Introduction to MFM

Multi-focus microscopy (MFM) is a microscopy that captures multiple focal planes with a single shot [1]. A diffractive grating splits the light from different focal depth to form an array of $K \times K$ image tiles on a camera. It is able to capture dynamic scenes in biological samples, such as movement of a cell or a molecule.

Single-Frame (SF) MFM Reconstruction

Xiang et al. presented a 3D image reconstruction algorithm from MFM images [2]. The forward model of MFM can be represented as a linear model assuming Gaussian noise as

and we formulate a TV-regularized least squares to reconstruct a 3D image as follows:

$$\hat{f} = \arg \min_{f \geq 0} \| g - Hf \|^2 + \lambda \Phi(f)$$

where $\Phi(f) = \sum_{i} \sqrt{(\Delta x_i f)^2 + (\Delta y_i f)^2 + (\Delta z_i f)^2}$

Multiple-Frame (MF) MFM Reconstruction

Given a sequence of MFM images, we can utilize multiple MFM images to achieve a higher quality 3D image reconstruction. The forward model of MFM in a dynamic scene is represented as

$$g_k = Hf_k + \epsilon_k$$

and it can be extended as

$$g_k = HM_{l,k}(\alpha_{l,k}) f_l + \epsilon_{l,k}$$

where $\alpha_{l,k}$ is a set of motion parameters and $M_{l,k}$ is the corresponding warping matrix.

We propose two MF MFM reconstruction algorithms:

1. **Batch approach**

$$\hat{f}, \hat{\alpha}_{l,k} = \arg \min_{f \geq 0, \alpha_{l,k}} \sum_{k=1}^{m} \| g_k - HM_{l,k}(\alpha_{l,k}) f_l \|^2 + \lambda \Phi(f_l)$$

2. **Recursive approach**

$$\hat{f}_{l,k}, \hat{\alpha}_{l,k-1,k} = \arg \min_{f_{l,k}, \alpha_{l,k-1,k}} \| g_k - Hf_{l,k} \|^2 + \lambda \Phi(f_{l,k})$$

$$+ \eta \| f_{l,k} - M_{l,k-1,k}(\alpha_{l,k-1,k}) f_{l,k-1} \|^2$$

Experimental Results

References
