Analysis of multispectral images using ANNs trained on *in vivo* data for estimation of hemoglobin oxygen saturation in skin microcirculation

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To estimate hemoglobin oxygen saturation from multispectral imaging (MSI) data, an algorithm needs to account for complexity of sensor characteristics and modeling of photon transport in tissue. This novel method is based on training artificial neural networks (ANNs) on *in vivo* measured MSI data, targeting values from a point-measuring reference method.

Introduction

Optical methods, such as diffuse reflectance spectroscopy (DRS) can access skin microcirculation non-invasively. The spectrum of backscattered light reflects impact of skin tissue absorption and scattering on the incident light. From measured spectra, physiologically related parameters, such as hemoglobin oxygen saturation (S_{O_2}), red blood cell (RBC) tissue fraction, and melanin content can be estimated.

Method

MSI data were acquired by a snapshot camera system (xiSpec MQ0022HG-IM-SM4X4-VIS, XIMEA, Germany) from 20 healthy subjects. Venous and arterial occlusion provocations were performed on the subjects to capture both high and low S_{O_2} values.

ANNs were trained to estimate S_{O_2} with MSI data as input, targeting data from a validated probe-based reference system (PF6000 EPOS, Perimed AB, Sweden). The training was performed using the leave-one-subject-out method, where an ANN is trained on data from all but one test person. The left-out data set was used for evaluation. The method is described in Fig. 1. Performance of ANNs with different properties and training data sets was compared to find an efficient ANN design.

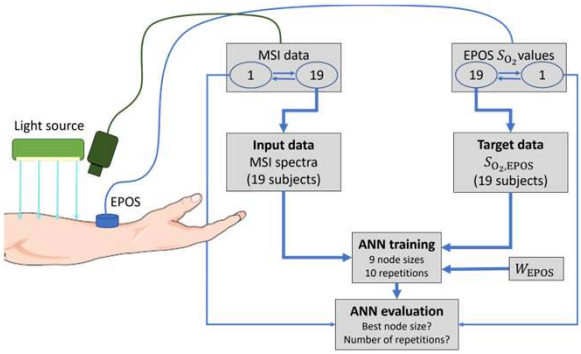
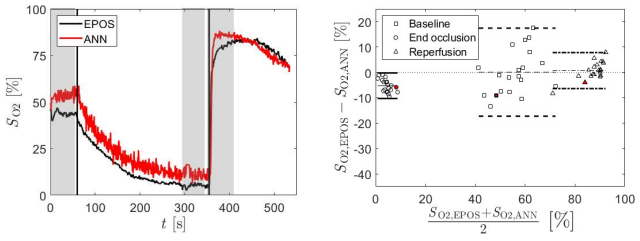


Fig. 1. An overview of the experiment set-up and main steps of training and evaluation procedures. Each training data set consisted of data from 19 out of 20 subjects. Data from the left-out subject were used for evaluation.



(a) (b)

Fig. 2. (a) S_{O_2} estimated by ANN (red) and measured with the EPOS system (black) during arterial occlusion in a typical measurement. (b) Agreement between the two presented in a Bland-Altman analysis of 20 subjects at baseline (squares/dashed lines), end of occlusion (circled/solid lines), and reperfusion (triangles/dash-dotted lines).

Results

Time resolved S_{O_2} values estimated by ANN and measured by EPOS system are shown in Fig. 2. together with Bland-Altman analysis of the 20 evaluation sets (estimated by their respective trained ANN) at three time intervals. Fig. 3 shows S_{O_2} maps of the volar forearm of one subject at three points in time. Analysis of a 512 x270-pixel image took 0.056 s.

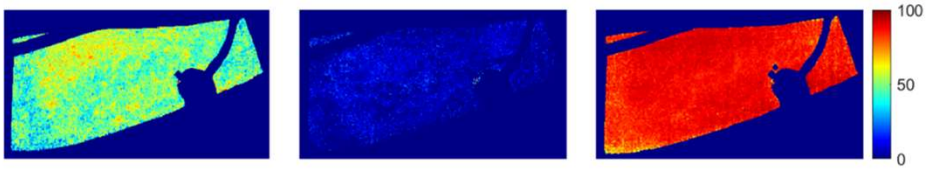
Discussion

Data used for training were measured by the same system and under similar conditions as the evaluation data, which eliminates the need to account for the system's specific characteristics, such as impinging light spectrum and sensor characteristics. The presented method can be applied to other MSI systems if training data are acquired by the system used for measurements.

Training data must cover a wide range of target values, e.g., acquired during an occlusion protocol. Data from the probe-based reference system can be used as target despite differences in sampling depth and measurement position.

Conclusion

Snapshot MSI cameras with complex spectral properties can be calibrated using *in vivo* data from a reference system to train an ANN. This enables real time S_{O_2} assessment.



(a) (b) (c)

Fig. 3. Estimated S_{O_2} of the volar forearm for one subject during an arterial occlusion protocol: (a) baseline, (b) end of occlusion, (c) reperfusion.

Read more:
Ewerlöf, M., Strömberg, T., Larsson, M., Salerud, E. G. "Multispectral snapshot imaging of skin microcirculatory hemoglobin oxygen saturation using artificial neural networks trained on in vivo data". Journal of Biomedical Optics Vol. 27(3), 2022