Boston University Office of the Provost
Undergraduate Research Opportunities Program

Deep Learning for Blood Pressure Estimation

Jivesh Jain[1], Ariane Garett[2], Darren Roblyer[2]

BOSTON UNIVERSITY

1. Department of Electrical and Computer Engineering , Boston University, Boston, MA
2. Department of Biomedical Engineering , Boston University, Boston, MA

Abstract

Nearly half the population in the United States is suffering from hypertension. For continuous noninvasive blood pressure estimation, various studies have constructed machine learning algorithms which use photoplethysmography [PPG] (which is an optical technique for detecting blood volume changes) and electrocardiograph (ECG) signals as inputs. In our laboratory, we are trying to show that the blood flow index [BFi] (which is an optical technique that gives information about vascular blood flow) is more correlated with blood pressure than PPG signals.Therefore, in this study, we used different deep learning techniques to estimate blood pressure for 20 subjects using the combination of BFi and PPG waveforms. Also, since we used BFi and PPG waveforms, only one optical setup was needed for taking measurements (BFi and PPG can be extracted from one waveform) and hence this made the blood pressure estimation process more practical.

Introduction

This study has the following characteristics:

1) We use a dataset that contains highly variable blood pressure data to train our model.
2) We show that BFi and PPG combination is more helpful in predicting blood pressure than PPG alone.

- For this purpose, we trained a model on features extracted from just PPG and another model on features extracted from a combination of BFi and PPG and then tested these models on the dataset.
- The deep learning model that we build consists of convolutional layers and an LSTM layer to help predict time series data more accurately. [1]

Methods

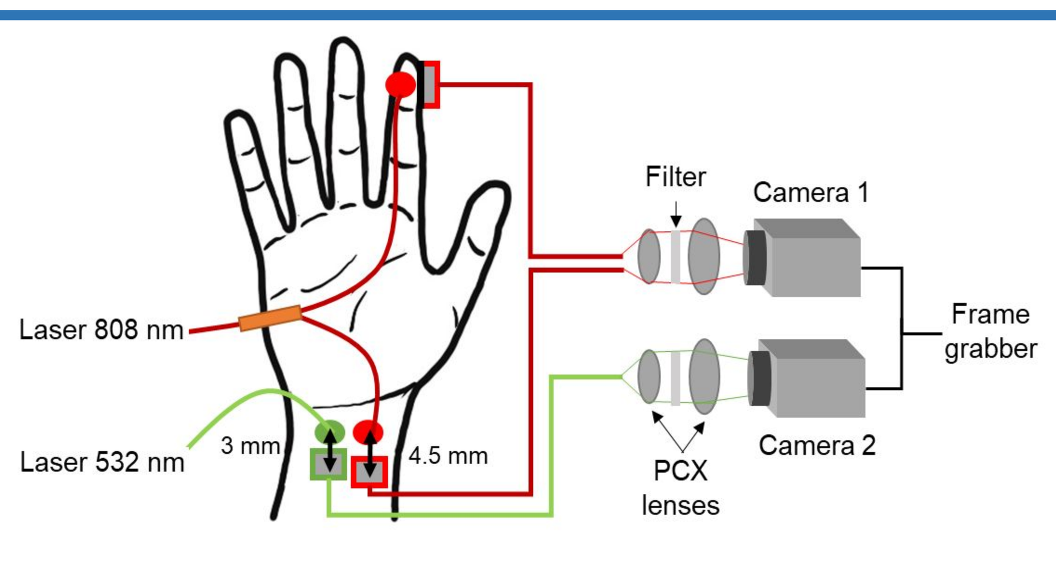

Figure 1. Measurement set up. SCOS measurements are taken on the finger and wrist.
PCX: plano-convex [2]

