SBC based Optical Imaging System

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Abstract— Diffuse optical tomography (DOT) is a noninvasive diagnostic imaging technique which uses near infrared (NIR) light to measure optical properties of tissue. Absorption and scattering are the major optical properties of the tissue which can characterize tissue functional and metabolic activities. The basic idea of diffuse optical tomography imaging is to illuminate the tissue with an array of light sources and to measure the light leaving the tissue with an array of detectors. DOT imaging system comprises light illuminating and light detector system, and a controlling unit. The controlling unit controls and synchronizes various components of the DOT system to acquire high speed optical measurement data. The data are sent to a high performance computing unit to reconstruct high speed 3D- DOT image. In this project, high power LED will be used to illuminate the tissue because of its simple design, fast response times, good intensity characteristics, cost effective and efficient modulation up to 100 to 150 MHz. For the detection of the diffused light Silicon photo detectors will be used as it is cost effective and compact. In this project, building of an instrument which can illuminate tissue and measure diffused light at high speed as well as accurately is the aim. To achieve high speed controlling, compact design and fast data acquisition, Raspberry Pi is used. By building such a system cost effective high speed optical data measurement can be achieved along with a compact design and good accuracy.

Key words: Diffuse Optical Tomography (DOT), Near Infrared (NIR) Light Optical Properties, Raspberry Pi, Compact

I. INTRODUCTION

The term optic in general refers to light. Optics is the branch of physics which involves the behavior and properties of light, including its interactions with matter and the construction of instruments use or detect it. Optics usually describes the behavior of visible, ultraviolet, and infrared light. Because light is an electromagnetic wave, other forms of electromagnetic radiation such as X-rays, microwaves, and radiowaves exhibit similar properties.

The term Tomography is derived from ancient Greek words Tomos, meaning "slice, section" and Grapho, meaning "to write". Thus tomographic image is a cross section image of an object. Tomography refers to imaging by sections or sectioning, through the use of any kind of penetrating waves. A device used in tomography is called a tomograph, while the image produced is a tomogram.

The most common method of visualizing the tissues is by using the conventional medical imaging modalities such as X-ray imaging, Computed tomographic imaging, MRI, Ultrasound imaging, Positron emission tomography (PET) etc. Each of the above imaging modalities carries some advantages and some unavoidable disadvantages. X-ray imaging is the most commonly used for visualizing the defects in dense tissues such as bones and it does not give any information of soft tissues and has the hazardous radiation effect on the human body [1]. Computed tomography gives the visualization of the dense as well as soft tissues but have hazardous radiation effect as seen in X-ray imaging. MRI is a good imaging modality which gives good quality images with maximum information and it can give functional information with the administration of external contrast agents but it is costlier method and the patient is subjected to high magnetic field of 2 to 3 tesla which is some sought of danger to human body. Moreover people who have metallic implants, pace makers, and any other external implants in their body are not referred to the MRI scan. Ultrasound imaging is low cost and uses non-ionizing radiation, but provides a comparatively low resolution and noisy image, which does not give useful functional information. Optical imaging holds its appeal as an alternative tool in tissue imaging because it uses non-ionizing radiations, non-invasive, does not require injection of any contrast agents, is relatively portable and is economical compared with MRI or Positron emission tomography. Optical imaging techniques measures unique characteristics of tissue that are not detected by other imaging modalities mentioned above. These techniques also offer the potential to provide quantitative measurements, including functional information about the tissue [2].

Optical tomography has come to mean the use of low-energy visible or near infra-red light to probe highly scattering media, in order to derive qualitative or quantitative images of the optical properties of these media.[2], [4]. Of the potential applications, the one that has received a great deal of attention is medical imaging, where optical tomography is hoped to be a low-cost alternative or complement to existing medical imaging technology, with the particular advantage of providing functional as opposed to anatomical information.

