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GEOMETRIC AND COLORIMETRIC CALIBRATION FOR MULTIVIEW CAMERA ADJUSTMENTS

Daniel Kapusi[1], Philipp Prinke[1], Rainer Jahn[1], K.-H. Franke[1,2], Rico Nestler[1]

[1]Zentrum für Bild- und Signalverarbeitung e.V., [2]Ilmenau University of Technology

ABSTRACT

A mixed adjustment of monocular or stereo cameras is used to observe an areal of interest autonomously from different points of view and to extract location and movement parameters of interesting objects. To obtain a geometric relationship between the different imaging sensors, they have to be calibrated in a preferably simple calibration procedure. A plane chessboard target with integrated color markers acts as the calibration reference for gathering the intrinsic and extrinsic parameters from multiple cameras by means of subpixel accurate edge detection and the color transformation parameters at one go. The statistical uncertainty of the determined parameters decreases by extracting and collecting the features of interest from the chessboard at multiple target poses for each camera. Furthermore the resulting calibration parameters enable the correction of lens distortions, the rectification of stereo images and the color correction.

Index Terms – Camera calibration, color calibration, 3D scene modeling, multiple cameras

1. INTRODUCTION

In modern computer vision the sophisticated task of camerabased autonomous areal observation has a great application field, which is often subjected to very high safety requirements. So the data aquisition and interpretation at such security systems has to be failsafe. Therefore multiple points of view are used to increase redundance, to handle occlusions and to obtain additional 3D informations which leads added together to a robust and extensive scene modeling.
To fuse the image data from different points of view to a global representation of the scene it is assumed, that the geometrical relationship between the sensors is known. Additionally it is essential for tasks like object-classification and -tracking that the manner of perception is aligned between the sensors. That means that lens distortions and differences in color exposition have to be corrected.
The intrinsic and extrinsic camera parameters and the parameters for color balancing are gathered by means of a common calibration procedure.
The geometrical calibration methods are classificable into the 2d/3d reference object-based calibration, where the camera calibration is performed by observing a calibration target whos geometry is exactly known [1] [2], and into the Auto-calibration techniques, where the calibration parameters are estimated directly from uncalibrated images from different views [3] [4], which is a flexible but also very complex attempt that can not obtain reliable results in any case.
Bouguet [5] introduces a formalism based on a so called dual space which allows to decouple the intrinsic from the extrinsic camera parameters. Furthermore he picked up and continued the calibration approach of Zhang [6], who has proposed a flexible technique to easily calibrate a camera by using planar pattern at a few different orientations, and a similar method of Sturm and Maybank [7]. Bouguet publishes a Camera Calibration Toolbox for Matlab [8] on his webpage, which uses a plane chessboard target at multiple poses as the calibration reference. Bradski and Kaehler have been taken over and adapted the algorithms from the Bouguet Camera Calibration Toolbox for Matlab to the open source library OpenCV [9] [10], which have been used to implement the geometrical part of the multi camera calibration described in this article.
Furthermore algorithms from the ZBS e. V. CCal-ColorCalibration library [11] have been utilized for a contemporary color calibration to the end that also a unified color representation between the imaging sensors can be achieved.
The geometric and the colorimetric reference features are located at the same calibration target; so that the entire calibration can be performed simultaneously.

2. FEATURES OF THE CALIBRATION TARGET

The calibration target includes two types of calibration features.
On the one hand there are striking points in a regular grid needed for geometrical referencing, from which the chessboard position in relation to the camera position and the intrinsic camera parameters are calculable. The edges from the squares of a chessboard act as these points, how it is employed by Bouguet [8].
The number of the edges in the horizontal and the vertical direction have a different parity. So there exists only one symmetry axis, which allows determining the orientation of the chessboard clearly.

The edges are detected with sub pixel accuracy by means of a two-step iterative gradient based corner detection algorithm implemented in the OpenCV library [9]. In a first step the edges are detected roughly with pixel precision by a contour extraction around the black squares, which have been binarized with an adaptive threshold before. For the second step a mathematical fact is used, that the dot product between a vector and an orthogonal vector is zero. This relation is usable at corners, where a vector from a corner position **q** to a second position **p** along the edge of the chessboard square is always orthogonal to the gradient at **p** (Figure 1). Other positions away from the edge within a uniform region are not an issue, because their gradient is zero (Figure 2).

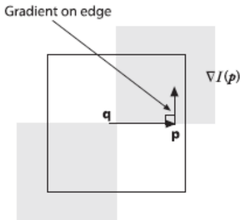

*Figure 1 gradient on **p** is orthogonal to vector **q-p** [9]*

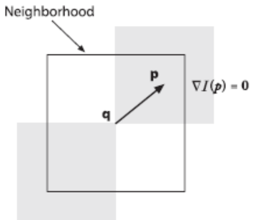

*Figure 2 gradient on **p** within a homogenous region is zero [9]*

A set of equations is optimized iteratively, so that the vectors outgoing from the real corner position **q**, which is aimed to be estimated with sub pixel accuracy, to the reference positions **p** within a windowed neighborhood dot-multiplied with the gradients at these **p** positions is zero.

On the other hand there is a set of circular color markers in each case placed at the center of a chessboard-square on the calibration target. They act as color references. The reference value of a color marker on the target usually differs from the nominal value, if the calibration target was simply printed out. In that case the approach of Nestler [12] is recommended to measure onetime the color at the markers and update the nominal values, as far as gathering the real color is important for the application. Normally it is sufficient for many application cases, e. g. object-matching and classification, to have the same color impression of an object from different views. So the color measuring and the update of the nominal color values can be neglected.
The circular color markers do not impair the edge detection algorithm described above while they are small enough that they are not protruded into the window around an edge for calculating its sub pixel accurate position. The center position of such a color marker is easily calculable from the four corner positions of the surrounded chessboard-square. Outgoing from the center of the color marker the whole colored circle is gathered by a simple segmentation algorithm, like region growing [12] with a single seed point. It is recommended to apply a 3x3 median filter before at the segmentations starting point to be more unaffected by single pixel deviations. Ideally the dark colors should be placed on the white squares and the bright colors on the black squares to facilitate the segmentation of the color markers. The selection of the target colors depends on the expected colors in the scene and has to be increased with the number of parameters, which are used by the color calibration method. The quality of the color calibration depends on the number of target colors and their distribution. To obtain a high qualitative calibration the color target should be distributed uniformly and densely in the color space. Sparsely occupied regions cannot constrain the transformation rule, which leads to high transformation errors especially if the calibration method uses many degrees of freedom.
In Figure 3 a chessboard target with the colors from the "Macbeth"-ColorChecker-Chart proposed by McCamy [14] [15] is shown. The colors from this frequently used chart exhibit a good distribution in the color space and are suitable for the most common scenes. The chart provides good results for calibration methods which have sparse degrees of freedom.

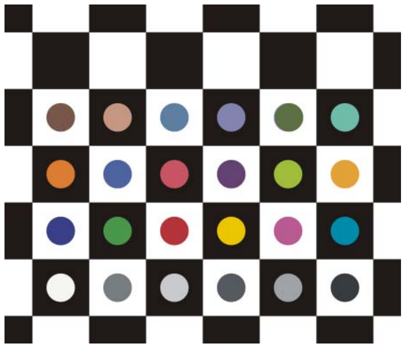

Figure 3 chessboard calibration target with integrated color markers

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