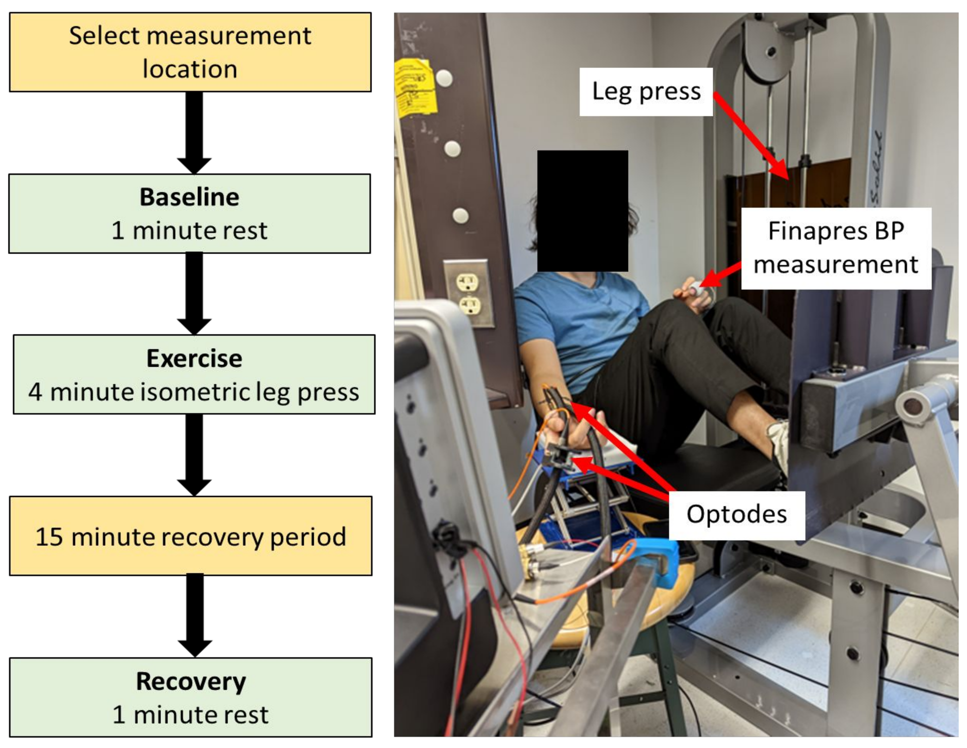

Figure 2. Measurement Setup [2]

