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Shape from Sharp and Motion-Blurred Image Pair

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Abstract Motion blur due to camera shake is a common occurrence. During image capture, the apparent motion of a scene point in the image plane varies according to both camera motion and scene structure. Our objective is to infer the camera motion and the depth map of static scenes using motion blur as a cue. To this end, we use an unblurred–blurred image pair. Initially, we develop a technique to estimate the transformation spread function (TSF) which symbolizes the camera shake. This technique uses blur kernels estimated at different points across the image. Based on the estimated TSF, we recover the complete depth map of the scene within a regularization framework.

Keywords Motion blur · Blur kernel · Transformation spread function · Belief propagation · Depth map

1 Introduction

Motion blur has long been an important topic in the image processing literature. During image capture, due to the effect of averaging of light intensities at the camera sensors, the relative motion between the scene and the camera results in motion blur. With the increase in the usage of handheld cameras, the study of motion blur is receiving considerable attention. Although the main objective has been to remedy the effect of blur, works also exist that focus on inferring valuable information about the object or camera motion by using blur as a cue (Boracchi 2009; Caglioti and Giusti 2008; Dai and Wu 2008; Klein and Drummond 2005; Sellent et al. 2011). In this paper, our objective is to use motion blur induced by camera motion for recovering the depth map of static scenes. Depth from motion blur can serve as an alternative to depth from defocus (DFD) (Chaudhuri and Rajagopalan 1999) (a popular approach for structure estimation). DFD techniques generally do not allow for any camera motion. In contrast, depth from motion blur will be useful for autonomous vehicle navigation, and for enabling 3D awareness in handheld imaging devices wherein camera motion inevitably results in motion blur.

In a 3D scene, when a camera moves, the apparent motion of the scene points in the image plane depends on the value of depth. Hence, motion blur can serve as a cue for scene depth (Fox 1988). The blur at an image point is characterized by a blur kernel also known as the point spread function (PSF). For the case of pure in-plane camera translations, the shape of the PSF reflects the camera motion. In fact, the shape of the PSF is preserved at all the image points except for a scale factor which is related to the scene depth (Sorel and Flusser 2008). Points that are near to the camera are more blurred than those that are farther. Based on the extent of blurring at a point, the depth values can be estimated (Sorel and Flusser 2008; Paramanand and Rajagopalan 2010a, 2012). However, when the camera is free to undergo rotations or axial motion, the shape of the blur kernel varies across different image points. Depth estimation in such a scenario is quite a challenging task as compared to the case wherein camera motion is restricted to in-plane translations.

Our work in this paper focuses on estimating depth from a pair of images in which one of the observations is a blurred version of the other due to camera shake. For depth recovery, presence of translational component in the camera motion is a must. When the depth of the scene is constant, instead of relat-

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