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Dual slopes in diffuse optics

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Slope methods based on data collection at multiple source-detector separations have been widely used in the field of diffuse optics, especially in continuous-wave (CW) and frequency-domain (FD) near-infrared spectroscopy (NIRS). These slope techniques are typically based on a single source (and multiple detectors) or a single detector (and multiple sources), in which case they may be termed "single-slope" methods. Single-slope measurements are largely insensitive to instrumental and optical coupling effects associated with the single element. In the late 1990's, a dual-slope approach, identified as "self-calibrating," was introduced to perform slope measurements that are insensitive to instrumental and coupling effects associated with both sources and detectors, resulting in calibration-free measurements of the optical properties of highly scattering media. The source-detector arrangement of this self-calibrating approach was adopted by research groups and tissue oximetry companies to achieve robust measurements of the effective attenuation coefficient (with CW-NIRS) or the absorption and reduced scattering coefficients (with FD-NIRS) of highly scattering media such as biological tissue. Recently, dual-slope measurements, especially those based on the phase of photon-density waves in FD-NIRS or the mean photon time-of-flight in TD-NIRS, were shown to feature the additional property of being selectively sensitive to deeper layers of the sample, which is desirable in non-invasive biomedical applications that target deeper tissue (brain, skeletal muscle, etc.). In this presentation, we will review slope methods, and we will report latest developments in our group for the characterization and advancement of dual-slope methods. In particular, we will demonstrate the insensitivity of dual slopes on instrumental factors associated with both sources and detectors, describe the measurement of absorption changes using either intensity dual slopes (in CWNIRS) or phase dual slopes (in FD-NIRS), illustrate the regions of sensitivity of dual slopes in homogeneous and inhomogeneous media, discuss considerations for the design of source-detector arrays for dual-slope imaging, and report initial in vivo dual-slope measurements in human subjects for broadband spectroscopy, spatial mapping of tissue hemodynamics, and time-frequency characterization of oscillatory hemodynamics. Dual-slope measurements feature desirable aspects of practical and conceptual significance that can help advance a number of spectroscopy and imaging applications in the field of diffuse optics.

Biography

Sergio Fantini received his doctoral degree in physics from the University of Florence, Italy, in 1992. His dissertation was based on a Raman scattering study of ceramic superconductors. From 1993 to 1999, Fantini held postdoctoral and faculty appointments at the University of Illinois at Urbana-Champaign, in the Department of Physics. In 1999, he joined Tufts University as an assistant professor and has been one of the inaugural faculty members of the Department of Biomedical Engineering, which was created at Tufts in 2002.

KEYNOTE SPEAKER