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Diffuse Optical System for Monitoring Oxygen Pathways In Biological Tissue

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***Abstract*— Medical imaging with finer biological information is increasingly important, that too low cost technology. This work with designing of optical sensor systems integrated with data acquisition systems. The developed optical system was tested with developed phantoms and calibrated. Few images acquired with through hole phantoms for different layers of phantom. These images are compared and found to be in line with expectation.**

I. INTRODUCTION *Diffuse Optical Tomography (DOT)*

Diffuse optical tomography (DOT) is a type of imaging modality technique that is able to view living biological tissue at a depth not usually accessible to clinicians. DOT provides enhanced depth and clarity of viewing living tissues compared to other medical imaging modalities. Diffuse optical tomography investigated earlier as other form of imaging to detect malignant /tumours The method uses harmless, non-ionizing, near-infrared and red light to illuminate tissue which detects the light that has passed through it. From this data two-dimensional maps (2D maps) of oxy- and deoxy- haemoglobin, lipid, and water concentration inside the tissue can be calculated. It has been shown that DOT can visualize these vascular changes by observing changes in the concentrations of oxy- and deoxy-haemoglobin, lipids and water in the tumor region.

Figure 1.1: Two dimensional image of diffuse optical tomography [5]

Optical measurement is generally a type of imaging optical spectroscopy, to non-invasively (or minimally-invasively) perform a tissue diagnosis, in-situ, in-vivo and also in real time. The driving forces for such developments are several:
1.Elimination of surgical removal of biological tissue for tumor analysis. In this process optical probe is placed over the surface of the tissue only(in vivo).
2. The measurement is frequently done by optical probe, and a diagnosis of the tissue is then attempted based on the optical measurements.

Figure 1.2 illustrates the variety of processes possible when an optical photon impinges at the surface of a tissue boundary. For case “a” the simple reflection from the surface and it carries little information about the underlying tissue. Case “b” represents back scattering from cellular and structural components of the tissue, following one or a few scattering events, termed “elastic scattering” because the energy of the photon is not altered by the its process. The wavelength of the scattering probability depends on sizes and densities of sub-cellular structures, and consequently the elastically scattered light conveys significant information about microscopic tissue structure. Case “c” represents the absorption of a photon. Photons with energies/wavelengths which are more likely to be absorbed (due to the absorption bands of the chromophores in the tissue) are hence less likely to be scattered back, facilitating measurement of such chromophores (e.g., oxy- and deoxy-hemoglobin). Case “d” represents “inelastic” processes, wherein the energy (and, hence, wavelength) of the reemitted or scattered photon changes. The most relevant of these processes for diagnostic spectroscopy are fluorescence and Raman scattering. Cases “e” and “f” represent examples of photon trajectories for the majority of photons that simply scatter diffusely in the tissue, scattering numerous times before being absorbed or emerging from a surface. The terms photon “migration” and “diffuse” scattering are frequently used by researchers who develop functional imaging and spectroscopy methods with systems designed to sense diffusely-scattered photons [2]. The point measurements reviewed in this paper are aimed at providing more detailed information about the tissue, but for one spot at a time.

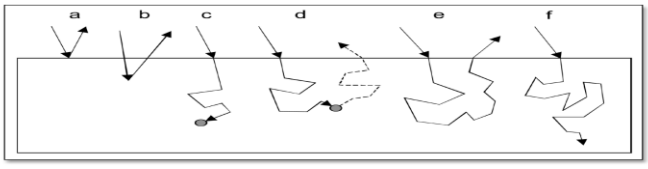

Fig 1.2: Interactions of light with the soft tissue [2]

Optical spectrum from the tissue yield diagnostic information based on the biochemical composition and structure of the tissue. It not only indicates the presence and location of cancer but also may indicate where cancer originated and what types of treatment will be most appropriate [1]. Different skin and sub-surface tissues have distinct or unique reflectance pattern which help us differentiate normal and cancerous tissues. Study reveals that the most noticeable difference between the absorption spectrum of HbO2 and that of Hb are found between 500 – 660 nm and 700 - 900 nm. The diffuse optical spectroscopy measurements have the following physiological meaning; High total haemoglobin concentration means elevated tissue blood volume, high water content reflects edema and increased cellularity, decreased oxygen saturation suggests increased metabolism and decreased lipid content reflects displacement of parenchyma adipose. These functional changes alter the optical properties of the tissue. The optical properties of tissue describe the behaviour of light in it.

