Wavelet Transforms and Object Quantification and Tracking in Microscopic Images

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A software system for tissue characterization and tracking by 2D and 3D image processing was developed. The focus is on applications in neurological (brain) experimental animal tissue due to specific agents. Applications include pathology, wound repair characterization, growth factors, response of endothelium to mechanical, hydrostatic-pressure and dynamic fluid influences.

The system architecture is built with general-purpose modules and a control engine that controls communications between the users and the individual modules. First, foreground voxels (pixels) are identified and background voxels suppressed. Then, 2D/3D blobs are located. The user then trains the system on “typical” blobs through a 3D visualization module which allows the user to click on and select blobs that represent the type of blobs the user wants to characterize and/or track. Nine 2D and 3D features (Area, Compactness, Circularity, Solidity, Eccentricity, Volume, Surface Area, Sphericity, and Convexity) are then calculated for the training blobs (the blobs selected by the user). A modified watershed segmentation algorithm is then applied on all the foreground blobs to separate touching cells and new blobs are found. This is followed by feature extraction for all blobs. After that, an object recognition module is invoked that classifies blobs based on the features of the training blobs. If multiple time points in a time-lapse image series were acquired, the system allows the user to automatically track objects over time. The user can then perform 3D visualization of an individual time point, an individual track (single object over multiple time points), and/or all objects from all time points.

In this paper we will focus on the utilization of wavelet transforms in the segmentation step and its effect on the performance of the overall system. We found that wavelet transforms can be used effectively in de-noising and segmentation of microscopic medical images. We will show that even with a simple HAAR transform and preliminary manipulation of the wavelets we can achieve better segmentation and blob separation. Other wavelet transforms will be evaluated and compared.

The innovations of this work are: (1) the use of wavelet transforms to automatically segment and preprocess microscopic images, the comparison between different wavelet transforms, and the study of the effect of wavelet transform on the overall system, not only the segmentation step (2) the novel extension of automated 2D/3D feature extraction and tissue characterization methods, (3) a novel interactive 3D editor system which provides powerful and easy-to-use 3D point-and-click training and displays 2D/3D morphometric measurements, and (4) the development of one comprehensive system that is modular to enable research on different parts at the same time, enable saving/loading training blobs, provide morphometric measurements to users, track objects overtime, interact in 3D with the original, segmented, and tracked objects, etc.; all in one software system.