Simultaneous Computation of Defocus Blur and Apparent Shifts in Spatial Domain

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Abstract

This paper presents an algorithm for a cooperative and simultaneous estimation of depth cues: defocus blur and spatial shifts (stereo disparities, 2D motion, and/or zooming disparities). These cues are estimated from two images of the same scene acquired by a camera evolving in time and/or space and for which the intrinsic parameters are known. This algorithm is based on generalized moment expansion. We show that the more blurred image may be expressed as a function of the partial derivatives of the two images, the blur difference and the horizontal and vertical shifts. Hence, these depth cues can be computed by resolving a system of equations. The proposed algorithm is tested using synthetic and real images. The results are dense and accurate. They confirm that defocus blur and spatial shifts can be simultaneously computed at a single scale.

1 Introduction

In computer vision, the three-dimensional perception of a real scene allows us to understand the 3D relationship of objects in world space. 3D perception is generally related to the computation of depth information which involves the extraction of relevant image features (*depth cues*) such as shadows, motion, blur, disparity, etc. Most existing techniques compute depth cues independently and usually rely on simplistic assumptions. For example, one of the most common hypothesis for spatial shift estimation is the brightness constancy assumption [1, 2, 3]. Concerning defocus blur estimation, most existing approaches assume that spatial shifts between a pair of images of the same scene are negligible [4, 5, 6]. However, all of these implicit assumptions imply a perfect control of both the environment and the acquisition system, which is usually difficult and even insufficient in many practical cases [7, 8, 9].

Inspired by the 3D perception system of human being, many searchers suggest that the use of only one depth cue is insufficient and that it is essential to consider complementary sources of information [10, 11, 12]. They affirm that the limitations associated to the use of a single depth cue can be overcome by taking into account complementary information obtained from additional cues. In this line of thoughts, we are interested in simultaneous and cooperative estimation of blur differences (depth from defocus) and spatial shifts (stereo disparities, 2D motion, and/or zooming disparities). Let us consider $I(x(t_i,p_i), y(t_i,p_i), t_i, p_i, \gamma_i)$, $i = 1, 2$, a pair of images of a real scene obtained by a camera evolving in time (t) and space and for which the values of the extrinsic (p: position and orientation) and intrinsic parameters (γ: aperture, focal length, lens radius, etc.) are known. In order to simplify notation let us replace $x(t_i,p_i)$ with x_i and $y(t_i,p_i)$ with y_i in what follows. We propose to use general and flexible constraint given by:

$$I(x_2, y_2, t_2, p_2, \gamma_2) = I(x_1, y_1, t_1, p_1, \gamma_1) * g_\beta(x, y), \quad (1)$$

where $*$ is the convolution operator, g_β the PSF and β the blur parameter. Based on this relation, we derive an unified approach for the estimation of spatial shifts (stereo disparities, 2D motion, and/or zooming disparities) and defocus blur which considers their mutual interdependence. Using generalized moment expansion and assuming perspective projection, passive image formation system, PSF Gaussian and blur locally constant, we will show that the more blurred image may be expressed as a function of its partial derivatives, the partial derivatives of the other image, the blur difference (β) and the horizontal and vertical shifts δ_x and δ_y. Hence, β, δ_x, and δ_y can be computed by resolving a system of equations. All computations required by our algorithm are local and are carried out in the spatial domain. Our algorithm yields a dense estimation of the previously mentioned depth cues. A major interest of such a model is thus to simultaneously take different depth cues into account in order to potentially reduce estimation errors related to simplistic models.

In the next section, we will first summarize related work. In section 3, we will derive a system of equations for simultaneous estimation of defocus blur and spatial shifts. The resulting algorithm is described in section 4. Section 5 presents the experimental results.