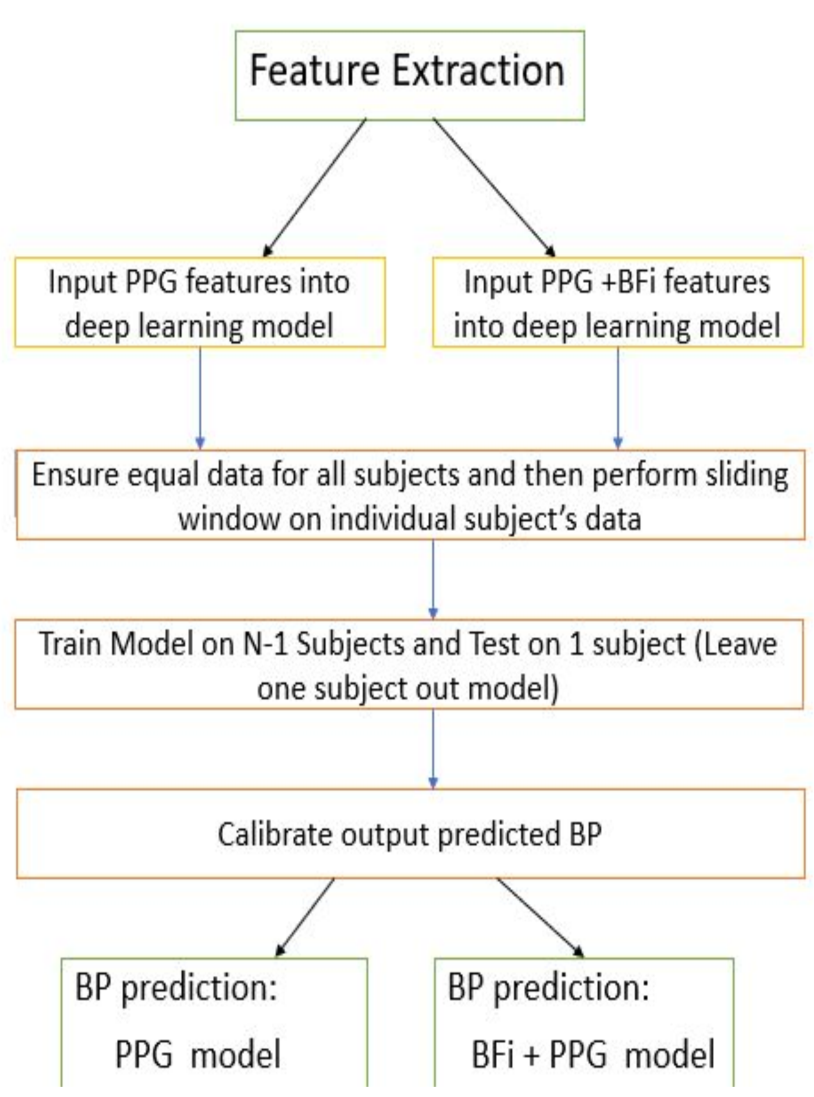

Figure 3. Blood Pressure Predicting Pipeline

Results

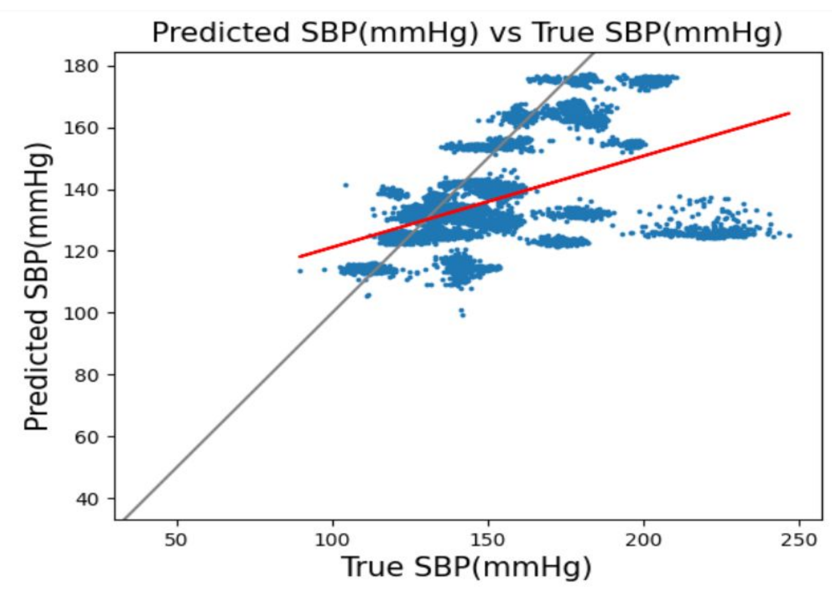

Figure 4. Correlation between predicted SBP vs True SBP as determined from only PPG features

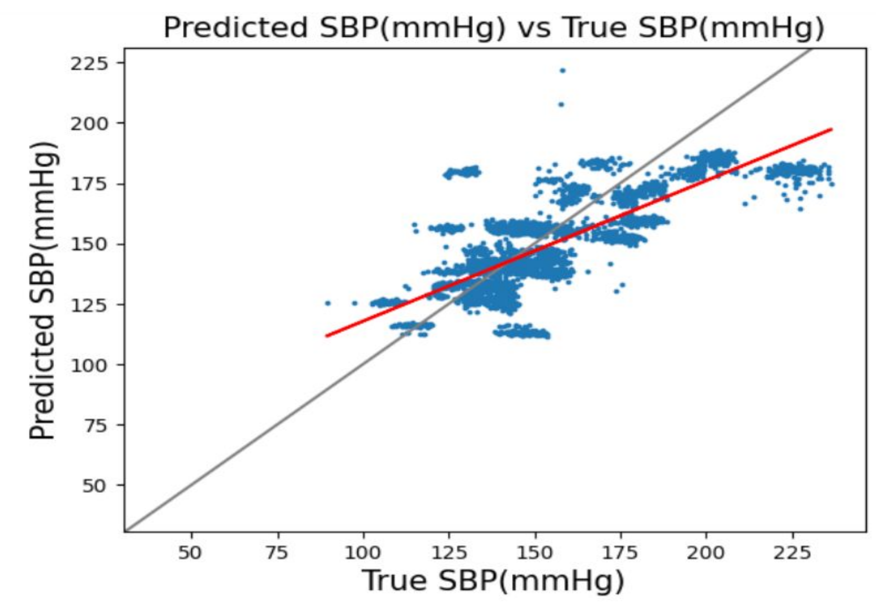

Figure 5. Correlation between predicted SBP vs True SBP as determined from BFi + PPG features

