Image restoration by total variation based methods applied on images from extended depth-of-field microscopy

Frank Haußer and Ingeborg E. Beckers

Beuth University of Applied Sciences Berlin, Luxemburger Str. 10, 13353 Berlin

Imaging of dynamic cellular processes is a challenging problem but necessary for e.g. investigation of drug delivery. A simple method for the detection of whole cell volumes in real time preforming high lateral resolution of a few 100 nm and without limited depth-of-field (DOF) due to axial resolution is ‘Extended depth-of-field’ microscopy (EDF microscopy) [1]. In principle a programmable space light modulator (SLM) is incorporated in the light path between microscope and camera. A phase function applied to the SLM modulates the wavefront of light and hence the focal ellipsoid is smeared out. The phase mask function has been optimized in a previous study. Image restoration by deconvolution using the known point-spread-function (PSF) of the optical system is necessary to achieve sharp microscopic images of an extended depth-of-field.

This work focuses on the investigation of deconvolution algorithms to solve this restoration problem satisfactorily. Two dominant problems are challenging during image restoration. First, since information is detected within an extended depth-of-field, stray light is likewise detected within this range. For fluorescence this contribution can be assumed to be Poisson distributed. Additional noise from the detection system, which can be presumed as Gaussian noise leads to further corruption of the image. Furthermore the PSF used for deconvolution fits in just one plane within the object exactly.

Deconvolution of images is known to be an ill-posed inverse problem, which cannot be solved directly by inversion. Rather small deviations of the input image would lead to some completely corrupted restored image. Thus, in the case of considerable noise and inexactness of the convolution kernel, advanced regularization techniques are needed to solve this inverse problem properly. In recent years nonlinear regularization methods based on total variation [2] have proven to be very effective in several applications. The scope of this work is the optimization of TV-based image restoration techniques depending on the predominant noise type. The algorithms are evaluated for 3D Helix structure images convolved by a phase mask function based on the combination of Zernike polynomials and noise is added. The different image restoration algorithms are compared. Finally, results are presented for the restoration of fluorescent cell samples and bright field microscopic images. The combination with a stereoscopic imaging setup additionally resolves the axial component of the 3D object [3].