Diseases involving the skin and underlying soft tissues are lesion. These tissues are involved by a wide range of congenital, inflammatory, infectious diseases, distressing, and neoplastic processes. Aside from physical examination, the diagnosis of most of these lesions is invasive, time consuming, and costly, often requiring surgical excision or biopsy followed by pathological investigations. A non-invasive, efficient, low cost technique of evaluating skin and soft tissue cellular changes would be extremely valuable in the management of numerous conditions. The proposed non-invasive technique can distinguish healthy from pathological tissue based on their microscopic morphology and the variations in their diffuse reflectance spectra. This instrumentation measurement system allows quantitative assessment of certain physiological parameters which leads to non-invasive cancer diagnosis [1].

Techniques of optical analysis has been used for continuous pulse monitoring which changes with blood volume in peripheral vascular areas**.** It is possible for the tissue to be directly transilluminated where the light source is on one side of the tissue and the detector on the other side (transmittance mode) or where the light source and the photo detector can be positioned side by side (reflectance mode) [3]. The transmittance mode is limited to areas such as the finger, the earlobe or the toe where the reflectance mode allows measurements on virtually any skin area. The intensity of the light that reaches the photo detector in either reflectance or transmittance mode is measured and the variations in the photo detector current are assumed to be related to blood volume changes underneath the probe. These variations are amplified and recorded as a voltage signal.

Computerized medical imaging and analysis methods using multiple modalities have enabled diagnosis in initial stages, continuous evaluation, and therapeutic intervention in the clinical management of critical diseases. Since X-ray radiographic imaging became a primary radiological diagnostic imaging method in the early part of the 20th century, there have been several advanced medical imaging modalities which have emerged and are available today to acquire anatomical, functional, metabolic, and physiological information from the human body. In parallel, optical imaging methods including endoscopy and fluorescence imaging have been successfully used in clinical applications. Optical imaging is the oldest imaging method, well known for taking photographs of an object using the visible light spectrum of electromagnetic radiation. A simple form of optical imaging using fibre optics and a charge-coupled device (CCD) camera has been successfully used in endoscopy for imaging internal tissue structures with a narrow field of view. More recently, optical coherence tomography, confocal microscopy, and multispectral diffuse reflectance methods have been investigated for molecular and functional imaging, with innovative applications in biomedical research and targeted towards clinical applications. The information obtained through advanced medical imaging systems [4] can be very expensive, whereas optical imaging systems are relatively inexpensive, portable, non-invasive, and adaptable to acquire physiological and functional information from microscopic to macroscopic levels.

Optical imaging modalities may utilize the visible light spectrum from 400 to 700 nm of electromagnetic radiation to produce visible images in biomedical applications optical imaging modalities is not restricted to the visible spectrum, but can be extended out on both sides into the soft ultraviolet 400 nm and near-infrared [(NIR) 700 nm] range for fluorescence and multispectral imaging applications. Optical imaging modalities have a common advantage of low infrastructure costs while being portable and capable of functional imaging at tissue, cellular, and even molecular levels. As detector technology continues to improve, the sensitivity of optical imaging modalities will continue to progress, as will the development of cost-effective portable imaging technologies for structural and functional imaging at tissue, cellular, and molecular levels for clinical diagnostic and therapeutic application [4]. Future work is expected to focus on developing a reliable and standardized system for clinical applications.

II. METHODS

2.1 System overview

Diffuse optical tomography (DOT) system is a non-invasive method to detect tumor cell in the tissues. If a light incident onto your hand, you can clearly see that light can penetrate through a few centimetre of tissue and it can be detected by photodetector and the detected values can able to reconstruct an optical image.

Diffuse optical imaging with multi-wavelength light radiation is being tried for early detection of oxygen disturbances and also functional state of tissue. Changes in Oxygen diffusion in tissue alters the optical properties of tissue. This optical

property this investigation proposed to capture and convert to images.

