Reflective Thoracic Pulse Oximetry via Textile-integrated Flexible Sensors

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Arterial blood oxygen saturation is a vital parameter routinely monitored via pulse oximetry. The current use of transmission probes (e.g. fingertip or ear lobe probes) induces motion sensitivity and user discomfort for ambulatory monitoring. In order to overcome these limitations, a reflective multi-channel thoracic oximeter is developed.

Pulse oximetry (SpO_2) is a surrogate value for estimating in a non-invasive way the oxygen saturation in patients' blood. Often referred to as the fifth vital sign, its monitoring is of paramount importance notably for neonates, patients undergoing unstable blood oxygenation (*e.g.* in intensive care units), or those encountering extreme situations (*e.g.* high altitude) or sleep-related disorders (apnoea).

Pulse oximetry is usually measured in *transmission* mode, that is by injecting red and infrared light through a patient's limb (usually a finger or an earlobe) and recovering the transmitted light via a photodiode. While this method offers the advantage of producing strong and clean photopletysmographic (PPG) signals, it suffers from being used in body locations (extremities) where large movements occur and induce massive motion artefacts (in particular when it comes to neonates). This is why *reflective* pulse oximetry is a valid alternative: reflective sensors are placed at locations where motions remain small, such as the chest. Unfortunately, body parts such as the chest present low blood perfusion, producing PPG signals with very low signal-to-noise ratios.

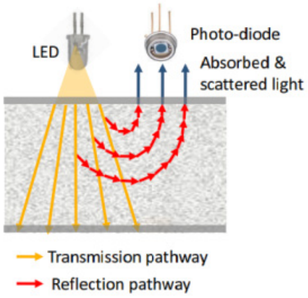

Figure 1: Transmission versus reflection pulse oximetry

In order to overcome the limitations of the state of the art, a novel reflective oximetry technique is under development at CSEM. The oximeter consists of an electronic box where the optical signals are emitted and acquired via three silicone rubber optical sensors, pre-processed for noise reduction and stored for offline SpO_2 estimation. An electro-cardiogram (ECG) is acquired too. Embedding the optical components within a rubber silicone support ensures an optimal contact between the perfused tissues and the sensing devices.

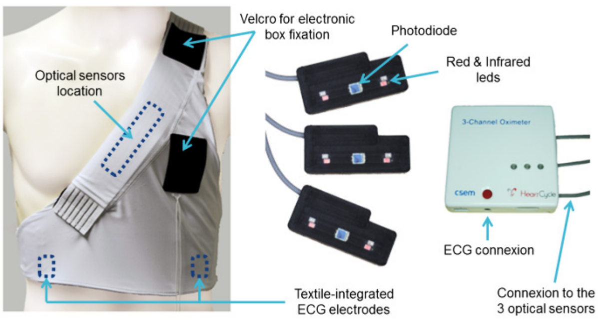

Figure 2: Shirt, flexible optical sensors and electronic box

A dedicated shirt (from the company Clothing+, Finland) firmly maintains the optical sensors in contact with the irrigated tissues at the sternum region. The ECG is measured via two textile electrodes woven into the shirt.

An innovative algorithm developed and patented at CSEM [1] exploits the cardiac information of the ECG to robustly extract the perfusion characteristics of the PPG signals. Further classification based on the computed perfusion indexes and their temporal variance enables the assessment of reliability indexes for each of the 3 optical channels, which are then combined accordingly to produce one single SpO_2 estimation.

The system has been tested on 7 healthy male subjects undergoing a decrease in blood oxygenation via mild hypoxic exposure (using the Altitrainer™ altitude simulator).

Figure 3: Validation setup for inducing hypoxic conditions. The subject breathes a low-oxygen mixture of ambient air and nitrogen

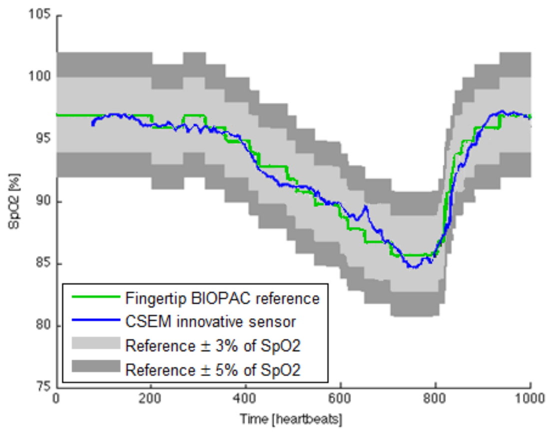

Figure 4: Example of SpO_2 estimation via CSEM chest sensor, compared to a standard commercial fingertip probe

For all subjects, a mean error of 0.44 and a standard deviation of the error of 1.49 [% of SpO_2] has been obtained. The percentage of values falling within a ±3 and ±5 [% of SpO_2] confidence intervals were 89.6% and 99.0% respectively.

This research is under development at CSEM in the framework of the FP7 European project HeartCycle. CSEM thanks the SFOET for its financial support.

[1] R. Vetter, M. Correvon, L. Rossini, A. Ridolfi, J. Solà, "Monitoring device and method for estimating blood constituent concentration for tissues with low perfusion", WO2011/026669 A1, 2011