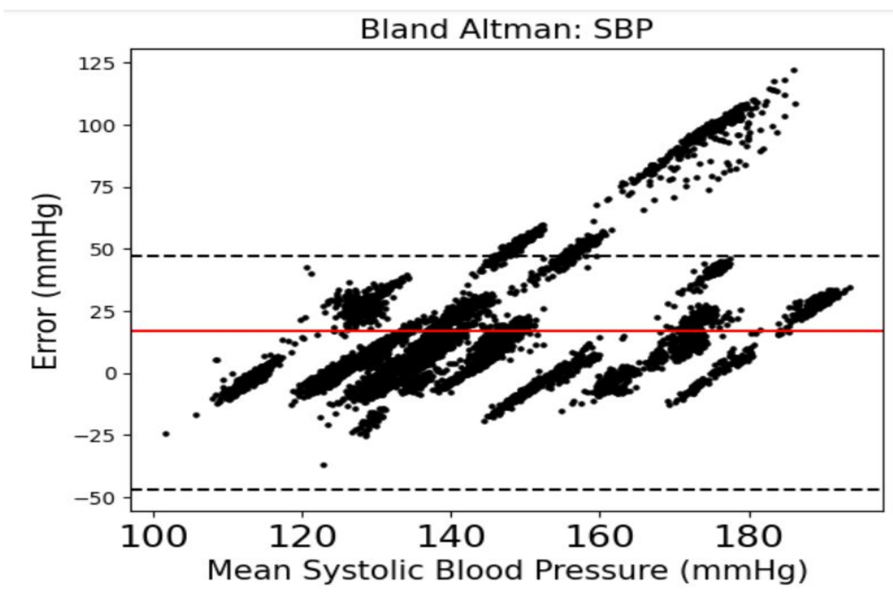

Figure 6. Bland Altman plot for predicted SBP from PPG features

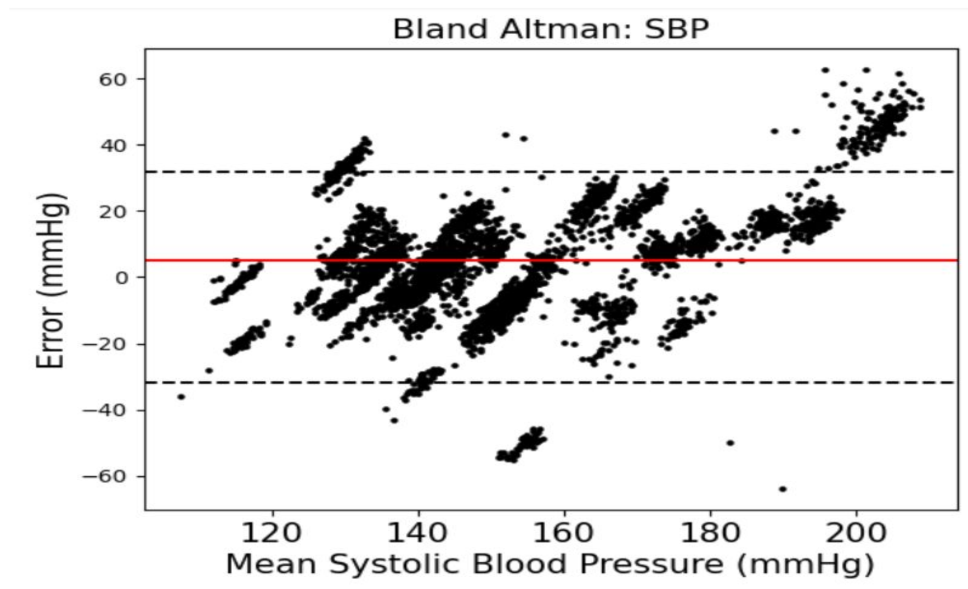

Figure 7. Bland Altman plot for predicted SBP from PPG + BFi features

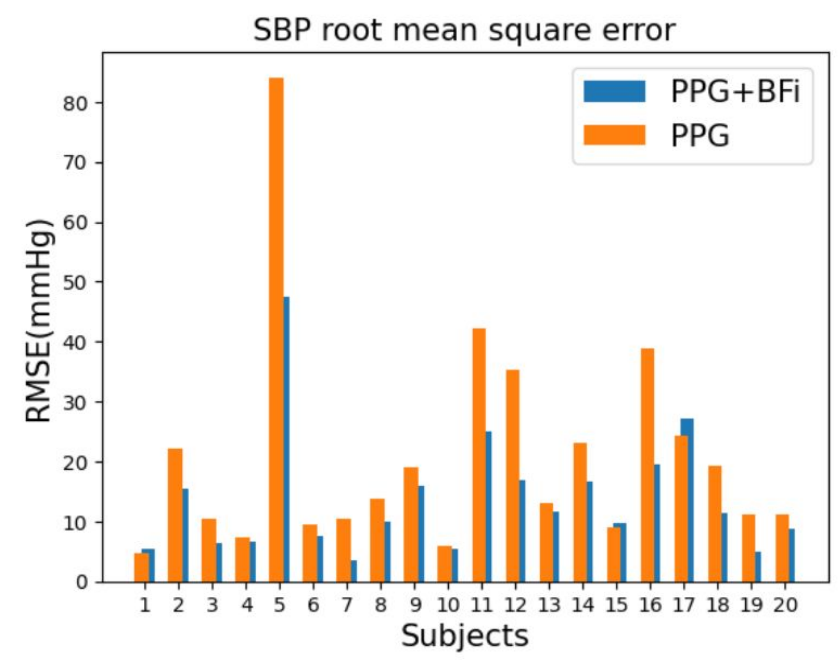

Figure 8. Comparison of Root mean Square error for different subjects

	PPG	PPG + Bfi
ME (mmHg)	15.89	5.62
SD (mmHg)	12.22	11.64
RMSE(mmHg)	20.76	13.86

33% improvement in RMSE

Table 1. Comparison between the PPG and BFi + PPG model errors

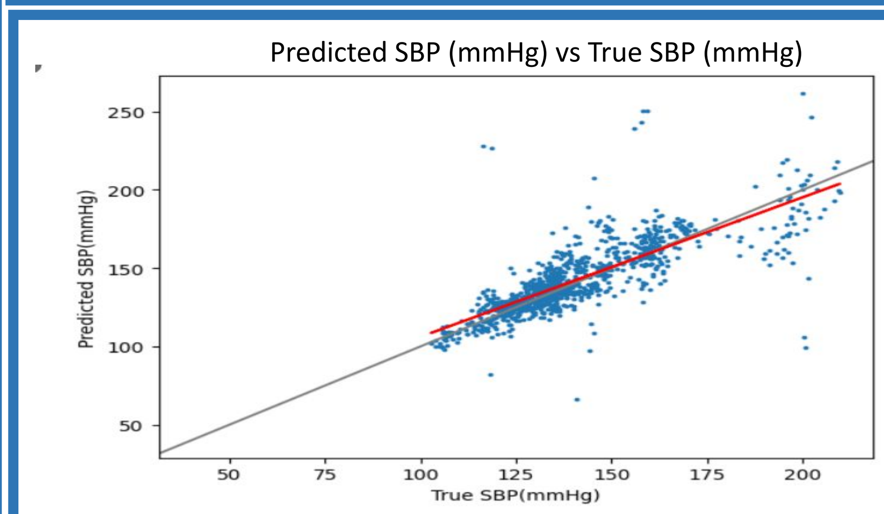

Figure 9. Correlation between Predicted SBP(mmHg) vs True SBP(mmHg) as determined from PPG + BFi features (less datapoints per subject)

	More datapoints (Baseline+Exercise)	Less Datapoints (Baseline)
ME (mmHg)	5.62	-1.71
SD (mmHg)	11.46	9.64
RMSE(mmHg)	13.86	11.26

18% improvement in RMSE

Table 2. Comparison between less data points vs more data points per subject (for the same model)

Conclusions

1) Through the graphs at the top, it is easy to conclude that BFi + PPG is a better combination for blood pressure estimation (than PPG alone).
2) The graph and table shown at the bottom of the results section prove that it is indeed easier to predict stable blood pressure values as compared to the ones which are fluctuating often.(Example- BP values of a person doing an exercise)

All these conclusions help us form considerations for what dataset to use, what model to build and which parameters to use in order to achieve portable, continuous, noninvasive blood pressure estimation.

Future Directions

Build more complex models that can help build a machine that predicts blood pressure within the error range of FDA.

-Train the model on more data in order to increase its performance .

Acknowledgements

This research was funded by Undergraduate Research Opportunities Program, Boston University

References

1. Mou, Hanlin, and Junsheng Yu. "CNN-LSTM Prediction Method for Blood Pressure Based on Pulse Wave." *Electronics*, vol. 10, no. 14, July 2021 https://doi.org/10.3390/electronics10141664
2. Garrett, Ariane et al. "Simultaneous photoplethysmography and blood flow measurements towards the estimation of blood pressure using speckle contrast optical spectroscopy". Biomedical Optics Express. 2023