UKRAINIAN CATHOLIC UNIVERSITY

MASTER THESIS

Corner localization and camera calibration from imaged lattices

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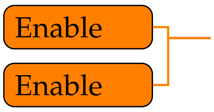
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Corner localization and camera calibration from imaged lattices

by Andrii STADNIK

Abstract

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Camera calibration is a crucial step in many computer vision applications. Typically, it involves taking a set of images of a calibration pattern, detecting its' features, and estimating the camera parameters. However, under certain conditions (including occlusions, bad lightning, highly distorted images etc.), feature detectors might fail to detect some of the features.. Do I have to justify it?

In this paper, we propose a novel approach to feature detection in the context of camera calibration. After the initial feature detection and calibration, we use the intermediate camera parameters to predict the possible positions of the previously undetected features. Those features are filtered using the binary classifier, and the remaining features are used to further constrain the camera calibration.

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Chapter 1

Introduction and motivation

1.1 Outline of the problem

Better camera calibration improves the performance of various downstream tasks by providing a more accurate mapping between 3D world coordinates and 2D image plane coordinates. This improved mapping enables precise alignment, positioning, and scaling of objects within the scene. By determining the camera's intrinsic and extrinsic parameters, algorithms can correct for lens distortion, estimate depth information, and accurately overlay virtual content. Consequently, tasks such as 3D reconstruction, augmented reality, and object detection can achieve better results in terms of precision, spatial consistency, and overall visual quality.

Although manufacturers can estimate camera calibration parameters a priori, fully automatic calibration is often preferred, especially when camera metadata is unavailable. Currently, wide-angle lenses, particularly in mobile phones and GoPro-type cameras, dominate consumer photography. These cameras pose additional challenges due to their requirement for highly non-linear models with numerous parameters. The high distortion of the image plane also makes finding key points robustly challenging.

Typically, camera calibration is obtained by capturing an image of a known calibration pattern, which is then used to estimate the camera parameters. Alternatively, some methods do not use a calibration pattern but instead infer geometric constraints directly from the scene. However, this approach is generally less accurate.

As reported by Duisterhof et al. (2022) on Oct. 5, 2022, the current state-of-the-art methods Olson, 2011 Schöps et al., 2020 Krogius, Haggenmiller, and Olson, 2019 fail on images with high distortion. Duisterhof et al. (2022) suggested an iterative the approach of image undistortion and target reprojection, achieving the superior robustness to the noise than the state-of-the-art methods because the feature detection is performed on the undistorted image.

Instead of searching for the features on the undistorted image from scratch, it is possible to utilize the prior knowledge of the geometry of the calibration board, effectively predicting the possible positions of previously undetected features. It can be done by projecting the board onto the image using the intermediate camera calibration, and then filtering the possible positions in order to eliminate false positives.

This additional points will further constrain the camera calibration, improving the accuracy of the calibration parameters.

Explain why more features is better

Missing figure

Show the example of the calibration board and the image

1.2 Thesis structure

This paper has the following structure: in **??**, we will describe the related work, including the literature search method and methodology, various subtopics of the camera calibration, mention conjugate translations, and outline the state-of-the-art solutions. We define the research gap in **??** and outline the proposed approach to solution and evaluation in **??**. We will describe the early results in **??**, including the dataset analysis, feature detector, and conjugately translated points simulator. In **??**, we will summarize the results and outline future work.

Update

Chapter 2

Related work

2.1 Camera calibration

Getting the correspondence between the spatial and the image coordinates requires camera calibration. Camera calibration consists of the geometric camera model and the parameters of this model. That information makes it possible to obtain the 2d image coordinates of any point in the 3d space.

Usually, the geometric camera model is obtained from the domain knowledge of the researcher or the camera manufacturer. Often, they choose the simplified model as a trade-off between accuracy and complexity. The model's parameters are usually obtained by solving the constrained optimization problem, given the set of points with known geometry.

