# FOUR-DIMENSIONAL COLLABORATIVE DENOISING AND ENHANCEMENT OF TIMELAPSE IMAGING OF MCHERRY-EB3 IN HIPPOCAMPAL NEURON GROWTH CONES

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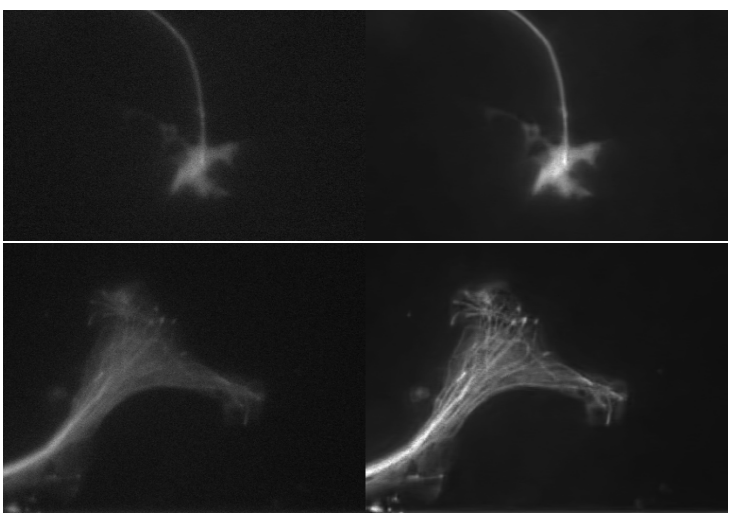
**ABSTRACT** Biomedical video sequences are often blurry and characterized by low contrast and noticeable noise. This can be particularly detrimental for image analysis, as the features of interest may not be detected because of the degradations. In this work, we demonstrate the application of the recently proposed V-BM4D video filtering algorithm [1-2] to timelapse imaging of mCherry-EB3 in hippocampal neuron growth cones, in order to simultaneously remove the noise and enhance the contrast and sharpness. The V-BM4D algorithm implements the paradigm of nonlocal grouping and collaborative filtering [3], where a four-dimensional transform domain representation is leveraged to enforce sparsity and thus regularize the data. V-BM4D constructs three-dimensional volumes, by tracking blocks along trajectories defined by the motion vectors, and then groups together mutually similar volumes by stacking them along an additional fourth dimension. Each group is transformed through a decorrelating four-dimensional separable transform, and then it is collaboratively filtered by spectrum shrinkage with alpha-rooting. As a conclusive step, the different block estimates from the filtered groups are returned to their original position and adaptively aggregated to produce a final estimate of the video. The experiments show that V-BM4D successfully preserves and sharpens all details visible in the original sequences, including the most faint ones. Further, it is able to reveal details and important structures that cannot be detected from visual inspection of the sequences. This preprocessing step renders the images more suitable for subsequent automated analysis such as particle tracking.

**HIPPOCAMPAL** neurons transfected using lipofectamine with DNA that genetically encodes GFP-tagged SCG10 phosphorylation site mutants. In addition, cells expressed RFP-EB3 (microtubule +TIP binding protein) to track plus-end dynamics of microtubules. Image sequences of RFP-EB3 movement was captured using a Hamamatsu-ERG CCD camera attached to a Zeiss axiovert 200M equipped with environmental control. The time interval for acquisition was 3 sec, exposure time varied from around 70-500ms depending on signal intensity. Images were taken with a 100x objective with cropping to better visualize growth cone compartments. RFP-EB3 movements are visualized as fast moving comets. Subsequent tracking of RFP-EB3 comets reveals information on speed and length of microtubule polymers and allows us to determine the molecular function of SCG10 on neuronal cytoskeleton. Noisy input is shown next to filtered output.



**INPUT**

**DEFLICKERING AND STABILIZATION**

A time-dependent affine scaling of the frame intensities that jointly stabilizes the noise variance and reduces the flickering is applied to the input video $z$.

**GROUPING**

Similar spatiotemporal volumes, built following the motion vectors of each block in $z$, are collected in 4-D groups. Such groups are characterized by local spatial correlation, non-local spatial selfsimilarity, and temporal correlation.

**COLLABORATIVE FILTERING**

The correlations allow for a sparse representation of the group in transform domain. Each group firstly undergoes a decorrelating 4-D transform $\mathcal{T}_{4D}$, then denoising is realized as hard-thresholding of the 4-D spectrum; enhancement (sharpening) is thereafter achieved by alpha-rooting the thresholded coefficients. The final estimate of the group is obtained by applying the 4-D inverse transform of $\mathcal{T}_{4D}$ on the processed spectrum.

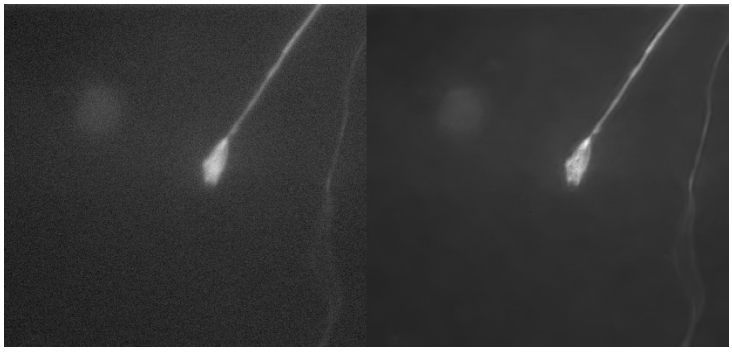
**AGGREGATION**

The estimates of each block are returned to their original spatiotemporal positions, and, since they are likely to overlap, subsequently aggregated through an adaptive weighting to produce the global estimate $\hat{y}$.

**INTENSITY RANGE EQUALIZATION**

A smoothly varying time-dependent affine scaling is applied to $\hat{y}$ in order to return all frames to a common suitable intensity range.

**OUTPUT**



[1] M. Maggioni, G. Boracchi, A. Foi, K. Egiazarian, "Video denoising using separable 4D nonlocal spatiotemporal transforms," to appear in Proc. SPIE Electronic Imaging 2011.

[2] M. Maggioni, G. Boracchi, A. Foi, K. Egiazarian, "Video filtering using separable 4D nonlocal spatiotemporal transforms," submitted to IEEE Trans. Image Processing.

[3] K. Dabov, A. Foi, V. Katkovnik, and K. Egiazarian, "Image denoising by sparse 3D transform-domain collaborative filtering," IEEE Trans. Image Process., vol. 16, no. 8, pp. 2080-2095, August 2007.