Three-dimensional structure calculation: achieving accuracy without calibration

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Abstract

This paper addresses the problem of computing the camera motion and the three-dimensional structure of a scene using two uncalibrated images as inputs. The camera motion is calculated by estimating the essential matrix and using approximate values, easily available, for the intrinsic parameters. The classical eight-point algorithm to calculate the essential matrix is known to be very sensitive to pixel-noise even when the intrinsic parameters are perfectly known. This paper shows that by using the normalized eight-point algorithm, aimed at calculating the fundamental matrix, the pixel-noise sensitivity is reduced significantly. More importantly, we show that the intrinsic parameters do not have to be accurately known in order to get very good quality reconstruction. In particular, we have investigated and compared the effect of errors on the intrinsic parameters together with pixel-noise on the calculated motion/structure, when using the straightforward eight-point algorithm and its normalized version respectively.

keywords: three-dimensional reconstruction, camera motion, essential matrix.

1 Introduction

Our surrounding environment is three-dimensional (3D) by nature. This 3D structure is very important and is often a prerequisite for other subsequent activities such as navigation, 3D modeling, surgery, etc. However, the most common way to capture this environment is through two-dimensional (2D) images. In computer vision, three-dimensional reconstruction of a scene is the process of recovering/computing the 3D coordinates (or depth) of the scene's points using 2D images as inputs.

Although the projective 3D structure of a scene can be recovered from point correspondences only [3] [13] [7], such a structure lacks metric information making its use limited. The Euclidean structure remains the most useful one in computer vision. The classical way for solving the Euclidean reconstruction problem requires the calibration of the cameras and the matching of the features in the different images. This approach is nonrealistic and it is not always possible. Hence, several researchers have developed methods for obtaining the Euclidean reconstruction without calibrating the camera. Most of these researchers have assumed less general camera models [11] [15] [16]. These methods have their limitations. In particular, they assume that the size of the scene is small compared to the scene-camera distance.

Another direction for solving the Euclidean reconstruction has focused on the self-calibration of the camera, where matched points in the images are used to estimate the intrinsic parameters [5]. Once the camera is calibrated, the problem of calculating the motion of the camera/scene and the Euclidean reconstruction of the observed scene becomes easier [12] and can be calculated by triangulation or by a least-squares algorithm.. However, the proposed self-calibration methods are nonlinear and do not yield accurate values for the intrinsic parameters.

This paper shows that the eight-point algorithm can be modified into a more stable and robust algorithm. As it was done for the calculation of the fundamental matrix[6], we applied the same type normalization and used the eight-point to calculate the essential matrix. In this method, we do not extract the essential matrix from the fundamental matrix which is not needed here. Instead, we use approximate values for the intrinsic paremeters, change pixel coordinates to the unit sphere coordinates, apply the normalization on these coordinates and, finally calculate the essential matrix using an SVD routine. Our main goal is to show that the intrinsic parameters need not to be precisely known in order to get an accurate three-dimensional Euclidean reconstruction.

As expected, this normalized eight-point algorithm has proven to be less sensitive to pixel noise. However, less expected, this algorithm has also proven to be less affected by