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WearMeSoC RTD 2013

FNSNF

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

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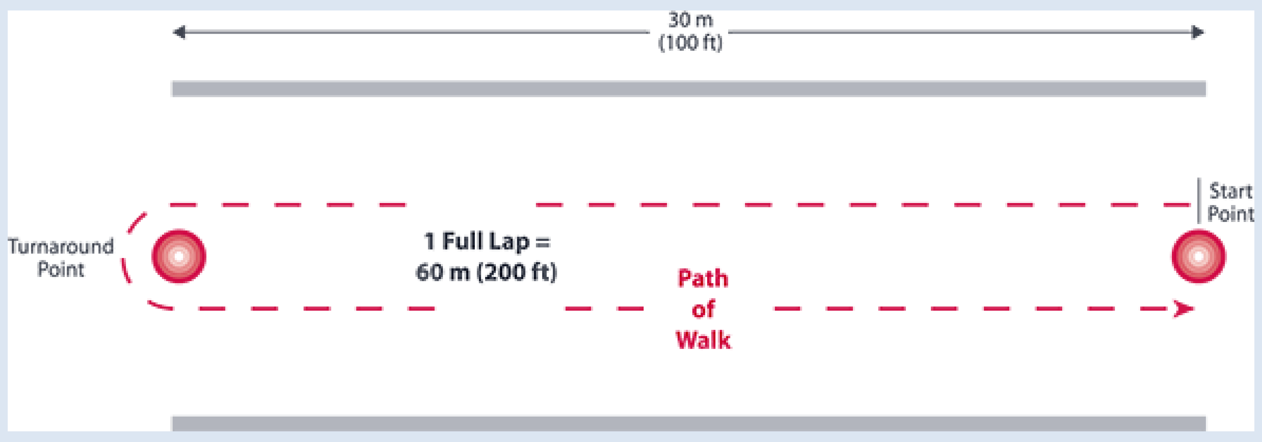
The 6 Minute Walk Test

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 1960ies 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 SpO_2 based on reading of the SpO_2 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].

[Sol2001] Solway S, Brooks D, Lacasse Y, Thomas S. A qualitative systematic overview of the measurement properties of functional walk tests used in the cardiorespiratory domain. Chest 2001;119:256–270

[ATS2002], American Thorax Society (ATS), Official Statement by the Board of Directors, ATS Statement: Guidelines for the Six-Minute Walk Test, March 2002

