The Curse of Big Data in Diffuse Optical Spectroscopic Tomography: The LUCA approach

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Abstract: NIR technologies now allow large scale data capture; therefore, computational and image recovery tools face new challenges to allow accurate and real-time applications. Key significant advancements as developed under NIRFAST will be presented together with clinical examples.

OCIS codes: (100.3190) Inverse problems; (170.3660) Light propagation in tissues;

1. Introduction

The development of Near Infrared (NIR) optical tomography and spectroscopic (NIRS) imaging as a functional imaging modality has relied largely on the use of model based image reconstruction. The recovery of optical parameters (inverse problem), namely spectrally varying absorption and scatter based parameters, from limited number of discrete boundary measurements of light propagation within tissue is inherently a difficult one as (1) Non-linearity means that a change in optical parameters does not provide an equal or linear change in the measured data, (2) Ill-posedness meaning that if a solution exists it may not be unique and its behavior does not change continuously with the initial conditions (3) Ill-conditioned such that a small change in measured data maybe due to a large change in optical parameters and (4) Under-determined as there are often many more parameters to be recovered than there are measured data. The continued development of the technology to date has made a substantial contribution towards providing more information regarding the tissue being imaged either through sophisticated systems that provide many more sets of data (Intensity, Phase, Time-of-Flight, Speckle, Luminescence to name a few) as well as systems that combine multiple-modalities (such as Ultrasound, CT, MRI) to help better constrain the problem as well as providing complementary functional data. The challenge from a model-based analysis then becomes how to incorporate these large sets of data, in a computational efficient manner, which is useful, accurate and meaningful.

To demonstrate the utilization of large sets of data, the LUCA project is used as an example, with specific emphasis on the novel numerical modeling approach of light propagation in tissue (such as spectral deconvolution, self-calibrating spectral Time Resolved data, data-reduction) as well as image reconstruction (single-step for NIRS and DCS, utilization of multi-modal data, structural and spectral priori) using boundary data using large sets of single and multi-modality data. Specific details regarding the creation, utilization and validation of these novel and sophisticated numerical models, as well as detail of the basis for using spatial and structural prior information will be outlined, together with phantom and patient data, whereby the use of spectral and dual-modality systems can improve contrast and spatial resolution. This work will demonstrate and highlight that the utilization of Big Data, if implemented correctly, is useful and does overcome the constrains of traditional diffuse tomography.

2. Methods

A system has been developed as a standalone tool for recovery of human thyroid hemodynamic parameters and is configured to utilize data from three complimentary diagnostic techniques: multi-spectral time resolved spectroscopy (TRS) [1] to measure concentrations of tissue constituents, diffuse correlation spectroscopy (DCS) [2] to assess perfusion and ultrasound images (US) for optical probes positioning and developing the tissue computational model.

3. Results

The thyroid parameters recovery as implemented in the LUCA device is shown in Fig.1. A cloud-based system (NIRFAST) has been tested within the LUCA device environment and phantom data. Execution time of the recovery procedure is <120s and marginally increases if multiple parallel examinations are processed with the parameter recovery algorithm as used in the LUCA device tested on in-vivo patient data [3]. Data were measured on 4 points above thyroid and 2 reference points outside. The TRS data were measured at 3 wavelengths (690, 785 and 830 nm) with the recovered hemodynamic thyroid parameters are shown in Fig. 1.

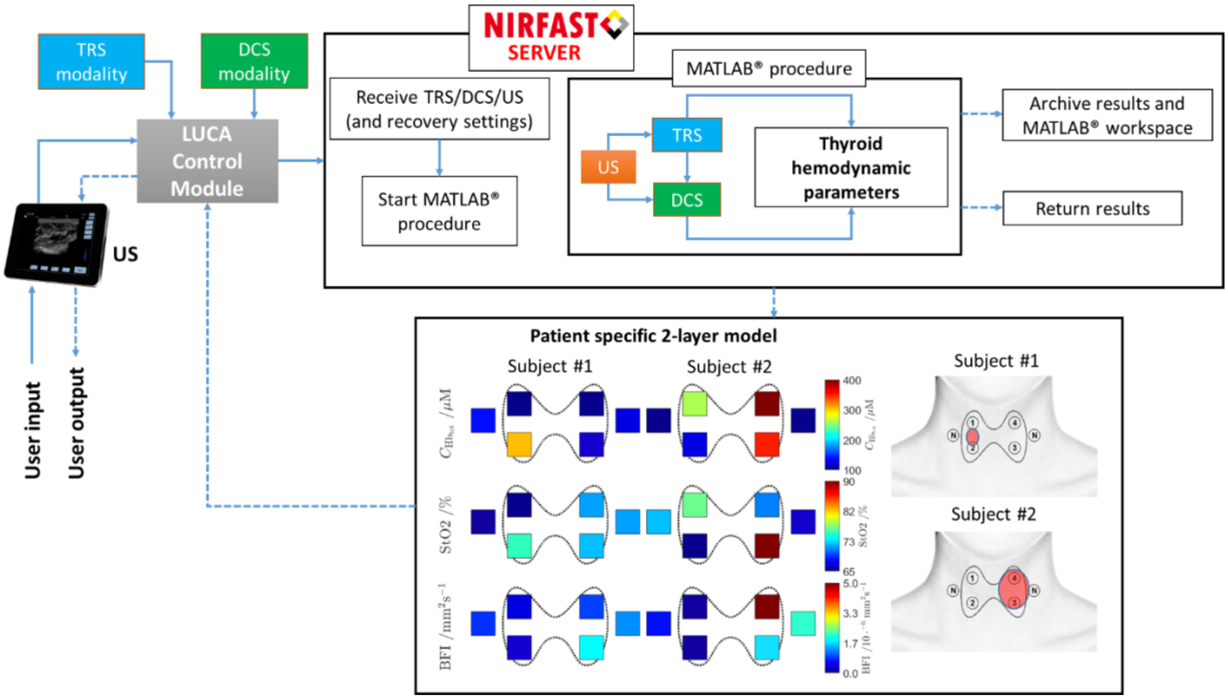

Figure 1. Thyroid parameters recovery as implemented in the LUCA system. Malignant lesions and measurement points locations are overlaid on the neck images. TRS – time resolved spectroscopy, DCS – diffuse correlation spectroscopy, US – ultrasound, C_{Hbtot} – total haemoglobin concentration, StO2 – tissue perfusion index, BFI – blood flow index (perfusion index).

4. Discussions and Conclusions

The model-based tissue parameters recovery has been implemented as a standalone tool within the LUCA thyroid cancer screening system. Modular architecture and remote access through TCP/IP protocol make the server a universal tool, which can be utilized for a wide range of biomedical optics applications as a post-processing box within an instrument, a WWW-based calculation service with e.g. a web interface or as a laboratory calculation server where researchers can operate on remote NIRFAST instances directly from their own MATLAB® copy. A number of new developments to allow fast real-time implementation of model-based parameter recovery have been utilized, such as self-calibrating algorithms [4], spectral deconvolution of Time Resolved NIRS data [5] and GPU implementation of the forward solver to dramatically enhance computational time [6]. This work has demonstrated and highlighted that the utilization of Big Data, if implemented correctly is useful and does overcome the constrains of traditional diffuse tomography.

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6. References

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