for all types of perspective and omnidirectional cameras.

• Herrera’s model for the depth camera [2].
  • Includes radial and tangential distortion correction and calibrates the conversion to metric measurements.

Type of input images

• The calibration pattern must be visible in the fisheye image and its supporting surface in the depth image.
  • To calibrate the fisheye distortion the camera must be close to the pattern.
  • The depth camera is unable to retrieve depth information in close range.

Method outline: two alternatives

A. Joint calibration

1. Fisheye camera intrinsic calibration $\mathbf{A}, \mathbf{t}, \mathbf{g}(x_s, y_s)$
2. Depth camera intrinsic calibration $\mathbf{f}_d, \mathbf{x}_d, \mathbf{y}_d, \mathbf{u}_d, \mathbf{v}_d, \mathbf{k}_d$
3. Extrinsic calibration $\mathbf{T}_d$
4. Depth correction $\alpha_0, \alpha_1, \mathbf{D}, \delta_1, \mathbf{c}_1, \mathbf{c}_0$

B. Stepwise calibration

Computation of each stage

• Fisheye camera intrinsic calibration $A1$ $B1$
  • Solved using the method from [1]

• Depth camera intrinsic calibration $B2$
  • Standard camera calibration using IR images

• Extrinsic calibration $B3$
  • Average rotations and translations $\Rightarrow$ Minimize reprojection error
    
    $d\mathbf{R}_f = \mathbf{R}_f, d\mathbf{R}_d, d\mathbf{t}_f$

    $\mathbf{a} = \mathbf{a}_f, \mathbf{b} = \mathbf{a}_d, \mathbf{c} = \mathbf{b}_d$

    $\mathbf{d} = \mathbf{b}_f, \mathbf{e} = \mathbf{d}_d$

    $\mathbf{f} = \mathbf{d}_f, \mathbf{g} = \mathbf{d}_d$

• Global optimization and refinement $A2$ $B4$

$$J = \beta \frac{\sum \mathbf{R}_{f}^d}{\sigma_f^2} + \frac{\sum \mathbf{R}_{d}^d}{\sigma_d^2}$$

Experiments with real images

Calibration was performed and evaluated with two similar sets of images: Set A (25 images) and Set B (28 images). Mean reprojection error shown in the table.

Some examples of depth information mapped to the fisheye image:

Example of application

• We used this hybrid system to perform the extension of the depth information to the whole field of view of the fisheye in one single shot [3].
  • The estimation of the depth in the periphery is done via layout extraction, where the solutions have scale and can be merged with the initial depth information.
  • Some results with the final 3D reconstruction:

References


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