II. OPTICAL PROPERTIES OF TISSUE

The development of optical methods in modern medicine in the areas of diagnostics, therapy and surgery has stimulated the investigation of optical properties of various biological tissues, since the efficacy of laser treatment depends on the photon propagation and fluence rate distribution within irradiated tissues.

The optical properties of a tissue affect both diagnostic and therapeutic applications of light. The ability of light to penetrate a tissue, interrogate the tissue components, and then escape the tissue for detection is the key to diagnostic applications [5], [6]. The ability of light to penetrate a tissue and deposit energy via the optical absorption properties of the tissue is the key to therapeutic applications. Hence, specifying the optical properties of a tissue is the first step toward properly designing devices, interpreting diagnostic measurements or planning therapeutic protocols. The second step is to use the optical properties in a light transport model to predict the light distribution and energy deposition.

The main constituents of biological tissue that contribute towards absorption in the near infrared region are water, lipids and hemoglobin [3]. While the former two remain fairly constant over short time scales, the concentrations of oxygenated and deoxygenated hemoglobin change according to the function and metabolism of the tissue. Thus the corresponding changes in absorption can provide clinically useful physiological information.

The optical properties that are directly responsible for the behavior and transport of photons through tissue are absorption and scattering. The optical properties of a tissue are described in terms of the absorption coefficient, μa (mm−1), the scattering coefficient μs (mm−1).

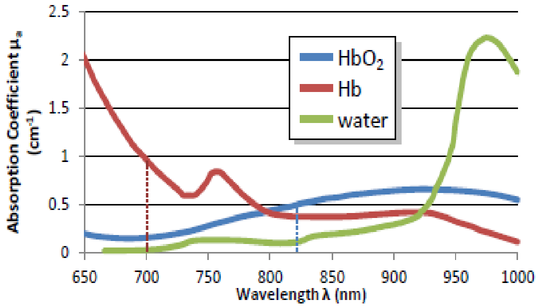

Fig. 1: Near-infrared spectrum of absorption coefficient of oxy-hemoglobin (HbO2), deoxy-hemoglobin (Hb), and water

In NIR spectrum, photons whose wavelengths lie within the 650-950 nm spectral regions are emitted . The photons that are not reflected keep propagating within the tissue and undergo scattering which continues until they either exit the tissue at some other location or are absorbed. The NIR spectrum presents a useful window for light transmission (see Fig. 1). Within the NIR window, there exists a few chromophores, i.e. light absorbing molecules, such as oxy-hemoglobin (HbO2) and deoxy-hemoglobin [1] which absorb NIR photons at wavelength dependent rates. Thus, the NIR photons can be used to provide spectrum-based signatures of tissue.

III. Diffuse Optical Tomography

Diffuse optical tomography (DOT) is a noninvasive technique used to measure the optical properties of tissue. It is an emerging medical imaging modality in which tissue is illuminated by near-infrared light (600nm to 1000nm) from an array of sources, the multiply-scattered light which emerges is observed with an array of detectors, and then a model is used to infer the localized optical properties of the illuminated tissue. The three primary absorbers at these wavelengths, water and both oxygenated and deoxygenated hemoglobin, all have relatively weak absorption. This fortuitous fact provides a spectral window through which we can attempt to localize absorption (primarily by the two forms of hemoglobin) and scattering in the tissue. The most important current applications of DOT are detecting tumors in the breast and imaging the brain [9].

The basic idea of diffuse optical tomography imaging is to illuminate the tissue with an array of light sources and to measure the light leaving the tissue with an array of detectors. For each source location, one records an image of the light reaching each detector from that particular source. A model of the propagation of light in tissue is developed and parameterized in terms of the unknown scattering and/or absorption as a function of position in the tissue. Then, using the model together with the ensemble of images over all the sources, one attempt's to "invert" the propagation model to recover the parameters of interest, or, in other words, to estimate the scattering and/or absorption parameters out of the data, using the model.

