Title:	Defocus Map Estimation and PSF Characterization
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Abstract:

Depth map is an integral part of various applications such as 2D-to-3D conversion, vision based navigation, image refocusing, dehazing etc. Defocus is one of the main cue for depth estimation due to its natural presence and does not require any special condition unlike other cues e.g. relative size, texture gradient, perspective etc. However, problems such as focal plane ambiguity, holes, presence of motion blur and false depth edges affect the quality of defocus map adversely. In this thesis, we have addressed some of these problems to obtain more accurate defocus maps. We introduce a novel concept of Blur Parameter Locus Curve (BPLC) that relates underlying Point Spread function (PSF) to observed blur. We have derived the analytical relations for effect of image scaling on blur and BPLC. Using these BPLC/scaling constraint, we introduce the notion of reliability for blur estimation which discards the erroneously estimated blur values and results in more accurate defocus maps. This lays the framework for combining and comparing various defocus estimation techniques. We further present applications of BPLC in PSF characterization and decomposition. We demonstrate applications of such a decomposition and BPLC in the proposed novel spectrum based image compression and Blind Deconvolution. In proposed spectrum based image compression method, we choose the blurring PSF based on orientation of image spectrum and compress the blurred image with standard JPEG compression. Results show that the proposed method obtains 25-30% more compression over the standard JPEG compression. The proposed Blind Deconvolution method produces result comparable to state of the art methods in significantly less amount of time. The presence of motion blur is another main source of error in defocus map estimation. We have developed a robust method to estimate the linear motion blur by proving the completeness of the motion blur kernel with respect to Gaussian functions. We derive the closed-form expression for blur variation with direction in simultaneous presence of defocus and motion blurs and propose a strategy to decompose the two. We demonstrate that the proposed method can be used to estimate the spatially varying linear motion and defocus blurs for the case when both are simultaneously present in a single image. We have also developed a framework for combining defocus and motion cues for generating depth map for video. Unlike state of the art methods, proposed method accounts for simultaneous presence of both camera and object motion. Proposed method combines defocus and motion cues to generate the depth map using camera parameters. This also corrects the estimation errors in defocus and motion cues. Presence of holes is another main source of errors in the defocus map. We propose Color Uniformity Principle (CUP) for correcting the hole regions in defocus map and also use it for dehazing. CUP is asymptotic behavior of texture with depth. Texture at far depth becomes smooth due to space quantization and large defocus at camera plane.

We refer to this as CUP and use it to detect holes in defocus map. Our Proposed method minimizes both false and miss detection of holes unlike other state of the art methods. We also present application of CUP for realtime Haze/Fog removal. Proposed method produces good quality dehazed output in realtime unlike the state of the art methods. Finally, we resolve the focal plane ambiguity with the help of chromatic aberration. Focal Plane Ambiguity is another fundamental limitation of depth from defocus methods. A given amount of defocus corresponds to two different positions in world coordinate which cannot be distinguished. However, chromatic aberration induces different orderings of defocus blur amounts in R, G and B planes for two positions. We use this information to resolve this ambiguity and obtain more accurate defocus map.

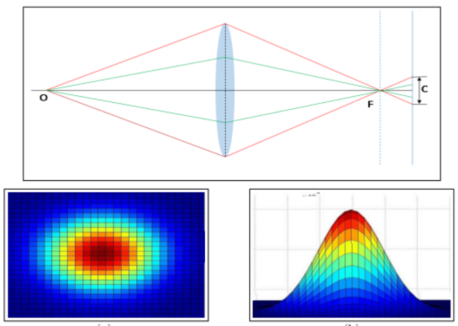

FIGURE 1.2: Defocus Blur Circle, (a) Transverse and (b) Lateral view of blur circle

