Subject: Estimating Pulse Transit Time and Arterial Stiffness Using Seismocardiography and Ballistocardiography Sensors

Location: Cardiology Department, Université libre de Bruxelles (Brussels, Belgium)

Context

The assessment of arterial stiffness is a key indicator of cardiovascular health and a predictor of adverse cardiovascular events. A widely used surrogate for arterial stiffness is Pulse Wave Velocity (PWV), which can be estimated non-invasively using Pulse Transit Time (PTT)—the time it takes for the arterial pulse wave to travel between two sites in the circulatory system.

Recent advances in wearable sensors have enabled the measurement of mechanical signals associated with cardiac activity through techniques such as Seismocardiography (SCG) and Ballistocardiography (BCG). SCG captures local chest wall vibrations using accelerometers, while BCG records the recoil of the entire body due to cardiac ejection forces, typically from a sensor placed under the back or feet.

When combined, SCG and BCG can offer a unique way to estimate the timing of central and peripheral cardiac events. This enables the estimation of PTT—and therefore provides a proxy for arterial stiffness—using compact, wearable, or even contactless systems.

At the Erasme Hospital, a unique dataset is already available, including simultaneous SCG and BCG recordings from healthy volunteers undergoing bedrest protocols, as well as cardiac MRI-derived PWV measurements. This provides an exceptional opportunity to correlate mechanical signal-derived PTT with ground-truth arterial stiffness values. Additionally, the student will be able to design and conduct a small pilot protocol to test new hypotheses or sensor configurations.

Master thesis project

- Literature Review: The student will begin by reviewing the state of the art on PTT estimation, arterial stiffness, SCG and BCG signal analysis, and relevant validation methods. Emphasis will be placed on understanding the temporal correspondence between signal landmarks and physiological events.
- Signal Processing Development: Preprocess SCG and BCG signals to remove noise and motion artifacts, synchronize signals, and identify relevant fiducial points such as the aortic opening or foot of the pulse wave.
- PTT Estimation Algorithm: Design and implement algorithms to estimate PTT from the time delay between SCG and BCG features. Explore different combinations of signal landmarks, filters, and signal fusion strategies.
- Validation Against MRI-Derived PWV: Compare estimated PTT values with ground truth PWV measurements obtained from cardiac MRI in the existing dataset. Statistical methods will be used to evaluate correlations and model accuracy.
- Pilot Protocol Development and Testing: Design a small-scale experimental protocol to test new ideas, such as alternative sensor placements or additional modalities (e.g., photoplethysmography). The student will be involved in data collection and initial analysis.

Scientific environment

The student will collaborate with an interdisciplinary team of engineers, cardiologists, and researchers at the Erasme Hospital's Cardiology Department. This vibrant environment offers extensive expertise in cardiac

signal processing. The intern will also have access to laboratories located at the Erasme Hospital (LPHYS, Department of Cardiology).

Keywords: Seismocardiography, Ballistocardiography, Pulse Transit Time, Arterial Stiffness, Pulse Wave Velocity, Signal Processing, Cardiovascular Health, Bedrest Study.

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Bibliography

O. T. Inan et al., “Ballistocardiography and seismocardiography: a review of recent advances,” IEEE J. Biomed. Health Inform., vol. 19, no. 4, pp. 1414–1427, Jul. 2015, doi: 10.1109/JBHI.2014.2361732.

A. Hossein et al., “Accurate Detection of Dobutamine-induced Haemodynamic Changes by Kino-Cardiography: A Randomised Double-Blind Placebo-Controlled Validation Study”, Sci. Rep., vol. 9, no. 1, pp. 1–11, Jul. 2019, doi: 10.1038/s41598-019-46823-3.

J. Rabineau et al., “Closed-Loop Multiscale Computational Model of Human Blood Circulation. Applications to Ballistocardiography.”, Front. Physiol., 12:734311, Nov. 2021, doi: 10.3389/fphys.2021.734311