IV. Methodology

The Diffuse optical tomography instrumentation primarily includes a light source and a set of detectors a computer and electronic components. Light sources can be LED, LASER, etc. Here in this paper high power LED will be used to illuminate the tissue. The choice of LED as a light source is because of its simple design, fast response times, good intensity characteristics, cost effective and efficient modulation up to 100 to 150 MHz. Some of the typical detectors include Silicon photo detectors, PMT (Photo Multiplier Tubes) etc. Here Silicon detectors will be used as it is cost effective when compared to PMT's and very compact design [8].

Here, building of an instrument which can illuminate tissue and measure diffused light at high speed as well as accurately is the aim. High speed light measurement for DOT system is essential to reconstruct DOT images and monitor tissue functional activity in real time. To achieve high speed controlling, compact design and fast data acquisition, single board computer is used. The conceptual block diagram is described in Fig. 2. The single board computer used here is a Raspberry Pi.

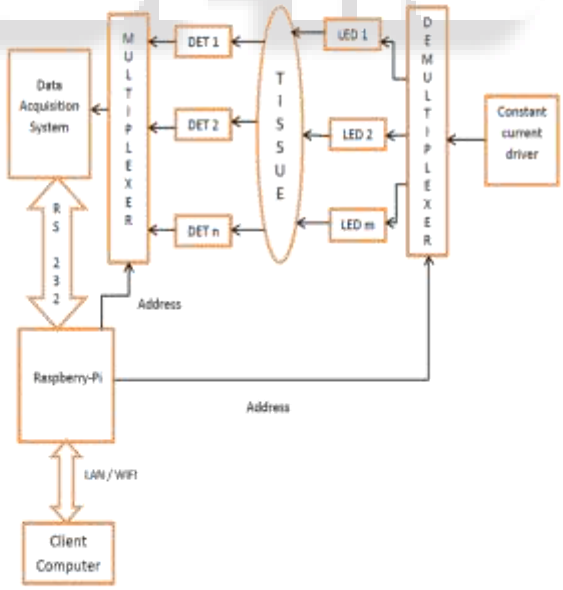

Fig. 2: Conceptual block diagram of Portable DOT system.

A raspberry pi is a single-board computer (SBC) with the complete computer built on a single circuit board, with microprocessor, memory, input/output (I/O) ports and other features required of a functional computer. Developments in VLSI technology have led to implementation of an entire microcomputer on a single board. Raspberry pi is built with the ARM microprocessor and standard connections like LAN, PCI, USB, Ethernet and

HDMI with minimal component count and smallest package size. Unlike a desktop, raspberry pi is compact in size, lighter in weight, consume less power, portable and are capable of fast computations. As the tissue monitoring needs fast computations and controlling of the devices is simple such single board computer is used.

Fig. 3: Raspberry Pi.

The Raspberry Pi shown in Fig.3, is the heart of the system which is used for controlling the LED's, detectors, and data acquisition system. Here high power LED's are used as the light source with wavelength of 700-950nm. Here we used M7XX or M8XX series mountable LED's are used. The silicon photo detectors FDS100 are used as to detect the light emerging from the tissue.

The data sets obtained from the data acquisition system is the acquired by Raspberry Pi by RS-232 communication and is sent to the client computer by socket programming. The client computer will process the data sets and the image reconstruction is done by using MATLAB.

V. Conclusion

In summary, the device and method for diffusion optical tomography of the present invention minimizes traditional large machines used for diffusion optical tomography into a Single on Chip system. The proposed system will perform the tissue optical imaging by using high power LED as the light source and Silicon photo detector as the detector to measure the diffuse light. Compared to the other imaging systems that employ computers or other large equipment, the device and method of the present invention have the advantages of real-time imaging, low cost and high portability, making it more suitable for home care system. Therefore, this system can be applied to

– Tumor detection
– Cancer detection
– Pathogen detection
– Tissue monitoring
– Anatomical structuring
– Tissue response

Acknowledgement

I am thankful to TEQIP-II.-Technical Education Quality Improvement Programme of the MHRD, Government of India.

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