A Multi-Wavelength Optical Sensing Framework for Calibration-Free Wearable Blood Pressure Monitoring

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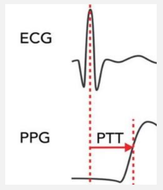
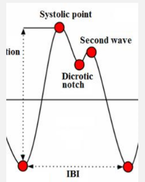
Overview

Current tools for monitor blood pressure are non-continuous, need calibration, and/or are impractical.

Cuff
Non-continuous

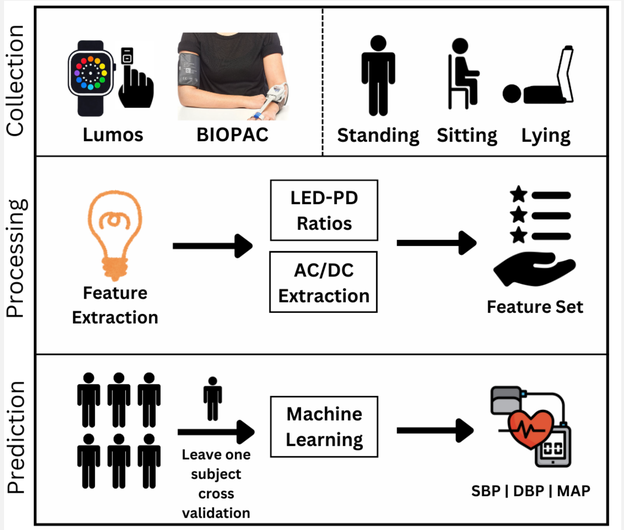


Pulse TT
Needs calibration



PPG Deep Learning
Impractical

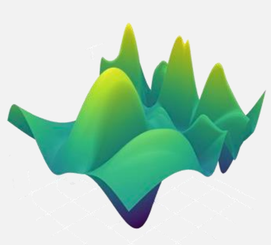
Methodology



- N=9 pilot study
- 3 minutes per posture per subject
- 90 LED-PD readings every 1.7 seconds

400-1000nm

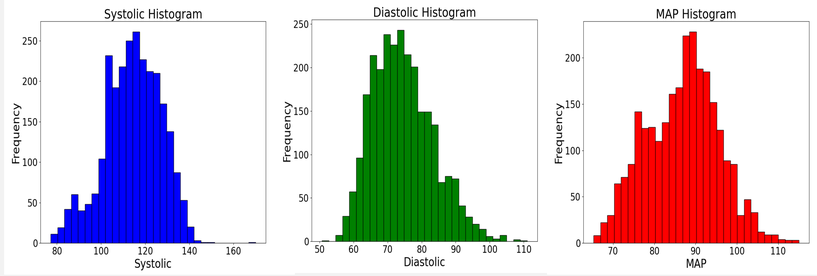
SBP-DBP-MAP



3D Projection

Results

A. Histogram of collected SBP, DBP and MAP blood pressure values



B. Subject-Specific Model Results

Model	Finger (Subject-specific)			Wrist (Subject-specific)		
	MAP MAE (SD)	Diastolic MAE (SD)	Systolic MAE (SD)	MAP MAE (SD)	Diastolic MAE (SD)	Systolic MAE (SD)
XGBoost	4.14 (0.52)	4.36 (0.41)	5.37 (0.69)	4.09 (0.50)	4.23 (0.47)	5.30 (0.97)
CatBoost	4.15 (0.60)	4.37 (0.55)	5.31 (0.76)	4.04 (0.62)	4.33 (0.55)	4.99 (0.95)
LightGBM	4.18 (0.57)	4.53 (0.54)	5.31 (0.88)	4.11 (0.53)	4.27 (0.54)	5.62 (1.40)
RandomForest	4.39 (0.65)	4.75 (0.72)	5.22 (0.82)	4.24 (0.60)	4.26 (0.48)	5.67 1.77)
GradientBoosting	5.07 (0.28)	5.43 (0.27)	6.80 (0.82)	5.07 (0.25)	5.37 (0.15)	7.27 (1.01)

C. Generalized Model Results

Model	Finger (Generalized)			Wrist (Generalized)		
	MAP MAE (SD)	Diastolic MAE (SD)	Systolic MAE (SD)	MAP MAE (SD)	Diastolic MAE (SD)	Systolic MAE (SD)
XGBoost	7.04 (2.43)	7.21 (2.14)	9.50 (3.35)	6.92 (1.69)	6.76 (1.70)	10.21 (3.25)
CatBoost	6.71 (2.31)	6.99 (2.22)	9.30 (3.29)	7.19 (2.20)	6.48 (1.60)	10.26 (3.03)
LightGBM	7.31 (2.33)	7.58 (2.11)	10.20 (2.92)	7.47 (2.22)	7.23 (2.08)	11.42 (3.91)
RandomForest	7.53 (2.44)	7.89 (2.45)	10.65 (2.84)	8.55 (2.70)	7.52 (1.65)	13.19 (5.23)
GradientBoosting	7.12 (2.32)	7.34 (2.10)	9.60 (3.17)	7.20 (1.95)	6.74 (1.72)	10.19 (3.17)

D. British Hypertension Society Compliance

Target	BHS Compliance (%)			
	≤ 5 mm	≤ 10 mm	≤ 15 mm	Grade
SBP (W)	59.8	88.0	97.0	B
DBP (W)	65.8	92.5	99.2	A
MAP (W)	68.9	93.5	99.4	A
SBP (F)	57.4	86.1	96.0	B
DBP (F)	64.5	92.7	99.3	A
MAP (F)	68.0	93.1	99.1	A

TABLE II: BHS compliance and grades for wrist (W) and finger (F) measurements.

Results cont.

E. IEEE / AAMI Compliance

Target	IEEE and AAMI Results				
	MAD	ME	SD	IEEE Grade	AAMI
SBP (W)	5.06	0.88	6.67	B	Compliant
DBP (W)	4.32	0.40	5.47	A	Compliant
MAP (W)	4.05	0.56	5.15	A	Compliant
SBP (F)	5.26	0.37	6.94	B	Compliant
DBP (F)	4.40	0.52	5.52	A	Compliant
MAP (F)	4.14	0.32	5.32	A	Compliant

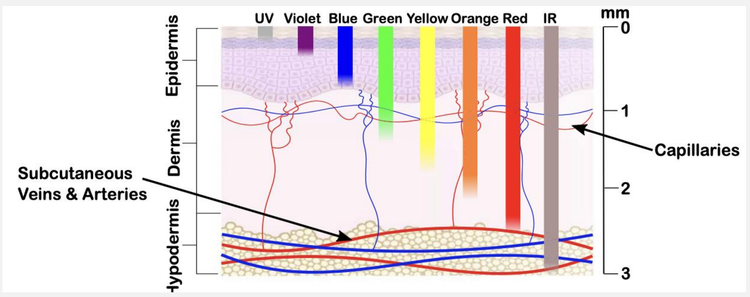
TABLE III: IEEE and AAMI results for wrist (W) and finger (F) measurements.

F. Feature Importance

PD responses in the 400-700nm range.

Feature 1: LED633-PD590 / LED670-PD415
Feature 2: LED415-PD680-DC / LED633-PD590-DC
Feature 3: LED633-PD590-IBI / LED670-PD415-IB

Future Work



D. Ray et al., "A review of wearable multi-wavelength photoplethysmography," IEEE Reviews in BME.

1. Larger sample size
2. More hypertensive / hypotensive representation
3. Diversity in skin-tone, ethnicity, race

Q: How do different wavelengths contribute to blood pressure calculation?
Q: How are different wavelengths impacted by motion artifact?