On-line Patient Monitoring during 6 Minute Walk Test for Improved Diagnosis

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The 6 Minute Walk Test

Measurement of exercise capacity is an integral element in assessment of patients with cardiopulmonary disease. The 6-min walk test (6MWT) provides information regarding functional capacity, response to therapy and prognosis across a range of chronic cardiopulmonary conditions. Developed in the 1960ties the 6MWT still belongs to the standard medical investigation methods. A review of functional walking test in 2001 (Sol2001) tests concluded that “the 6MWT is easy to administer, better tolerated, and more reflective of activities of daily living than the other walk tests”.

The above picture shows the set up that is commonly placed in the corridor of a hospital. Before and after the test blood pressure, heart rate and SpO₂ based on reading of the SpO₂ meter are measured, the distance covered in the 6MWT is noted, as well as post walk dyspnea and fatigue levels according to Borg scale. Special occurrences during the test such as a break or limitations of the patient to walk are also put down as remarks. The procedure details can be found in [ATS2002].

![Heart beat extraction based on the pulse oximetry signal: the raw data of the infrared channel (top) gets band-pass filtered to obtain the ac-part for heart beat extraction (2nd). The computed beat pulses (3rd) are then averaged to obtain the heart rate and a validity signal (bottom)](image1)

The main technical challenge is the suppression of motion artifacts during the 6MWT in the plethysmographic curve that contains the main information on the pulsatile arterial blood needed to calculate the average oxygen saturation level and the perfusion. In order to obtain reliable data the evaluation of the latter quantities has to be synchronized with the heart beat and to be averaged over multiple heart beat periods (typically 6-10).

A robust heart beat extraction algorithm is therefore essential for an accurate SpO₂ measurement. It was found from the analysis of several data records that the infrared channel data from the head sensor provides most reliable data for heart beat extraction.

Zoom in of the heart beat extraction: the removal of low frequency drift between the input (top) and the filtered version (2nd) is clearly visible. Autocorrelation is then applied to the filtered signal to extract the periodicity that is tracked in a window of 4 pulses to smoothen the heart rate output.

Algorithm Development for Improved Stability

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![Algorithm Development for Improved Stability](image2)

Evolution of Wearable Monitoring Devices in WearMeSoC

Bluebox System (2013)
- Main board with Bluetooth sub module board
- Cardiobio AFE with 8 ExG channels, FPGA and AVR microprocessor for signal conditioning and processing
- No non-volatile data memory
- Bluetooth classic radio

Matchbox-Size System (2016)
- Single board system
- ETH VivaSoC1 integrated solution 8 ExG channels and Pulp processor, ETH pulse oxymetry IC and AVR microprocessor
- On board NAND-Flash
- Bluetooth 4.0 radio

Oxibox System (2014)
- Modular Platform with mother board and daughter board for different applications
- ETH Cerebro AFE with 8 ExG channels, commercial pulse oximetry ICs, FPGA and AVR microprocessor
- Micro SD Card
- Bluetooth 4.0 radio

On-line Monitoring during 6MWT

The Oxibox equipment developed by ETHZ in the past year of this nano-tera project allows to continuously record the important physiological signals such as ECG and SpO₂. The forehead where the acquired signals are more stable, but weaker. The continuous recording of the relevant physiological data will allow for refined diagnosis. It is planned to use the plethysmographic waveform recording for analysis of gas exchange limitations of patients with cardiopulmonary diseases in a future study at USZ.