Image processing for precise three-dimensional registration and stitching of thick high-resolution laser-scanning microscopy image stacks

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Résumé en anglais	The possible depth of imaging of laser-scanning microscopy is limited not only by the working distances of objective lenses but also by image degradation caused by attenuation and diffraction of light passing through the specimen. To tackle this problem, one can either flip the sample to record images from both sides of the specimen or consecutively cut off shallow parts of the sample after taking serial images of certain thickness. Multiple image substacks acquired in these ways should be combined afterwards to generate a single stack. However, subtle movements of samples during image acquisition cause mismatch not only in the translation along x-, y-, and z-axes and rotation around z-axis but also tilting around x- and y-axes, making it difficult to register the substacks precisely. In this work, we developed a novel approach called 2D-SIFT-in-3D-Space using Scale Invariant Feature Transform (SIFT) to achieve robust three-dimensional matching of image substacks. Our method registers the substacks by separately fixing translation and rotation along x-, y-, and z-axes, through extraction and matching of stable features across two-dimensional sections of the 3D stacks. To validate the quality of registration, we developed a simulator of laser-scanning microscopy images to generate a virtual stack in which noise levels and rotation angles are controlled with known parameters. We illustrate quantitatively the performance of our approach by registering an entire brain of Drosophila melanogaster consisting of 800 sections. Our approach is also demonstrated to be extendable to other types of data that share large dimensions and need of fine registration of multiple image substacks. This method is implemented in Java and distributed as ImageJ/Fiji plugin.
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