Retrieval of the Calibration Matrix from the 3-D Projective Camera Model

Gamal H. Seedahmed* and Toni Schenk
Photogrammetry Group
Dept. of Civil and Environmental Engineering and Geodetic Science
The Ohio State University
2070 Neil Avenue, Columbus OH 43210-1275 USA
seedahmed.1@osu.edu
schenk.2@osu.edu

Abstract

By relating the projective camera model to the perspective one, the intrinsic camera parameters give rise to what is called the calibration matrix. This paper presents two new methods to retrieve the calibration matrix from the projective camera model. In both methods, a collective approach was adopted, using matrix representation. The calibration matrix was retrieved from a quadratic matrix term. The two methods were framed around a correct utilization of Cholesky factorization to decompose the quadratic matrix term. The first method used an iterative Cholesky factorization to retrieve the calibration matrix from the quadratic matrix term. The second method used Cholesky factorization to factor the quadratic matrix term but after its inversion. The basic argument behind the two methods is that: the direct use of Cholesky factorization does not reveal the correct decomposition due to the missing matrix structure in terms of lower-upper ordering. This study presents two new algorithms to rebuild the missing matrix structure. In both methods, a successful retrieval of the calibration matrix was achieved. This paper explains the key ideas behind the two methods, accommodated with a simulated example to demonstrate their validity.

1 Introduction

In this study the term calibration will be reserved for the intrinsic camera calibration. Calibration of cameras, analog and digital-alike, is a prerequisite task for the precise extraction of metric information from imagery in photogrammetry, computer vision, and other vision applications in which the precise quantitative measurements are needed.

Most current vision applications, employed commercial off-the-shelf (COTS) cameras that exhibit a considerable amount of distortions due to various reasons. The camera assembly is often misaligned, the CCD chip may not be orthogonal to the optical axis, the effective focal length may not be known, and the camera lens may exhibits a high radial distortions. The removal of these distortions constitutes the objectives of geometric camera calibration, see [1]. Generally, camera calibration is formulated under the perspective or the projective camera model. Under the perspective camera model, a full calibration model, which retains the geometric integrity of the extracted features, can be achieved at the cost of non-linear system of equations. On the other hand, a partial calibration model can be achieved under the projective camera model but with the main advantage of having a closed form solution.

By establishing the relationship between the projective and perspective camera models, the calibration parameters can be retrieved either collectively or term-wise. The collective retrieval gives rise to what is called the calibration matrix. On the contrary, there exist a term wise retrieval for the calibration matrix. In the term-wise retrieval, the projective camera parameters are written as a function of the perspective camera model, which give rise to a set of equations that have to be solved sequentially to recover the calibration parameters, see [2].

Cholesky factorization in its original format is suggested as a decomposition method to retrieve the calibration matrix from the projective camera model, see [3] and [4]. In the subsequent sections of this paper, it will be shown that this is not a general decomposition. It is interesting to mention that the 3-D projective camera model is interpreted as perspective transformation combined with a 2-D affine transformation, see [2]. The inner meaning of this interpretation is that the image coordinates do not necessary to be referenced to the principal point. In other words, we can choose any image coordinate system and still be able to retrieve the correct perspective camera model. Clearly, this is not the case when using Cholesky factorization in its original format. We showed in the sequel of this paper that Cholesky factorization is not a valid decomposition when the

* The author is also with The Pacific Northwest National Lab.
E-mail: Gamal.Seedahmed@pnl.gov