PRELIMINARY INVESTIGATION OF NON-INVASIVE BLOOD PRESSURE ESTIMATION USING SPECKLE CONTRAST OPTICAL SPECTROSCOPY

Ariane Garrett, Department of Biomedical Engineering, Boston University
arianeg@bu.edu
Byungchan Kim, Department of Biomedical Engineering, Boston University
Edbert J. Sie, Reality Labs, Meta Platforms, Inc.
Nil Z. Gurel, Reality Labs, Meta Platforms, Inc.
David A. Boas, Department of Biomedical Engineering, Boston University
Darren Roblyer, Department of Biomedical Engineering, Boston University

Key Words: Blood pressure, speckle contrast optical spectroscopy, photoplethysmography

Speckle contrast optical spectroscopy (SCOS) allows for optical measurement of blood flow. When speckle images are acquired at a sufficient sampling rate, changes in blood flow within each cardiac pulse can be resolved. Similarly to the photoplethysmogram (PPG), which measures changes in blood volume at each cardiac pulse, the pulsatile speckle waveform measures changes in blood flow index (BFi). Although the signals are extracted from the same images, the PPG and BFi waveforms are morphologically and temporally distinct. There has been extensive research utilizing the PPG signal to estimate blood pressure, however errors remain unacceptable for clinical use.

Previously, we investigated correlations between features extracted from the BFi and PPG waveforms and blood pressure. We found that features extracted from the BFi waveforms and features combining both blood flow and volume information were more strongly correlated with blood pressure than PPG features alone. These results suggest that the addition of BFi information could improve blood pressure estimation compared to PPG alone. To investigate this question, we acquired speckle contrast images from 30 subjects before, during, and after a leg press exercise designed to perturb blood pressure. In addition, 10 subjects were remeasured using the same protocol several weeks after the first measurement. SCOS measurements were collected at two wavelengths, 532 nm and 808 nm, at the wrist (reflectance measurement) and finger (transmission measurement) at a frequency of 390 Hz. Light was coupled to the skin and detected using multimode fibers. Noise was subtracted to obtain the fundamental speckle contrast, and the BFi and PPG time series were calculated from the speckle contrast and intensity for each image, respectively. BP measurements were simultaneously collected using the Finapres BP monitor.

To estimate blood pressure, the eXtreme Gradient Boosting (XGBoost) model was used. XGBoost has previously been used to estimate blood pressure from PPG signals and has improved calculation speed and generalizability compared with other machine learning models. The XGBoost model was used to predict blood pressure for 30 subjects using leave-one-out cross-validation (LOOCV). In addition, for the 10 subjects that were remeasured, the XGBoost model was trained on the individual subject's first measurement and predicted blood pressure for that subject's second model. The first blood pressure time point of the second measurement was used to calibrate the predicted blood pressures. For each of the 10 remeasured subjects, the best 20 optical features were selected and used to predict blood pressure. An XGBoost model trained on both BFi and PPG features was compared to a model trained only on PPG features, and the predicted blood pressures were averaged to produce a blood pressure prediction every 5 pulses. We found that the model including both BFi and PPG information predicted blood pressure with a mean error of 0.91 +/- 7.9 mmHg and a root mean square error (RMSE) of 7.9 mmHg. The model built using PPG features alone predicted blood pressure with an accuracy of 2.4 mmHg +/- 9.1 mmHg and an RMSE of 9.4 mmHg. With the addition of BFi information, blood pressure estimation was significantly improved.

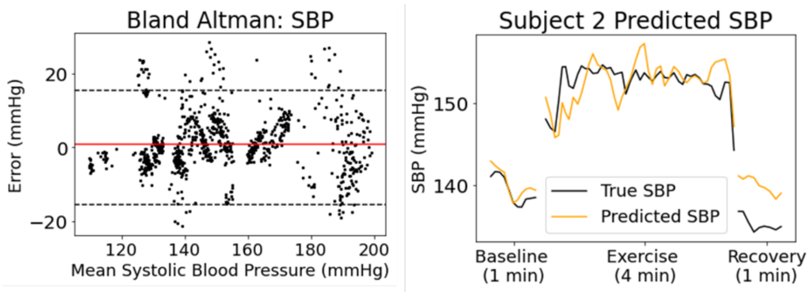

Figure 1: Left: Bland altman plot of systolic blood pressure predictions for ten subjects. Right: time trace of predicted blood pressure for subject 2 before, during, and after the exercise.