2. On-line Monitoring during 6MWT

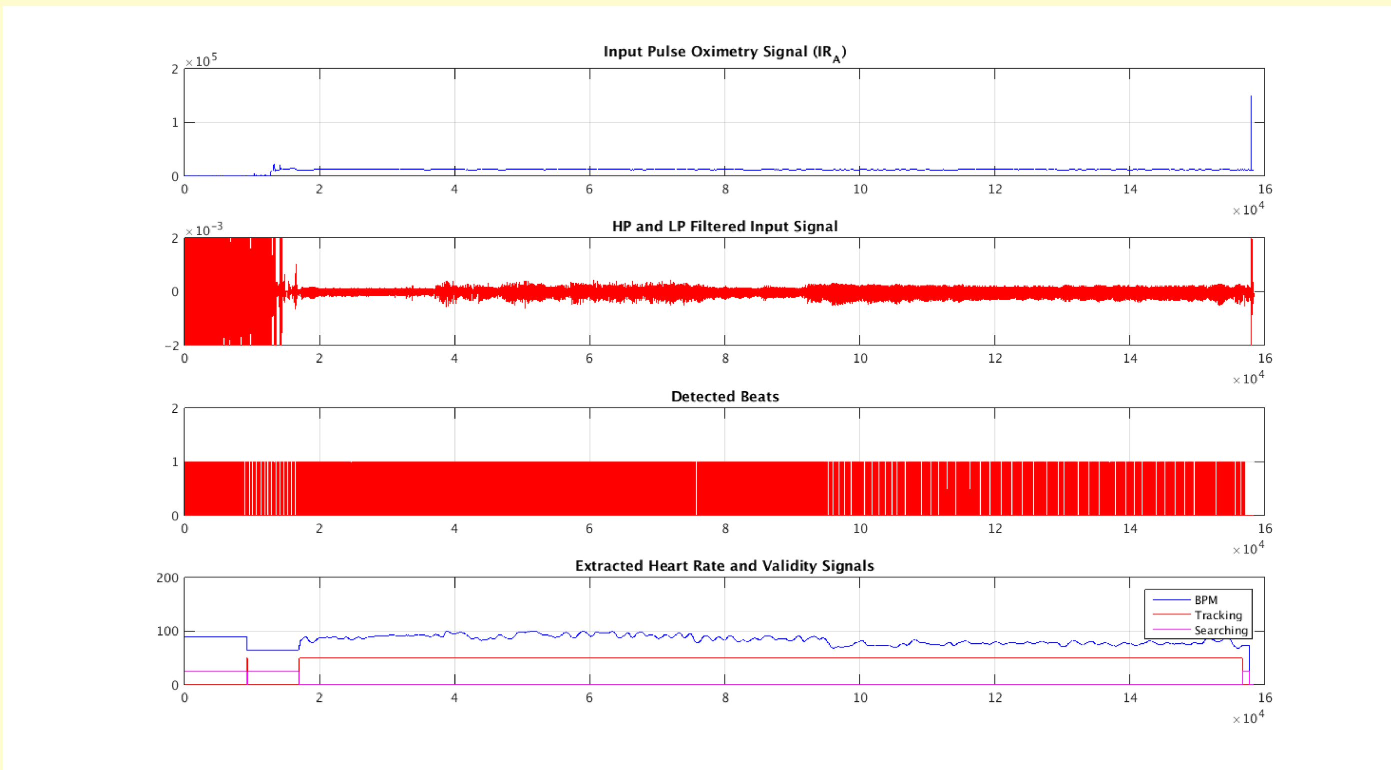
The Oxibox equipment developed by ETHZ in the past year of this nano-tera project allows to continuously record the important physiological signals such as ECG and SpO_2. the forehead where the acquired signals are more stable, but weaker.
The continuous recording of the relevant physiological data will 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.

6MWT trial at USZ with the Oxibox: test person with ECG electrodes, head and finger pulse oximetry sensor (left) and sample display of measured life data on tablet (right). The ECG signals are on top, the finger sensor signal is stronger but subject to more distortion by movement artifacts (red) and the head sensor signal is weaker, but more stable (bottom)

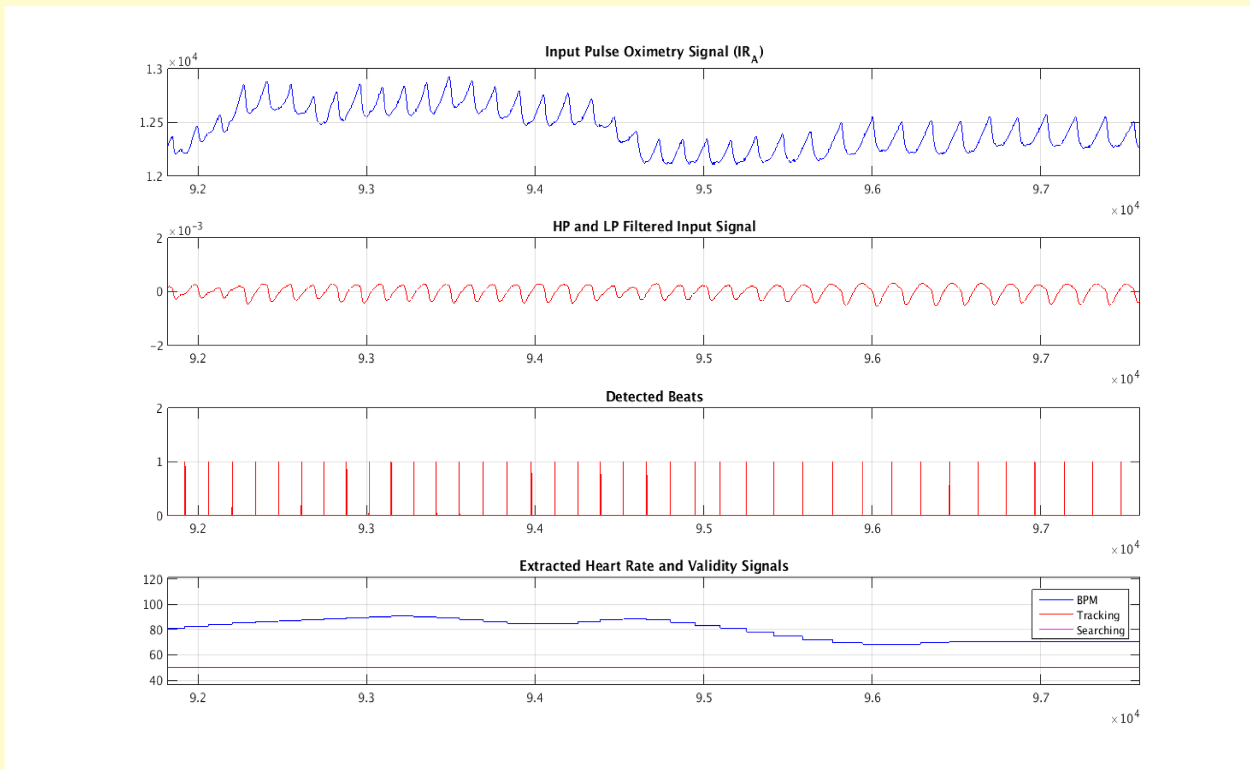
Algorithm Development for Improved Stability

