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Chapter III

Camera Calibration for 3D Reconstruction and View Transformation

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Abstract

This chapter presents an extensive overview of passive camera calibration techniques. Starting with a detailed introduction and mathematical description of the imaging process of an off-the-shelf camera, it reviews all existing passive calibration approaches with increasing complexity. All algorithms are presented in detail so that they are directly applicable. For completeness, a brief counting about the self-calibration is also provided. In addition, two typical applications are given of passive camera calibration methods for specific problems of face model reconstruction and telepresence and experimentally evaluated. It is expected that this chapter can serve as a standard reference. Researchers in various fields in which passive camera calibration is actively or potentially of interest can use this chapter to identify the appropriate techniques suitable for their applications.

Camera calibration is the process of determining the internal physical characteristics of a camera and its 3-D position and orientation with respect to a world coordinate system using some predefined objects or automatically detected features. The result of camera calibration is the establishment of a mathematical relationship between the 3-D coordinates of a point in the 3-D scene and the 2-D coordinates of its projection onto the image recorded by the camera.

Camera calibration is an important preliminary step towards many vision-related applications. Passive calibration, active calibration, and self-calibration are the most frequently referred to camera calibration algorithm categories. Active calibration methods were developed mainly for robotic systems. Recently, algorithms for active calibration purposes have been investigated that fall in the more general self-calibration category (Lamiroy, Puget & Ho-raud, 2000). While detailed discussions about self-calibration are given in Faugeras & Luong (2001), Hartley & Zisserman (2000) and Fusiello (2000), this paper intends to give an overview of passive calibration. However, for completeness, a brief counting about the self-calibration will also be presented.

Passive calibration has been used extensively in the synthesis and analysis of the human body for telepresence (Xu, Lei, & Hendriks, 2002) and in 3-D face modeling (Liu, Zhang, Jacobs, & Cohen, 2001). However, despite its wide range of applications and extensive investigations, no comprehensive overview of this topic exists. This chapter attempts to fill this gap by providing such an overview in a systematic and unified manner and by comparing and evaluating existing approaches. In addition, two typical applications are given of passive camera calibration methods for specific problems of face model reconstruction and telepresence and then experimentally evaluated. It is expected that this chapter can serve as a standard reference. Researchers in various fields in which passive camera calibration is actively or potentially of interest can use this chapter to identify the appropriate techniques suitable for their applications.

The chapter is organized as follows. In the next section, a detailed introduction and mathematical description is provided of the imaging process of an off-the-shelf camera. In the next section, all existing camera calibration techniques are classified based on several different points of view. The nonlinear component of the camera, responsible for distortion, is then modeled using two alternative methods and discussed in a following section. Key passive camera calibration algorithms are reviewed in detail, followed by a brief overview of self-calibration algorithms. Finally, two applications for which calibrated cameras are required are analyzed, and a summary and conclusions are presented.