The information collected from different set of detectors arranged with equidistance spacing correspond to different layers of tissue. There by data obtained correspond to tissue characteristics.

Under this instrumentation set up quantitative assessment of physiological parameters, possible mapping of oxygen distribution and changes there on. [1].

An optical imaging system is set up for this purpose, which is safe, conveyable and very affordable relative to other imaging modalities. In this the skin surface is exposed to light produced by an LED source. The back scattered photons emerging from various layers of tissue are detected by photo detector placed different position resulting in tissue surface emission profile. The data from the scan is processed to form an image which can directly assist us in differentiating the part which is affected by cancer visually.

This optical systems is safe since there is no harmful radiation
Compare to other imaging modalities, the resolution when the data is converted to image is much better than other imaging modalities.

2.2.1 Procedure

The target of the whole project is to reconstruct of an optical image of a tissue based on a tissue scattered response. This reconstructed image can able to detect the tumors cell and in future can able to evaluate the oxygenation and de-

Trans-impedance amplifiers are commonly used in receivers for optical communication to convert the current generated by a photo detector into a voltage signal for further amplification. The amplification is done by operational amplifier and it produces an output voltage.
The output voltage of an operational amplifier is fed into lab view through data acquisition card NI-6009. The acquired detector values are stored and by using this detector values can reconstruct the optical image of a tissue by using Matlab software.

The Data acquired using NI DAQ is converted using MATLAB to form image.

III. RESULTS AND DISCUSSION

3.1 Reconstructed phantom image

Imaging phantoms or simply phantoms are specially designed objects that are scanned or imaged in the field of medical imaging to evaluate, analyze and adapt to the performance of various optical imaging devices. These objects are more readily accessible_and provide more consistent results than the use of a living subject and avoid subjecting a living subject to direct risk.

oxygenation status of the tissue by knowing the value of absorption and scattering. The reconstruction of an optical image can be achieved by using diffuse optical tomography system (DOT).

When subject get illuminated by RED or INFRARED light, light penetrate into a subject in an order of few centimetres and back scattered light which is detected by photo detector. Photo-detector are used primarily as an optical receiver to convert light into current.

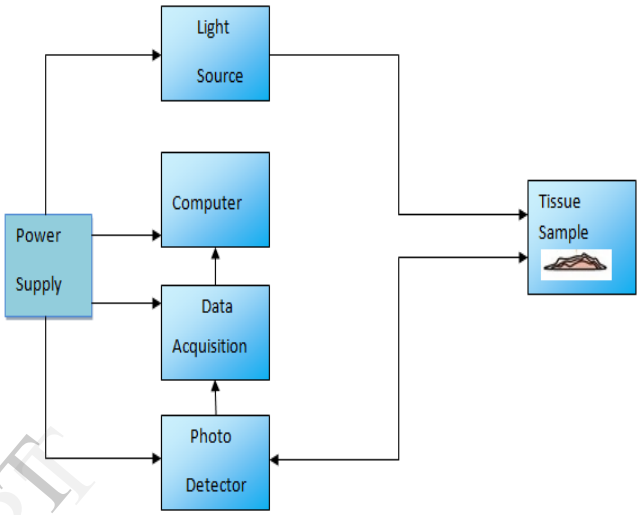

Fig 2.1: Block diagram of DOT system

Fig 3.1 represent the through hole phantom image which is reconstructed by a photodetector 1 values which indicate hole inside the phantom that is detected by a diffuse optical tomography (DOT) system by using IR source and RED source. Through hole phantom is more sensitive to IR source than the RED source.

IR SOURCE RED SOURCE

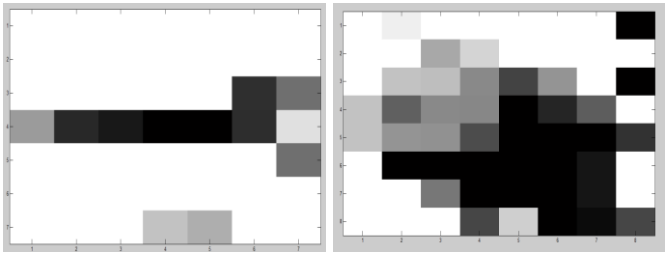

Fig 3.1 :Through hole Phantom image – detector 1

Fig 3.2, 3.3, 3.4 represent the through hole phantom image which is reconstructed by a photodetector 2, 3, and 4 output values respectively.

