A Novel Monitoring Solution to Reduce False Alarms in Neonatal Intensive Care Unit

M. Proença, F. Braun, D. Ferrario, A. Lemkaddem, S. Dasen, V. Moser, O. Grossenbacher

The continuous monitoring of heart rate (HR), breathing rate (BR) and oxygen saturation (SpO2) in neonatal intensive care units (NICUs) poses a significant metrological challenge. Over the last years, CSEM has been developing contactless solutions for the estimation of HR and BR, which allows a gain in patient comfort and a reduction in false alarms caused by sensor detachment. In parallel, CSEM has developed a SpO2 monitoring solution robust against limb motion, the main cause of SpO2-related false alarms in NICUs. These breakthroughs—carried out in the context of the Nano-Tera RTD project NewbornCare—are an answer to the strong clinical demand for reliable and patient-friendly monitoring solutions in NICUs.

False alarms in neonatal intensive care units (NICUs) lead to a strong overload for the medical staff and can—in the worst cases—lead to true alarms being missed. When monitoring the heart rate (HR) and the breathing rate (BR), the main cause of false alarms is the detachment of sensors, such as electrocardiographic electrodes. Regarding the monitoring of oxygen saturation (SpO2), false alarms are mainly induced by motion artifacts due to limb motion, as NICUs SpO2 probes are typically attached around the newborn's foot. In addition to being unsatisfying from a reliability viewpoint, the current monitoring setup in NICUs imposes a strong burden in terms of patient discomfort, thereby increasing the parents' anxiety. A patient-friendlier solution is strongly needed.

In the context of the Nano-Tera RTD project NewbornCare, CSEM has developed a solution—illustrated in Figure 1— aiming at filling the aforementioned loopholes of current NICUs systems. For HR and BR monitoring, CSEM's solution consists in replacing the standard wired sensors by two highly sensitive cameras allowing day (color) and night (near-infrared) vision, respectively. HR estimation is based on the analysis of pixel values in a region of interest (ROI) at the newborn's face [1]. BR estimation makes use of a motion estimation algorithm analyzing the movements of the chest ROI [2]. Both the face and chest ROIs are automatically obtained via a tracking algorithm. Regarding the monitoring of SpO2, CSEM has developed a dedicated reflectance pulse oximeter to be positioned on the forehead, a location less prone to body motion than the limbs, and thereby less prone to false alarms.

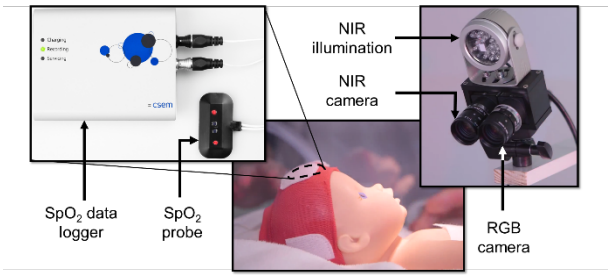

Figure 1: CSEM's monitoring solution for NICUs.

The performance of the proposed monitoring solutions was evaluated on datasets recorded on healthy adults. Figures 2, 3 and 4 (top panel) show example estimations of the HR, BR, and SpO2 algorithms, respectively. The global performance on all subjects is provided in Table 1, and complies with the accuracy requirements targeted by the NewbornCare project. The final validation of the approach will be performed in an ongoing clinical trial on newborns in NICUs at the University Hospital Zurich. Preliminary results on SpO2 monitoring in a newborn patient are shown in Figure 4 (bottom panel). Once validated, these monitoring solutions are expected to be a game changer for the reduction of false alarms in the future of NICUs.

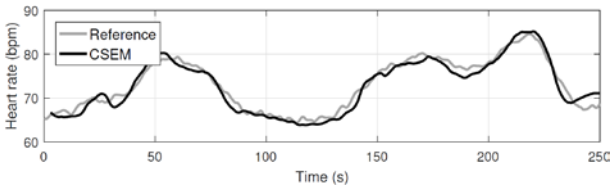

Figure 2: Example of HR validation.

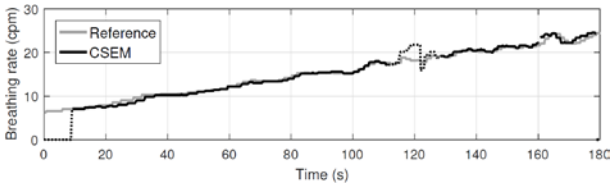

Figure 3: Example of BR validation. Dotted black lines are due to a low quality index during initialization or movement.

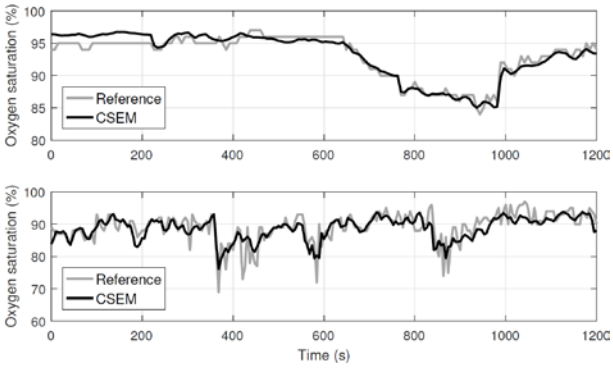

Figure 4: Example of SpO2 validation on a healthy adult (top) and on a newborn patient in NICUs (bottom).

Table 1: Performance of CSEM's monitoring solutions evaluated on datasets recorded on healthy adults.

Parameter (# of subjects)	Estimation error (mean ± SD)
Heart rate (n = 8)	0.70 ± 3.42 (bpm)
Breathing rate (n = 16)	0.20 ± 1.17 (cpm)
Oxygen saturation (n = 8)	0.07 ± 1.89 (% of SpO2)

This project was carried out in collaboration with EPFL (STI-JMV and LTS2 laboratories) and UZH (BORL laboratory and Neonatology Dept.). It was partly funded by Nano-Tera (RTD project NewbornCare).

[1] W. Wang, *et al.*, IEEE TBME, 63(9), pp. 1974-1984, 2016.

[2] F. Braun, *et al.*, Proc. of EMBEC & NBC, pp. 567-570, 2017.