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Dynamic Optical Tomography: Instrumentation and Calibration Protocol

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Abstract— **We present a multi-source / multi-detector optical tomography setup that is capable of fast imaging, thus allowing tracking time varying physiological states. To cancel out varying detector sensitivities and incoupling efficiencies, we developed a calibration protocol for our experiment. Analysis of the variances in the calibration factor of each detector provides an objective measure of the reproducibility of the performed experiments and an opportunity to identify corrupted data sets.**

Keywords: Optical tomography, Instrumentation, Calibration

I. INTRODUCTION

In recent years, there has been increasing interest in biomedical imaging using optical approaches [1,2]. This is due to their ability to add further physiologic and pathologic information to the results obtained from established methods, and because of the relatively inexpensive and simple technology involved. The main challenge results from the heavy elastic scattering light undergoes in most types of tissue, which leads to a strongly decreased spatial resolution and blurred images.

Nevertheless, optical contrast in tissue is directly influenced by fundamental biochemical processes and therefore contains valuable information of physiological and pathological states. We find that tracing short-term temporal (seconds to minutes) changes in optical properties of our target medium offers significant contrast enhancement and allows extraction of further physiologic information [3].

II. MATERIALS AND RESULTS

We perform measurements at two wavelengths (780 nm and 810 nm) simultaneously to distinguish fluctuations in blood volume and in oxygenation state. A stable, well-defined interface between instrument and tissue is crucial, and so we designed several specific sensor heads to ensure adaptation to different target geometries. Our probes contain arrays of optical fiber bundles that act acting as both sources and detectors. The source position on the target is changed by fast optical multiplexing of the laser diodes using a rotating mirror. Recent studies were made using a cylindrical sensing geometry of variable radius, which we refer to as the IRIS OPTI-Scanner [3]. With this device, we were able to achieve a sampling rate of 4 images/s using a fast sensitive CCD camera for reading out the fibers. Fig. 1 is a sketch of a recently proposed modification that uses photodiodes and precision current-to-voltage converting amplifiers, which are monitored using a PCI data acquisition board. By electronically switching gain factors, a large overall dynamic range over more than 8 decades can be achieved. It is our goal thereby to enhance the data acquisition rate to 10 images/s.

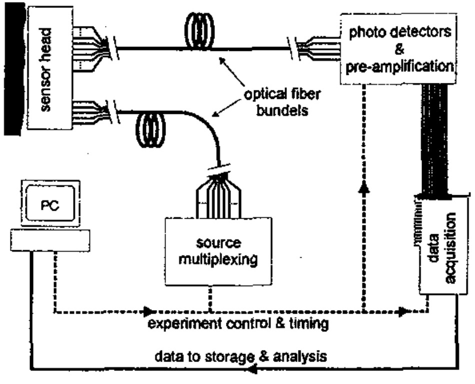

Fig. 1. Instrumentation scheme for multi source / detector optical tomography capable of fast image acquisition.

To account for differences in the coupling efficiencies at the various optical interfaces, a calibration protocol has been developed for determination of relative detector sensitivities. The underlying algorithm regards the over-all sensitivity at one position as composed from the detector coupling to the target, the source coupling and an influence of the medium itself. Using matrix formalism, this can be expressed as

$$\mathbf{R}=\begin{bmatrix} s_1 & 0 & \cdots & 0 \\ 0 & s_2 & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & s_N \end{bmatrix}\begin{bmatrix} m_{1,1} & m_{1,2} & \cdots & m_{1,N} \\ m_{2,1} & m_{2,2} & \cdots & m_{2,N} \\ \vdots & \vdots & \ddots & \vdots \\ m_{N,1} & m_{N,2} & \cdots & m_{N,N} \end{bmatrix}\begin{bmatrix} d_1 & 0 & \cdots & 0 \\ 0 & d_2 & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & d_N \end{bmatrix}=:\mathbf{SMD},$$

with **R** being the matrix of over-all response, and **S**, **D**, and **M** being the matrices of source- and detector-coupling efficiency factors, and the medium influence, respectively. We determined values for d_i and s_i (i denoting the position) by performing measurements on a homogenous phantom. Varying the target medium and keeping all other conditions unchanged, we found the d_i and s_i values reproducibly remain constant, with variations less than 5% and 10%, respectively.

III. CONCLUSIONS

We are able to perform dynamic optical tomographic imaging using multiple source and detector positions at two wavelengths. We are able to sample data sets at a rate of 4 images/s, and currently are redesigning our setup for reaching rates as high as 10 images/s.

We apply a calibration protocol that allows us to cancel out intrinsic variations in the sensitivity of the various detectors. The behavior of **S**, **M**, and **D** as experimentally observed agree very well with our model. This enables us to objectively judge the stability of our setup and identify corrupted data sets.

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