Abstract

A relative measurement of blood flow changes is of clinical importance to study vascular change due to tissue injury or diseased condition. In superficial organs (viz. eye, skin), changes in blood flow pattern can be caused by different risk factors: atherosclerosis, high cholesterol profile, diabetes and inflammatory disorders like burn injury, wounds, growth of benign and malignant tumors (lesions). In this context, Laser speckle contrast imaging (LSCI or LASCA) provides a low cost solution with high resolution images. It has significant potential for *in vivo*, non-invasive and real-time measurement of blood flow and tissue perfusion.

This work presents speckle contrast imaging technique for *in vivo* static and dynamic imaging of microvasculature and tissue perfusion in different physiological conditions. The objective is to develop computational models for processing of speckle images and evaluate its efficacy for quantifying changes in blood flow in abnormal state. The study includes applications like: detection and tracking of emboli in vascular model, changes in retinal blood perfusion due to external stimuli, label-free retinal angiography, and characterization of different regions of cutaneous wound. A novel approach adaptive contrast computation based LASCA (adLASCA) is introduced, using local speckle statistics. It reduces the unwanted speckle part, keeping the meaningful speckles intact. The efficacy of adLASCA is experimentally tested on mice models.

Segmentation and motion estimation of air embolus is performed by LSCI and swept source optical coherence tomography (SS-OCT) systems. A combined processing approach, using anisotropic diffusion (AD) and active contour (AC), is implemented to segment an air embolus with a high degree of segmentation accuracy (92% – 94%). For motion analysis, pyramidal and iterative refinement of Lucas-Kanade optical flow technique efficiently tracks the flow trajectory of moving air embolus.

A joint framework, based on hidden Markov random field (HMRF) and expectation maximization (EM), is implemented in the application of label-free retinal angiography using LSCI. A direction oriented connectivity analogy is introduced to track the blood flow in fine vessel structures, leading to an average segmentation accuracy of 96.41% in normal state and 97.12% during reduced blood flow after oxygen inhalation.

Besides, LSCI is applied for monitoring wound progression and assessment. Initially, the affected area is segmented by k-means clustering, taking wavelet energies in a local region as feature set. Changes in contrast due to heterogeneity in vascular pattern are modeled using speckle statistics to characterize different regions in a wound bed. A support vector machine algorithm is implemented using these statistical features and implemented to characterize progressive and non-progressive regions of wound bed. For training dataset, it yields a very good result; average sensitivity more than 97%, 98% and specificity around 98%, 97% for progressive and non-progressive wound regions respectively. When applied on testing data, the algorithm also efficiently characterizes both regions with average sensitivity of 96.18% and 97.62%, having specificity values of 97.24% and 96.42% (progressive and non-progressive wound regions).This work addresses the challenges in subsurface optical imaging and presents non-invasive, in vivo diagnostic solutions for the assessment of microvasculature and tissue perfusion.

Keywords: *Laser speckle contrast imaging, optical coherence tomography, blood flow, tissue perfusion, adaptive filtering, Markov random field, active contour, optical flow, support vector machine.*