IR SOURCE RED SOURCE

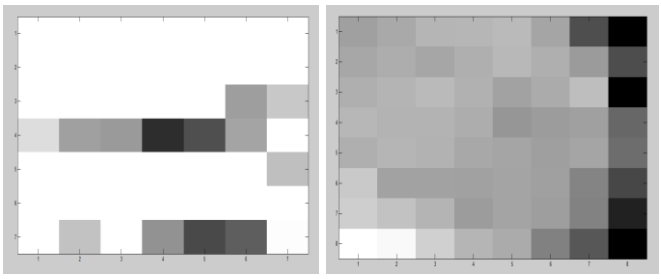

Fig 3.2: Through hole Phantom image – detector 2

IR SOURCE RED SOURCE

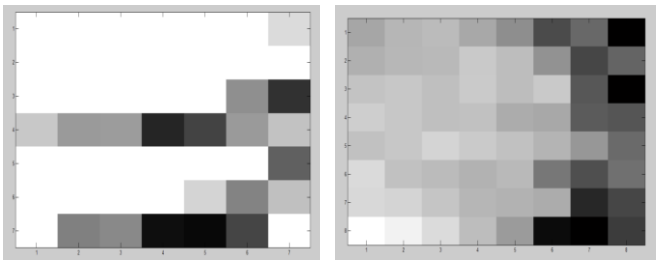

Fig 3.3: Through hole Phantom image – detector 3

IR SOURCE RED SOURCE

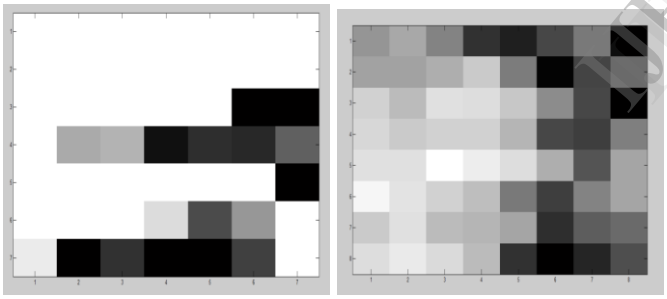

Fig 3.4 :Through hole Phantom image – detector 4

Verification and validation

Diffuse optical tomography system is first tested with phantom before bringing into clinical practice because it should not damage any subject. Diffuse optical tomography system is able to detect a phantom, graphite, foil placed inside the phantom, and also the pin hole made through the phantom. The detected images of the phantom are shown in the fig 3.8, 3.9, 3.10, 3.11. Once after Diffuse optical tomography system is ready to detect and then tested with real soft tissue (like breast, brain), this could be a forearm as shown in the fig 3.5.

3.2 Phantom Images

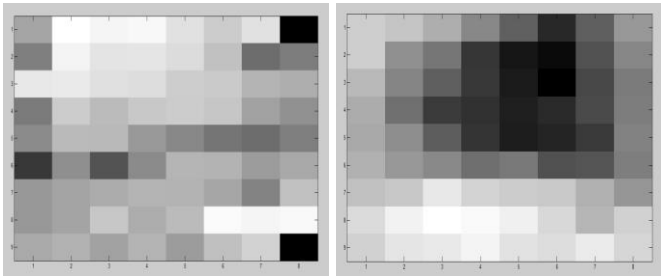

Fig 3.5 : Phantom image (IR) – Detector 1**Fig 3.6** Graphite Phantom image (IR) –Detector 1

