FREQUENCY DOMAIN DIFFUSE OPTICAL TOMOGRAPHY WITH A SINGLE SOURCE AND DETECTOR VIA HIGH SPEED HYPOCYCLOID SCANNING

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Key Words: Diffuse Optics, Imaging, Cancer, Tomography

Diffuse Optical Imaging (DOI) relies on the fact that near infrared light (600-1000 nm) is strongly scattered in biological tissue, and weakly absorbed by tissue chromophores such as blood, fat, water, and melanin. In frequency domain DOI, intensity modulated light is introduced into the tissue and the observed absorption and phase changes enable absolute concentrations of these chromophores to be calculated. These concentrations provide valuable insight into tissue metabolic activity that have proven useful for a variety of clinical outcomes from exercise physiology to predicting tumor response to treatment.

Diffuse Optical Tomography (DOT) is an extension of DOI that allows three dimensional reconstruction of tissue chromophore concentrations. Typically, DOT requires a large number (~10-100) of light sources and detectors to collect the data necessary for 3D reconstruction. In these systems, each source and detector pair probes a specific volume of tissue and an algorithm is used to reconstruct tissue chromophore concentration within each voxel. However, the use of large numbers of fibers results in imaging systems that are large, expensive, unwieldy, and often anatomically specific (i.e. systems are constructed for breast measurements and cannot be easily used on other anatomical locations). In this poster I will present a new method for DOT that uses a single source and detector fiber in a potentially hand-held format that is able to probe a large volume of tissue using rapid scanning of each fiber in a hypocycloid pattern.

Figure 1: Hypocycloid scanning DOT. A) Pattern of source (blue) and detector (red) during a portion of the scan. B) Source and detector separation as center gear rotates. C) Hypocycloid scanning system on a tissue mimicking phantom showing source fiber (left) detector fiber (right) and motor shaft (center).

A hypocycloid is the pattern produced when a smaller circle rotates around the inner circumference of a larger circle without slipping (Fig. 1A). By placing a source fiber in one of these circles and a detector fiber in a second offset by 180 degrees, a complex, but predictable, pattern of source and detector locations emerges. This pattern enables a wide range of source and detector separations (Fig. 1B) to be probed enabling 3D reconstruction of tissue optical chromophores. This instrument was realized by using a small center gear driven by a stepper motor which moves two larger gears along the circumference of a large gear with internal teeth. Holes drilled into the larger gears allowed a source and detector fiber to trace the hypocycloid pattern (Fig. 1C).

We use a high speed frequency domain diffuse optical imaging system able to collect phase and amplitude spectra for six wavelengths of light over a wide range of frequency modulations (50-400 MHz) at over 100 scans per second. Currently, the rate of acquisition is limited to 10 source detector locations per second by the speed of the motor, but we expect further design improvements to allow the full speed of the imaging system to be utilized. We anticipate that hypocycloid scanning will allow 3D imaging of anatomical locations that are currently impossible to image with traditional DOT systems extending the utility of DOT to new diseases and types of cancer.