Higher-order Total Variation Reconstruction for Structured Illumination Microscopy (SIM)

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Abstract

Structured illumination microscopy (SIM) is an effective and widely used method for producing high-resolution fluorescence micrographs. This imaging technique successively overcomes the diffraction limit and reaches up to twice the lateral resolution of conventional wide-field microscopy [1]. In SIM, the sample is imaged with varying configurations of an illumination pattern and a high-resolution image is reconstructed from the collected data (i.e. multiple low-resolution images). The quality of the reconstructed image depends strongly on the type of reconstruction method used. The classical Gustafsson-Heitzmann reconstruction method relies on a sequence of demodulation and recombination of the measurements, followed by some Wiener filtering [1]. This direct method typically does not include prior information about the image. Other recent approaches based on an variational formulation of the reconstruction have shown promising results for SIM [2,3].

By taking advantages of recent advances in mathematical imaging and sparse signal recovery [4,5], we have designed a fast iterative algorithm that imposes sparsity constraints on the Hessian of the image. By penalizing higher-order derivatives, Hessian-Schatten (HS) regularization favors piece-wise linear solutions which do not harbor block artifacts [5]. The non-linear optimization is performed iteratively via the alternative direction of multipliers method (ADMM), which decomposes the initial task into two basic optimization sub-problems.

By applying the proposed framework, we are able to outperform the current linear reconstruction methods (multichannel Wiener filter) (**Figure 1**), while avoiding the staircase artifacts of total variation regularization (**Figure 2**). As a result, thin filament-like cell structures can be distinguished more easily.

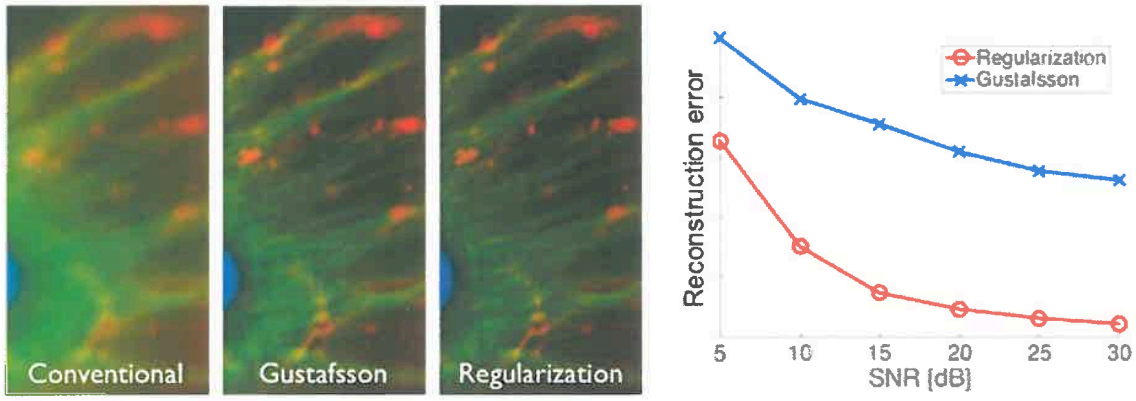

Figure 1: *Comparison of SIM reconstruction with Wiener-based method and our regularized approach*

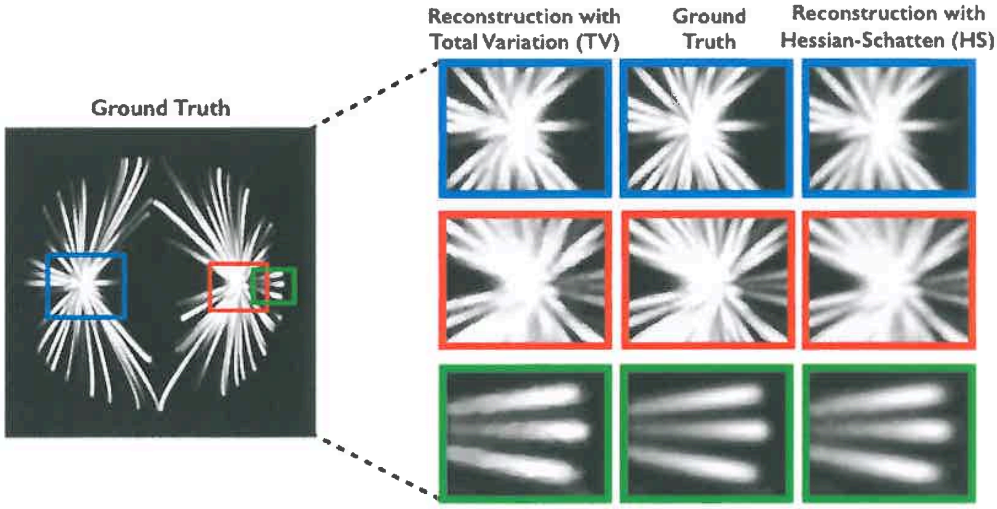

Figure 2: *Comparison of SIM reconstruction with TV regularization and HS regularization*

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