2.2 Calibration boards

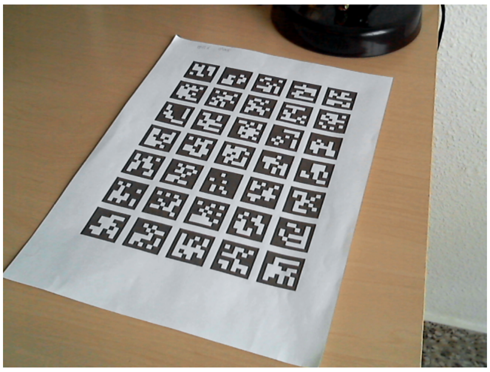
To achieve a robust calibration, images with repeating patterns are usually used. The camera calibration parameters can be found using prior knowledge of the properties of the pattern, such that the pattern invariants hold on the image. Initially, the chessboard (*OpenCV: Camera Calibration* 2023; V. Douskos, I. Kalisperakis, and G. Karras, 2007) patterns were used (Fig. 2.1a).

Later, ArUco Garrido-Jurado et al., 2014 allowed detecting the orientation of the pattern, as well as uniquely identifying each located pattern even under occlusion (Fig. 2.1b). Based on ArUco, ChArUcO *OpenCV: Camera Calibration* 2023 (Fig. 2.1c) and AprilTag Olson, 2011 (Fig. 2.1d) were proposed as more robust.

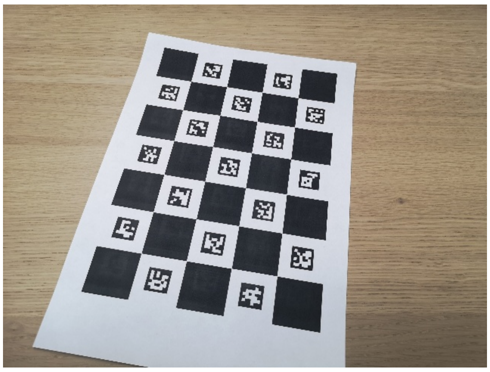
2.3 Camera models

The camera model's choice depends on the camera's physical properties and the accuracy required. Usually, the parametric models are simpler to use, as they have only a few parameters and deliver good accuracy. The most common are the Double Sphere model Usenko, Demmel, and Cremers, 2018, the Kannala-Brandt model Kannala and Brandt, 2006, and the Field-of-View model Devernay and Faugeras, 2001. In the ill-posed problem of camera calibration, the common choice of the camera model is the division model Fitzgibbon, 2001. However, Schöps et al. (2020) show that they tend to have significantly higher errors than the non-parametric (general) models. The Lochman et al. (2021) suggested a framework for converting the parameters of a powerful back-projection Zhang, 2000 model to recover different models' parameters.

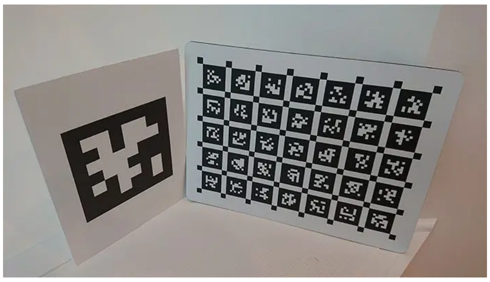
(A) Chessboard *OpenCV: Camera Calibration* 2023



(B) ArUco board *OpenCV: Detection of ArUco Markers* 2023



(C) Charuco board *OpenCV: Detection of ChArUco Boards* 2023



(D) AprilTag board Rosebrock, 2020 (right)

FIGURE 2.1: Calibration boards.

2.4 Camera parameters estimation

Camera calibration using repeating patterns was an important subject for a long time, for example, Schaffalitzky and Zisserman (1998) in 1998 and Zhang (2000).

Nevertheless, camera calibration is still an open problem; recently, multiple new approaches have arisen. Lochman et al. (2021) suggest a universal approach to camera calibration, with a separate step of converting between camera models. Hu et al. (2019) used deep learning to detect ChArUcO boards. Recently, on Oct. 5, 2022, Duisterhof et al. (2022) introduced the iterative approach to camera calibration, which outperforms the previous state-of-the-art approaches for wide-angle cameras.

Chapter 3

Background

Chapter 4

Approach

Chapter 5

Conclusions

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