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Camera calibration: What is important and what is important for underwater imagery

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Camera calibration is an essential part of image processing pipeline resulting with a 3D scene reconstruction. Traditionally, this term encompasses determination of properties of individual cameras (intrinsic parameters) and calculation of mutual poses of cameras (extrinsic parameters). Processing of underwater imagery adds another layer of complexity related to waterproof housings that enclose cameras, with transparent windows refraction index of which is different from that of air and water. Thus, light rays reflecting from an imaged object bend two times before arriving at a sensor–at water/window and window/air interfaces. For commonly used flat or dome-shaped windows, accounting for refraction adds three more calibration parameters. Until recently, many researchers were attempting to describe refractive distortion in terms of radial lens distortion, but this approach was proven to be not viable, as in presence of refraction camera becomes varifocal. Any quantitative result obtained from image processing requires knowledge of uncertainty related to calibration accuracy. We assume that resources available to researchers–measured in monetary and time units–are limited, and thus the guidance how to achieve maximal accuracy with minimal cost is important. This paper presents a comprehensive investigation of factors affecting the accurate determination of all calibration parameters. These factors include pixelation noise, shape, and pattern drawn on a calibration object, the necessary number of acquired images, the structure of a multi-camera rig, etc. For underwater cameras, with refractive interfaces, we propose a novel technique for determination of refraction-related parameters. This technique is fast and reliable, as it requires the only optimization in one dimension for flat interfaces. Experimental results demonstrate a good correlation between calculated parameters and the parameters that were possible to measure manually. Accurate knowledge of refractive calibration parameters allow for incorporation of refraction effects in a 3D scene reconstruction workflow and dramatically improves reconstruction results.

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