A Contactless Vision-based Technology for Heart and Respiration Rates Estimation

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A contactless vision solution has been developed to estimate heart and respiratory rates. This solution is based on the real-time processing of a sequence of images taken with a camera at one meter from the subject. The face and chest are recorded at 20 frames/second. A region of interest is selected on the forehead or the cheek to estimate the heart rate while the chest is used to estimate the respiratory rate. This technology will be tested in the neonatal intensive care unit and its performance compared to current solutions, based on gel electrodes, which are sensitive to body movements and thus responsible for a high rate of false alarms.

An increasing number of parameters are monitored in the neonatal intensive care units. This results in additional sensors placed on the body of the babies generating discomfort and stress. Moreover these sensors are often sensitive to body movements. In view of reducing the sensitivity to such motion artefacts and increasing the patient's comfort, contactless solutions for vital signs monitoring are needed.

CSEM's technology uses two highly sensitive cameras:

- Day vision: UI-3240CP-C-HQ with e2v Sapphire 1.3 Mpixel sensor (color sensor)
- Night vision: UI-3240CP-NIR-GL with e2v Ruby 1.3 Mpixel sensor (monochrome sensor with enhanced sensitivity in near-infrared) combined with a near-infrared light source

Three algorithms have been developed to process the images taken with these two cameras and thus estimate the heart and respiratory rates (HR / RR). Each of them works as well in day condition as in night condition with near-infrared illumination.

The algorithm for the estimation of the RR is based on the detection of chest movements. The developed approach uses a simple projection-based motion estimation, allowing for a real-time implementation [1]. The HR estimation algorithm detects the fluctuations of the skin color in a region of interest (ROI), which are due to blood volume changes. On each frame, the mean value of pixels is computed over the ROI. A real-time adaptive band-pass filter [2] is applied on the fluctuation of this mean value to estimate the dominating frequency, corresponding to the HR. The aforementioned HR algorithm is very sensitive to movements. Therefore, CSEM had to develop a third algorithm, which allows to compensate the movements by tracking the skin region. This algorithm uses support vector machine to track the selected ROI.

CSEM acquired a database with ground truth synchronization to evaluate the developed algorithms. A total of 16 subjects (11 male / 5 female) underwent the protocol described hereafter. The protocol consists of the following three sequences which were performed twice, once with artificial light (using the color camera) and once in darkness (using a near-infrared light source and the monochrome camera):

- Respiration sequence, 4 minutes recording: to train and evaluate RR algorithm
- Handgrip sequences leading to changes in heart rate, 4 minutes recording: to train and evaluate HR algorithm
- Movement sequences, 2 minutes recording: to train and evaluate the tracking algorithm

Besides the video data (investigational device), various physiological parameters were synchronously recorded using the BIOPAC system (reference device): ECG, respiration, SpO2 and accelerometer.

CSEM combined the three algorithms in an application that allows to acquire and analyze images in real-time or to load existing ones from the database (Figure 1). Our application plays the sequence and displays the estimated heart and respiratory rates. It can superpose the ground truth curves (BIOPAC) if available.

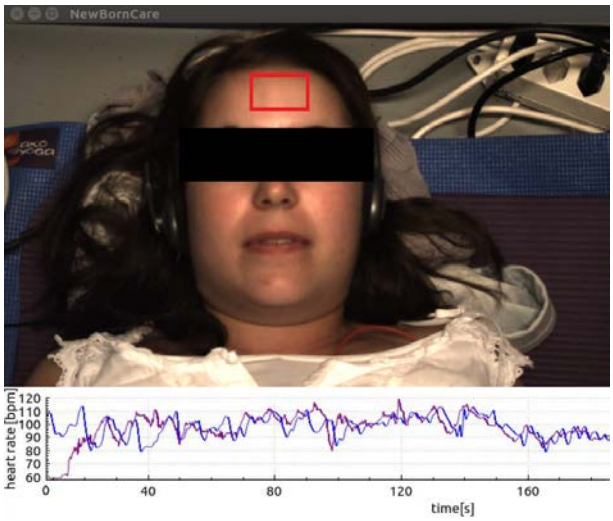

Figure 1: Application that estimates HR and RR in real-time or compares the estimated HR and RR from a video sequence with the corresponding ground truth. The tracked ROI for HR estimation is displayed in red. The mismatches that can be seen at the beginning of the sequence are due to the initialization time.

The performance of the algorithms was evaluated on the 16 adult subjects tested: The HR could be estimated with an average absolute error of 3.14/4.21 beat per minute on the visible/dark sequences, the RR could be estimated with an error of +/- 2.4 breathes per minute. These promising results - if confirmed in larger clinical datasets - could open the way for a new generation of contactless vital signs monitoring.

This work has been done in collaboration with STI-JMV and LTS2 laboratories from EPFL.

[1] F. Braun, A. Lemkaddem, V. Moser, S. Dasen, O. Grossenbacher, "Camera-based respiration monitoring", BMT (2016).

[2] S. Fallet, *et al.*, "Real-time approaches for heart rate monitoring using imaging photoplethysmography", CinC Computing in Cardiology (2016).