CALCULATING POINT SPREAD FUNCTIONS – METHODS, PITFALLS AND SOLUTIONS

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The knowledge of the exact structure of the Point Spread Function (PSF) for a given optical system is of a great interest in fluorescence microscopy to improve the image resolution. Nevertheless, the exact structure of the PSF is generally unknown and particularly difficult to construct due to the ever-present optical aberrations in real systems [1]. Moreover, the vector feature of a PSF is important to consider for a correct prediction of intensity-based measurements. This includes the polarization state and the direction of the energy flow in the image plane [2]. The scalar model is common as it is fairly easy to implement but limited whereas the vectorial model is computationally more expensive but more accurate, especially for high numerical apertures [3]. Therefore, we here present three different Fourier based techniques for calculating a vectorial PSF. The fast Fourier-transformation (FFT) is a very handy tool to speed up PSF calculations, but its pitfalls have to carefully be avoided [4]. The first method is named after "slice propagation". It uses the angular spectrum method to propagate the wave slice by slice in free space. The second technique is a Fourier shell interpolation. It consists of interpolating the 2D-pupil amplitude distribution onto a 3D k-sphere volume using a kernel determined by an iterative Fourier-transformation algorithm. The last method is called "SincR" which consists of representing the k-sphere directly using a sinc function in real space. These methods are compared in terms of accuracy, quality and computation time. The Richards and Wolf (RW) model is chosen as a ground truth for comparison due to its ability to represent an ideal field with a very high accuracy [2]. Whereas this last one is the most accurate model, its implementation leads to an under-sampling problem close to the focus. The slice propagation method, which makes use of a chirp Z transform instead of the standard FFT, tends to be the best technique but is a bit more expensive in time than the SincR and the Fourier shell interpolation methods.

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