

Abstract

Shape-from-focus (SFF) is a traditional technique in computer vision to estimate shape of 3D object from space-variantly blurred images by measuring degree of focus using focus measure (FM) operator. Since the estimation of 3D shape from images is typically an ill-posed inverse problem and hence, prior information is required to regularize the solution. In this thesis, the capability of SFF technique is extended by investigating low rank and sparsity priors for regularization with appropriate objective functions to address some weaknesses of this method.

Initially, it is assumed that the all-in-focus image of the 3D specimen is available and the 3D structure is estimated using space-variantly blurred observations from the captured. Recently, weighted nuclear norm (WNN) prior has shown the ability to preserve large-scale sharp discontinuities and small-scale fine details more effectively. Hence, in chapter 2, WNN prior is used as a regularizer to recover the 3D shape by utilizing a suitable cost function. Later, the estimated shape profile is post-processed to compensate for the loss of shape information at specular reflection regions in the observations.

Existing state-of-the-art SFF techniques require large number of images in the focal stack to reconstruct the all-in-focus image and 3D structure. If the availability of images in the captured focal stack is insufficient then the estimated focused image will not be accurate which leads to an erroneous estimate of the shape. Therefore, we propose an alternating minimization algorithm in chapter 3 of this thesis with suitable objective function to estimate both shape and the all-in-focus image of 3D object simultaneously by exploiting sparsity promoting total variation (TV) prior as a regularizer. Even though the sparsity prior preserves sharp edges more precisely, it fails to preserve the contrast and can result in over-smoothing of fine details. Hence, we propose another objective function in chapter 4 of the thesis which combines both low rank and sparsity promoting total variation (TV) priors to estimate the shape and the focused image simultaneously. To optimize this proposed objective function, we exploit alternating direction method of multipliers (ADMM) framework.

In the next part of the thesis we address the problem of shape estimation in the presence of parallax effect. When a stack of images is captured using a hand-held camera with relative motion between the camera and the 3D object, there exists an appreciable migration of pixel

location in the observations due to motion parallax. In this scenario, the parallax effect must be taken into account, otherwise SFF technique will yield an erroneous estimate of the shape profile. Also, since the position of every pixel changes among the observations due to parallax which dependent upon the unknown structure of the 3D object, constructing a perfect all-in-focus image is impossible. In order to address this challenge, we propose an optimization framework by formulating an appropriate objective function to tackle depth-dependent pixel motion due to parallax in SFF. Since defocus blur and pixel motion are tightly coupled to the underlying shape profile, simultaneous estimation of the focused image and the structure is a severely ill-posed problem. Hence, in chapter 5, we use non-local total variation (NLTV) prior to regularize the solution and utilize split Bregman framework for optimization. In chapter 6 of the thesis, we exploit the above parallax effect in SFF and propose an algorithm to reconstruct high-resolution shape and super-resolved focus image jointly from the stack of space-variantly blurred, low-resolution images which are affected by structure dependent pixel migration.

In chapter 7 which contains the last work in this thesis, we address the problem of estimating the shape from the stack of images captured under low-light scenario. When the focal stack in SFF is captured under low-illumination condition, the images suffer from Poisson noise. Therefore, we propose a two stage approach to reconstruct the 3D shape and the focused image. We first propose to use an efficient Poisson denoising algorithm followed by the joint estimation of shape and the focused image by optimizing a cost function utilizing low rank and sparse priors.

Finally, we provide a few potential future directions to explore beyond this thesis and conclude with an overall summary and discussion.

Keywords: Shape-from-focus, parallax, focus measure, sparsity, non-local, total variation (TV), low rank, weighted nuclear norm (WNN), proximal gradient, split-Bregman, augmented Lagrangian multipliers (ALM), alternating direction method of multipliers (ADMM), low-light.