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Correlation of relative and global sensor motion with motion artifacts in photoplethysmograms

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Introduction

The use of pulse oximeters (Fig. 1) is spreading in low acuity ambulatory settings, such as telemetric solutions in general wards, or home monitoring of patients with chronic lung disease. In these settings pulse oximetry is heavily affected by motion artifacts, because PPGs are highly susceptible to motion. The goal of this research is improving the robustness to motion of PPG measurements, enabling reliable ambulatory oximetry.

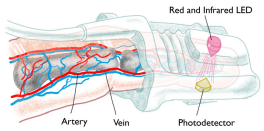

Figure 1: Pulse oximetry finger clip used to measure a patient's heart rate and blood oxygenation.

Measurement setup

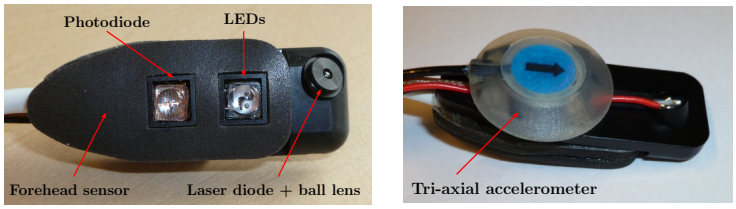

Figure 2: Customized forehead sensor to measure relative and global sensor motion.

- A laser diode and an accelerometer measure relative and global sensor motion respectively (Fig. 2).
- The forehead sensor has been attached by adhesives and a headband.
- A lead I ECG measurement provides a heart rate (HR) reference.
- A commercial pulse oximeter provides an oxygen saturation (SpO_2) reference.
- One subject walked on a treadmill at different speeds to generate motion artifacts.

Results

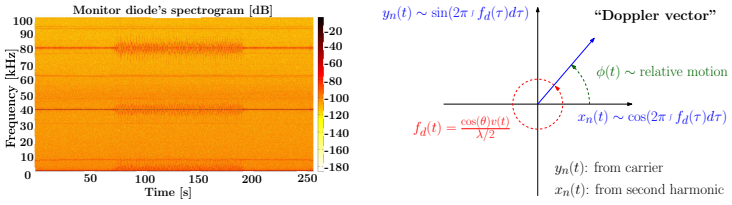

Figure 3: Relative sensor motion is measured via self-mixing interferometry. The phase of the Doppler vector gives the relative motion.

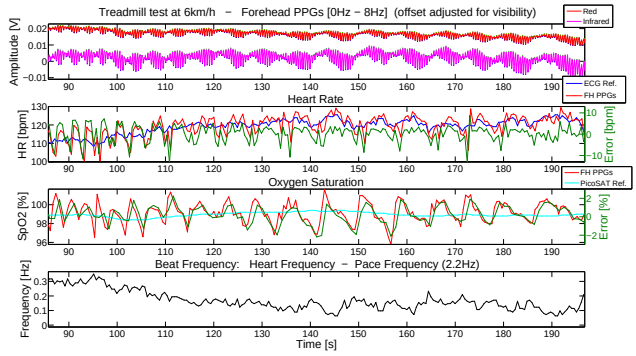

Figure 4: The effect of walking on PPGs and the derived HR and SpO_2.

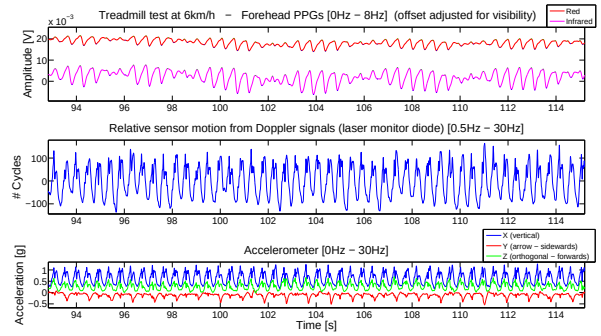

Figure 5: Relative and global sensor motion during walking.

Speed [km/h]	HR error: mean ± std [BPM]		SpO_2 error: mean ± std [%]	
	Rest	Motion	Rest	Motion
4	0.0576 ± 1.19	0.0958 ± 2.05	0.328 ± 0.507	0.294 ± 0.641
5	0.0414 ± 1.11	0.139 ± 2.92	0.704 ± 0.57	0.151 ± 0.891
6	0.0134 ± 1.10	0.361 ± 5.64	0.465 ± 0.599	0.291 ± 0.988
7	0.019 ± 1.16	0.328 ± 5.38	0.872 ± 0.604	0.234 ± 1.15

Table 1: HR and SpO_2 error versus speed of walking.

Conclusions

- While walking at constant speed, a beat phenomenon at $f_{beat} = |f_{HR} - f_{pace}|$ Hz is observed in forehead PPGs, affecting both HR and SpO_2 accuracy.
- The beating phenomenon suggests an additive motion artifact.
- During walking the relative sensor motion correlates best with the vertical accelerometer axis.
- Both measures of motion may perform comparably as artifact reference to suppress the beating effect and improve HR and SpO_2 accuracy.