FIGURE 1.3: Colormap for Defocus Map, PSF and Spectrum Representation

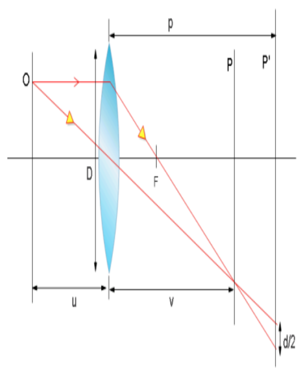

FIGURE 1.4: Relation between Blur Parameter and Camera Parameters

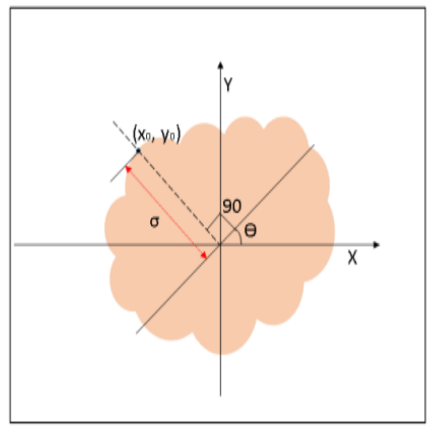

FIGURE 3.4: Blur Computation after Image Resizing using BPLC

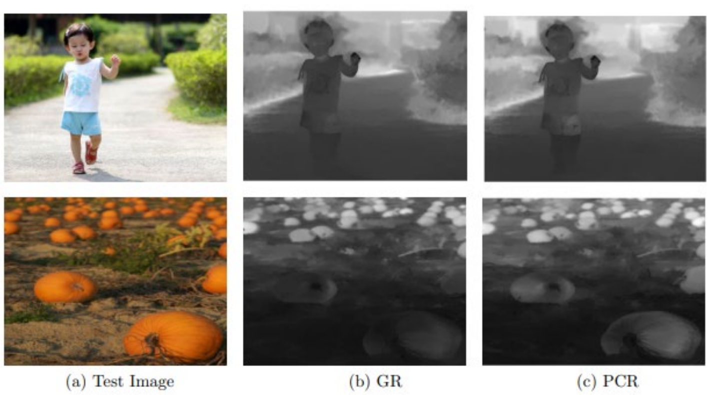

FIGURE 1.6: Full Defocus Map Creation using GR and PCR, Brighter region represents higher depth

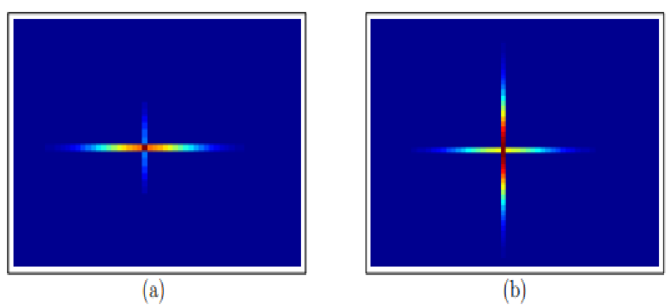

FIGURE 3.1: Blur Kernel Example for (a) Anisotropic-Isometric and (b) Isotropic-Anisometric Cases; Example demonstrates Isometry and Isotropy with respect to horizontal and vertical directions

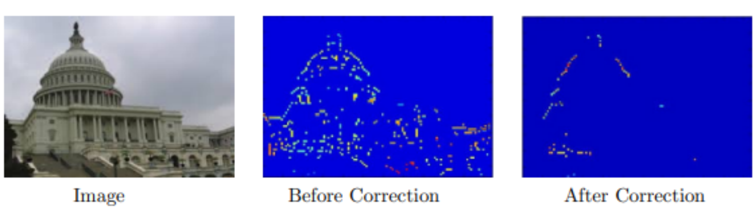

FIGURE 4.2: Sparse defocus map of 'Capitol Hill' image for before and after correction

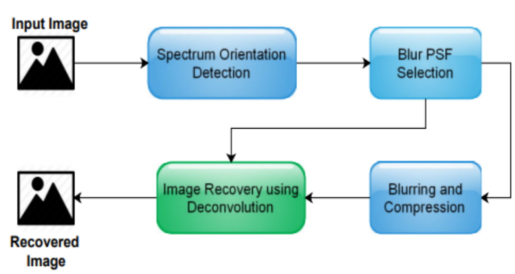

FIGURE 4.10: Flow Diagram for Proposed Spectrum based Image Compression Method [84]