DOCTORAL THESIS

Camera Calibration from Conics

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Abstract

Accurate acquisition of camera parameters is an essential step in computer vision-based applications, such as image measurement, 3D reconstruction, multimodal computing, autonomous driving, robotic arm motion, etc. Whether calibration objects are used, camera calibration is generally divided into two categories: calibration objects based and auto-calibration, which have different application scenarios. For example, methods based on calibration objects can provide accurate geometric constraints, therefore, more accurate calibration results but limited application scenarios. In contrast, although the auto-calibration method can be applied to many scenarios, it can only calibrate some of the camera parameters or requires iterative optimization due to the inadequacy of constraints. Therefore, accurately recovering all of the camera parameters remains a challenging problem.

The paper first investigates new properties of spheres as calibration objects, common objects in daily life and whose 2D contours can be easily extracted in images. A new method is created for calculating camera intrinsic parameters from a single view by connecting the concept of camera calibration with orthogonal constraints to the constraints offered by pairs of observed circular points. With the line-structured laser light, the single view contains contours of two spheres and intersections of the laser light plane with two spheres. A simple algorithm is thus proposed to recover the camera intrinsic parameters, simultaneously removing the ambiguity of the camera's extrinsic parameters.

This thesis then studies auto-calibration properties under general and constrained motion and introduces novel camera auto-calibration algorithms for generating accurate camera intrinsic parameters from sequence images. Under general motion, exploiting the geometry decomposition of the fundamental matrix, a new fixed line is derived from the image of the absolute conic and the symmetric part of the fundamental matrix. Then, its properties are used for camera auto-calibration for the first time and get state-of-the-art results. In addition, inspired by this fixed line, considering the derivation between the camera center and rotation center of the Pan-Tilt-Zoom camera into the projection matrix, the camera motion can be regarded as circular motion. Then the camera intrinsic parameters can be calibrated more accurately than existing techniques.

Keywords: Camera Calibration, Contours, Fundamental Matrix, the Steiner Conic