Novel ALIS™ Blood Flow index for improved health monitoring

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Summary

Non-invasive technologies in wearable health devices have become increasingly important due to the rising demand for remote health monitoring (RHM). Among these, photoplethysmography (PPG) is a widely adopted method that measures light absorption, mainly reflecting fluctuations in peripheral blood volume.

Praxa Sense has developed a novel sensor, ALIS™, that integrates the measurement of both light absorption and scattering. Alongside the traditional PPG signal, it provides an additional Blood Flow index (BFi). Establishing the relationship between flow velocity and the BFi signal is key for understanding and advancing this novel scattering-based technique. Controlled in-vitro experiments demonstrate a predictable alignment between the BFi signal and physiologically representative flow velocities, with an average mean percentage error (MPE) of −0.80±6.73%.

By combining BFi and PPG signals, ALIS™ offers a more comprehensive assessment of peripheral blood circulation, establishing a foundation for advanced algorithm development in RHM.

Background

As the healthcare system faces increasing pressure, the demand for remote health monitoring (RHM) methods is rising. In recent years, optical technologies have become essential in the field of RHM.

One of the most widely used optical methods is photoplethysmography (PPG), a simple, low-cost, non-invasive technique that utilizes a light emitting diode (LED) and photodiode to monitor vital parameters like heart rate and peripheral oxygen saturation. PPGs simple configuration allows a high degree of miniaturization and easy integration, which has made the technology very popular for wearable devices. The principle of PPG is based on light absorption, where light is emitted from the LED into the skin, and the variations in light absorption during the cardiac cycle are measured to assess vital parameters.

Although PPG technology has advanced significantly, like all biosignals it still faces inherent challenges. PPG signals are influenced by noise artefacts, particularly in ambulant conditions, complicating interpretation and analysis. Moreover, the full physiological origins of the signal remain an area of ongoing research. [1] These factors highlight the complexities of using PPG to develop reliable algorithms for predicting advanced vital parameters.

A complimentary approach can be the use of a sensing technique based on diffusing-wave spectroscopy (DWS) methods. DWS utilizes a coherent light source and rather measures the dynamics of scattering than absorption in the skin. [2] Based on these methods, Praxa Sense has developed a novel wearable sensor called ALIS™. The sensor quantifies both absorption and scattering and delivers the traditional PPG data along with a Blood Flow index (BFi), enabling the measurement of physiological features related to respectively mainly blood volume and blood flow velocity. ALIS™ aims to harness the strengths of both technologies, enhancing the accuracy and reliability of vital parameter monitoring in remote health applications.

Estimating Flow Velocity

The ALIS™ scattering-based technique is novel, making it valuable to understand the origin and behavior of the BFi signal. The aim was to explore the relationship between flow velocity and ALIS™ BFi signal amplitude.

To achieve this goal, a controlled laboratory setup was developed. A blood-mimicking fluid was pumped through a skin-mimicking phantom with a stepwise increase in flow, matching the flow velocities expected in the upper layers of skin vasculature (Figure 1). [3–6] The phantom contained rigid tubing as vessel representation to ensure that any signal detected by ALIS™ was attributed solely to variations in flow velocity, rather than changes in volume.

Eight in-vitro measurement series were conducted to investigate the relationship between flow velocity and ALIS™ BFi. To model the relationship between flow velocity and BFi, a temporal scattering correlation model was applied to the data, enabling the understanding and prediction of the behavior of the BFi. The model was fitted to every other data point for each measurement series. The remaining test data points were compared to the fitted model prediction to calculate the mean percentage error (MPE).

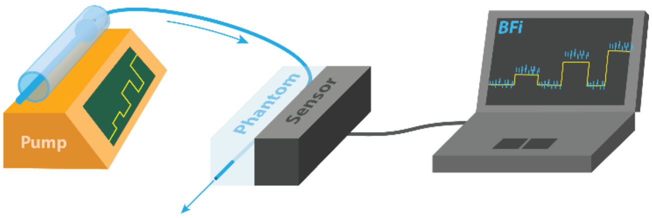

Figure 1. Schematic diagram of in-vitro setup.

Results and Interpretation

Figure 2 illustrates a representative in-vitro measurement series, highlighting the data points for respectively model fitting and testing, and the fitted model. For all measurement series, the fitted model demonstrated strong visual alignment with the measurement data. The bottom panel of Figure 2 summarizes the MPE across all measurement series. Combining all flow ranges, the average MPE was −0.80±6.73%. The MPE was largest for the lowest and highest flow ranges, which is to be expected since the scattering correlation model was fitted to limited measurement points. Nevertheless, with respectively an MPE of −7.88±7.86% and −6.55±5.89%, the highest average MPEs remained within a 10% deviation. These results demonstrate that the behavior of the ALIS™ BFi aligns with our expected scattering correlation model and that it has a predictable relationship to physiologically representative flow velocities.

By providing two distinct yet complementary signals – peripheral blood volume (ALIS™ PPG) and blood flow velocity (ALIS™ BFi) – the ALIS™ aims at delivering a more comprehensive assessment of vital parameters. Integration of this additional layer of information forms the groundwork for developing reliable advanced vital parameter algorithms for RHM.

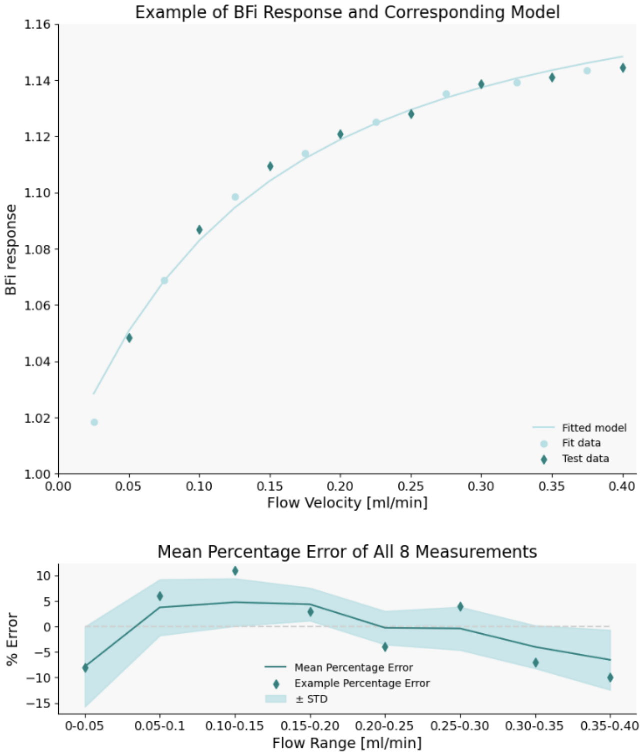

Figure 2. Top: Example of ALIS™ Blood Flow index response and corresponding fitted scattering correlation model on measurement fit data. Bottom: MPEs of all eight measurement series. The MPEs were calculated per flow velocity range and averaged across all eight measurement series.

References

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