Camera calibration using composed cubic splines

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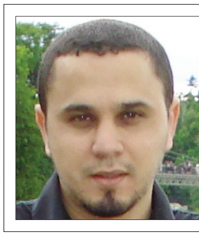
Camera calibration is a process whereby the geometric characteristics of a specific camera are determined. It is performed so that the photograph obtained can be used to produce accurate measurements. This paper presents a simple and accurate model for extracting the optical characteristics (intrinsic parameters) as well as the 3D position and orientation of the camera (extrinsic parameters) based on image coordinate measurements for targets of known 3-D position. The proposed algorithm is divided into two major steps. First, the behaviour of a grid of projected lines is studied and the required local corrections are applied. Such corrections are calculated using Composed Cubic Splines. This function covers radial, decentering and prism distortions. It provides a more realistic model of distortion which is represented as a composed surface. Then, calibration parameters are estimated using a pinhole model based on the minimization of a linear criterion relating the 3D coordinates of the targets with their 2D image projections.

L'étalonnage d'une caméra est un procédé par lequel les caractéristiques géométriques d'un appareil particulier sont établies. Ceci se fait de façon à ce que la photographie obtenue puisse servir à fournir des mesures précises. Cet article présente un modèle simple et exact d'extraction des caractéristiques optiques (paramètres intrinsèques) ainsi que la position et l'orientation 3D de la caméra (paramètres extrinsèques) selon les mesures de coordonnées-image pour les cibles de position 3D connue. L'algorithme proposé se divise en deux étapes importantes. D'abord, le comportement d'une grille de lignes projetées est étudié et les corrections locales requises sont apportées. De telles corrections sont calculées au moyen de splines cubiques composés. Cette fonction couvre les distorsions radiales, de décentration et de prisme. Elle offre un modèle de distorsion plus réaliste, qui se présente comme une surface composée. Ensuite, les paramètres de calibration sont estimés au moyen d'un modèle sténopé qui repose sur la minimisation d'un critère linéaire reliant les coordonnées en 3D des cibles avec leurs projections en images 2D.



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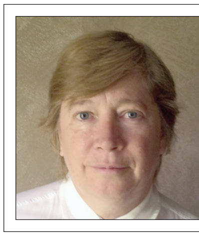

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1. Introduction

Camera calibration is particularly crucial in applications such as the construction of 3D models and the dimensional measurements of a given object. Accurate calibration is necessary in computer vision and photogrammetry.

Generally, the calibration of a camera is the determination of the relationship between 2D pixel coordinates and 3D object coordinates. It fixes the parameters, describing the projection of a three-dimensional scene onto a two-dimensional surface. These parameters describe the internal characteristics of a camera (focal length, pixel size, distortion coefficients and pixel coordinates of principal point) and external parameters (position and orientation of the camera frame relative to a given object coordinate system).

Existing camera calibration techniques can be classified into three methods [*Cramer* 2004]. The first method is laboratory calibration; used to verify the validity of camera parameters and it is repeated within certain time intervals. A second method, called on-site calibration, is performed by using targets positioned beside the object of interest. Camera calibration parameters and object space position are estimated simultaneously. A third method, called auto-calibration, does not use any calibration object. The internal and external parameters are estimated by using image information only [*Zhang et al.* 2008; *Ha and Kang* 2005].

Several techniques are based on image observation of points of known 3-D coordinates [*Ramalingam et al.* 2006] or shape like circles [*Mateos* 2000] and ellipses [*Zhang et al*. 2005]. They involve determining the mathematical model expressed in a perspective transformation matrix. Different techniques exist for the computation of that matrix and may be classified into two categories: linear techniques which use the minimization of a linear criterion relating 3D points coordinates and their 2D image projections [*Tsaï* 1987]; and non-linear optimization techniques which