Segmentation and tracking are two of the main computational tasks required to extract relevant biological information from many light microscopy recordings. Optical flow estimation has been used as a key module in many segmentation and tracking systems and is considered a mature technology in the field of computer vision. However, most of the research has focused on two-dimensional (2D) natural images, which are small in size and rich in edges and texture information. In contrast, three-dimensional (3D) time-lapse recordings of biological specimens can comprise up to several terabytes of image data and often exhibit complex dynamic behaviors as well as object blurring due to the point spread function of the microscope. Thus, new approaches to optical flow are required to improve performance for such data.

We solve optical flow in large three-dimensional (3D)+time microscopy datasets by defining a Markov Random Field (MRF) over super-voxels in the foreground of each volume and applying motion smoothness constraints between each super-voxel instead of voxel-wise. Super-voxels improve registration in textureless areas, the MRF over super-voxels efficiently propagates motion information between neighboring cells, and the background subtraction and super-voxels reduce the dimensionality of the problem by an order of magnitude. We validate our approach on large 3D+time-lapse data of *Drosophila* and zebrafish development by analysing cell motion patterns. We show that our new approach is on average 10x faster than the commonly used optical flow implementations in the Insight ToolKit (ITK) and 23% more accurate.

You can download the source code here

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