Postprocessing Algorithms to Minimize Fixed Pattern Artifact and Reduce Trigger Jitter in Swept Source OCT

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Technology description

Technology Overview

OHSU developed post-processing algorithms which could minimize fixed pattern artifact and reduce trigger jitter in swept source optical coherence tomography (SS-OCT).

Swept-source OCT has advantages of less fringe washout and faster imaging speeds compared to conventional spectraldomain detection. Therefore, it is attractive for both structural and Doppler OCT imaging. Unfortunately, in some SS-OCT systems, there is uncertainty in trigger timing so that the starting point of the spectral interferogram acquisition changes from cycle to cycle in wavenumber (k) space. In phase-sensitive OCT measurements such as Doppler OCT, this trigger jitter reduces the precision of phase measurement, as well as the effectiveness of subtractive removal of fixed-pattern noise artifacts (lines at fixed depths in OCT B-scans) which are caused by unintended internal reflections from fiber tips and sample/reference arm optics.

Several numerical methods have been proposed to improve the phase stability of SS-OCT systems, though they typically cannot remove the residual fixed-pattern noise. Effective methods to reduce the residual fixed-pattern noise have also been proposed, such as introducing an extra reference calibration signal or optical component to the existing system. However, they add additional system complexity and cost as well as additional power loss.

OHSU created novel signal processing software to solve the trigger jitter problem based on wavenumber alignment procedure. This technique eliminates the residual fixed-pattern noise and significantly improves the phase stability of the SS-OCT system. It works within the imaging range for all SS-OCT systems with residual fixed-pattern noise, and does not require hardware modification of existing systems. The improved image quality has enhanced the development of automatic detection of retinal tissue/vessels and the accuracy of total retinal blood flow (TRBF) measurement.

Market Size: Ophthalmology

North America is the leading market for OCT due to the rising aging population and high adoption rate. According to the U.S. Census Bureau, the percent of people above 65 years is projected to increase greatly from 22 in 2010 to almost 35 in 2020. This huge geriatric population (~62.8 million) would face various ophthalmologic complications such as diabetic retinopathy and age-related macular degeneration. OCT microangiography is a promising imaging technique, capable of providing a 3D reconstruction of the perfused microvasculature within the retina and choroid.The projected total U.S.

clinical market size for OCT microangiography in 2017 is about $79 million per year. This estimate was based on the number of billed U.S. FA and ICG procedures in 2011, the current $40 reimbursement rate for OCT scans of two eyes, and the assumption of a two-fold usage rate of a non-invasive test over an invasive one. Traditionally, annual OCT capital equipment sales track clinical market size by 25%, yielding a 2017 U.S. OCT microangiography equipment sales projection at about $20 million per year.

Application area

OHSU’ s OCT technique enables the removal of fixed-pattern noise artifacts and artifact-free in-vivo SS-OCT imaging of blood flow in the human eyes. It appears clinically relevant for the in vivo detection of blood flow in diseased eyes. Serious ocular diseases such as glaucoma, diabetic retinopathy and age-related macular degeneration are all connected with abnormalities in retinal blood flow. SS-OCT equipped with OHSU’ s technique is expected to be a powerful tool for 3D volumetric imaging of retinal vasculature and quantificatation of retinal blood flow in a wide range of retinal diseases, which will open new perspectives on understanding pathophysiology, as well as diagnosis and monitoring therapeutic response.

Advantages

Advantages of OCT using wavenumber alignment procedure over Competing Technologies
Several numerical methods have been proposed to improve the phase stability of SS-OCT systems. However, these methods typically cannot remove the residual fixed-pattern noise. This type of artifact manifests as horizontal lines across the image and originates from unintended reflections within the interferometer, the sample arm optics or the light source. In SS-OCT the image quality can be severely degraded by fixed-pattern noise.
One method to eliminate the residual fixed-pattern noise and improve the phase stability is to resample the wavenumber by using a simultaneously recorded calibration signal from an interferometer. However, it requires another reference calibration signal and digitizer channel, which greatly increases the system complexity and cost. An improved method is to insert a narrow band fiber Bragg grating (FBG) in one of the detection arms. The FBG produces a wavenumber reference signal in the acquired interferograms, which can be used for the interferograms shifting. Although the existing system is less modified, FBG brings optical power loss and extra cost to the system.
Unlike the other methods, OHSU’ s technique adopted the information at the residual fixed-pattern noise location to align the acquired interferograms. It does not require any hardware modification of the existing system and works within the imaging range for all SS-OCT systems with residual fixed-pattern noise. This robust, simple and computationally efficient approach significantly eliminates residual fixed-pattern noise and improves the phase stability of SS-OCT systems.
Doppler OCT retinal image from a diabetic patient. The volume scan covered a 1.6×2 mm^2 area of the optic disc and had 80 B-scans with 600 A-lines per B-scan. One cross section corresponding to a vertical line scan was selected to compare results between methods. (a) Cross section image obtained

using Bauman’ s (MIT) algorithm. (b) Cross section image obtained using OHSU’ s wavenumber alignment method.

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