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 SpO_2 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.



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)

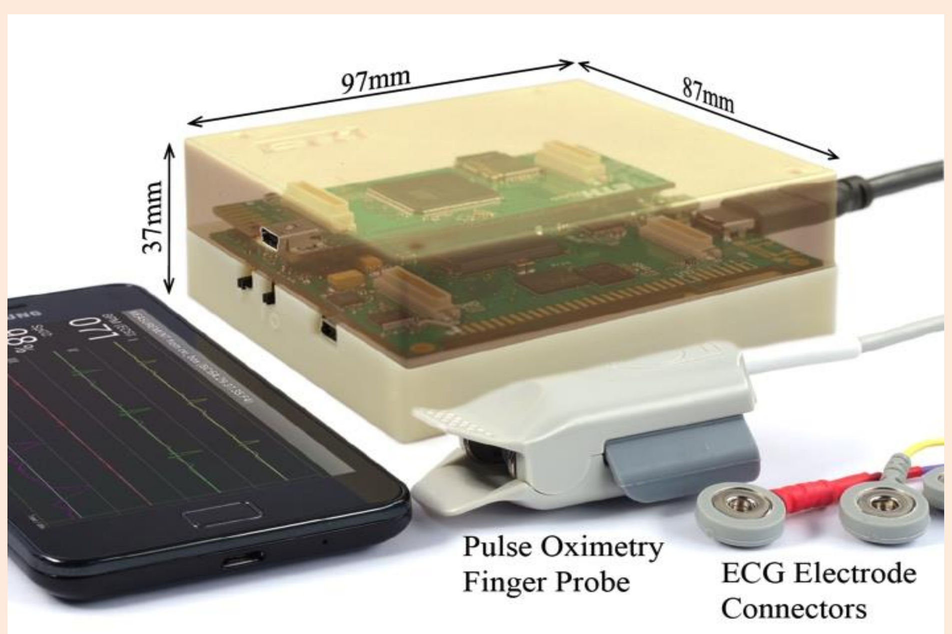


Zoom in of the heart beat extraction: the removal of low frequency drifts between the input (top) and the filtered version (2nd) is clearly visible. Autocorrelation is then applied to the filtered signal to extract the periodicity that is tracked in a window of 4 pulses to smoothen the hear rate output.

Evolution of Wearable Monitoring Devices in WearMeSoC

Bluebox System (2013)

- Main board with Bluetooth sub moduleboard
- Cerebro AFE with 8 ExG channels, FPGA and AVT microprocessor for signal conditioning and processing
- No non-volatile data memory
- Bluetooth classic 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 AVT microprocessor
- Micro SD-Card
- Bluetooth 4.0 radio

Matchbox-Size System (2016)

- Single board system
- ETH VivoSoc1 integrated solution 8 ExG channels and Pulp processor, ETH pulse oxymetry IC and AVR microprocessor
- On board NAND-Flash
- Bluetooth 4.0 radio