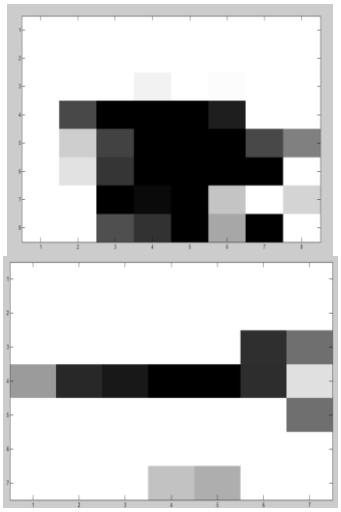

Fig 3.7 : Foil Phantom image (IR) - Detector 1 Fig 3.8 : Pinhole Phantom image (IR) - Detector 1

3.3 Tissue Images

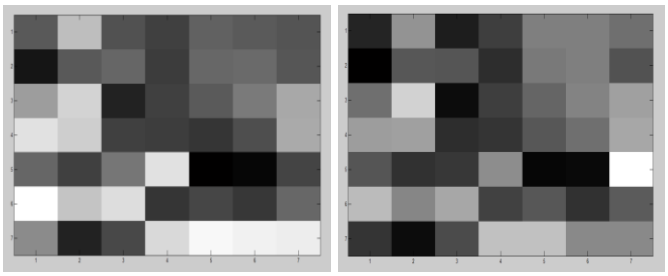

Fig 3.9: Detector 1 – RED Source Fig 3.10: Detector 2 – RED Source

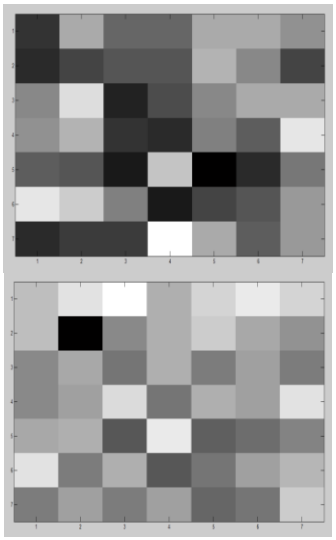

Fig 3.11: Detector 3– RED Source Fig 3.12 :Detector 4 – RED Source

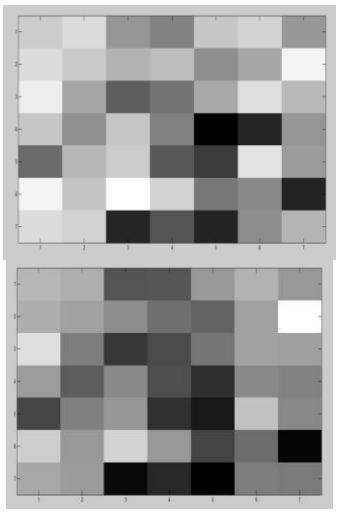

Fig 3.13: Detector 1 – IR Source Fig 3.14 : Detector 2 – IR Source

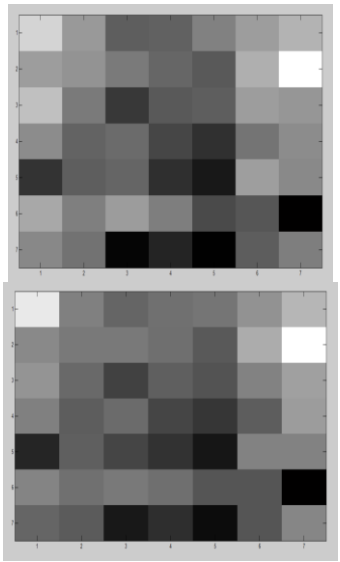

Fig 3.15 : Detector 3 – IR Source Fig 3.16 :Detector 4 – IR Source

IV. CONCLUSION AND FUTURE DEVELOPMENTS

4.1 CONCLUSION

1. Four different layers of tissue phantom and tissue image, was reconstructed by using optical output data sets.
2. The reconstructed image can be used for identifying the tumor cell in blood vessels.
3. Phantoms are more sensitive to Infrared light than the Red light.
4. Diffuse optical tomography system is a non-invasive, fast, risk-free, and inexpensive medical imaging modality.

4.2 FUTURE DEVELOPMENTS

1. Reconstructed image can also evaluate the oxygen status of the tissue, by knowing the absorption and scattering values of the tissue.
2. Optical fibers can be used
   a. To reduce the ambient light interfering with the measurement.
   b. To fine tune source detector distance to view/ image very fine layer of tissue.

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