Standard methods and tools for camera calibration

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Camera calibration is the process of establishing intrinsic or extrinsic camera parameters. It is essential for any computer vision application that needs to measure distances or spatial relations. Some tools and methods that are used for camera calibration are mentioned below:

1. **Classical planar patterns(Checkerboard / Zhang's method)**

   This is one of the most popular and widely used methods that uses a printed checkerboard photographed from multiple viewpoints. Zhang's algorithm calculates intrinsic parameters like focal length, principal point, and distortion coefficients by recovering correspondences between known 3D pattern points and their image coordinates in 2D in a sequence of frames. This method is easy to set up and works well with monocular calibration. The accuracy and precision are good for rectilinear lenses, and OpenCV provides robust, well-documented routines and tutorials to perform the full pipeline; however, it is less robust under poor lighting and motion blur.

2. **Circle grids / asymmetric circles**

   Circle grids(symmetric or asymmetric) are an alternative planar target where circle centers are detected instead of chessboard corners. They can be easier to detect reliably under some conditions (eg: slight blur) and are supported by OpenCV and other toolkits. This technique is used when the corner detection performs poorly.

3. **Fiducial markers**

   Fiducial marker patterns like AprilTags or ArUco boards give robust, high-accuracy detection and automatic indexing of target points. They are preferred when we want fast detection with known IDs or need to calibrate the field with mobile phones or robotic platforms. While this method requires printing of many tags or a specialized target, it is used mostly in tracking systems.

4. Fisheye models

Wide-angle or fish-eye cameras have a usual field of view 120°–180°, produce extreme radial distortions, and standard pinhole calibration models cannot handle these accurately. To correct this, fish-eye specific models are required, such as the OpenCV fisheye module, which utilizes the Kannala–Brandt distortion model for extreme off-axis rays. Calibration is done using checkerboard or circle grid patterns, but it is important to capture images covering the edges and corners of the lens where distortion is strongest. More calibration images than for standard cameras are usually needed, and once calibrated, fisheye images can be rectified into perspective or panoramic images. This is critical in surveillance, robotics, and automotive system applications where wide coverage is needed without sacrificing accuracy.

5. Matlab

The Computer Vision Toolbox in MATLAB offers a user-friendly app for interactive camera calibration. It contains functions for fast, precise calibration, stereo support and is good for prototyping and offline calibration in constrained labs. It is often favored in academic and research settings for its ease of use and visual feedback.

6. Specialized software

Professional-grade applications that require high precision, dedicated photogrammetry software like Agisoft Metashape or RealityCapture can be used. These tools are unnecessarily powerful for a standard security camera system, but are a good reference point for the highest level of accuracy.

References

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