Determination of vital parameters using photoplethysmography

6th semester summer training project

Objectives of the Training

- To create backend models for integration into their MyFitPrint Application.

- To create a contact plethysmograph model for determination of heart rate.

- To create a contact and contactless model for determination of SpO2.

- To create a deep learning based model for determination of blood pressure without ECG dependency.

Techniques and Technology used

The Technique

Plethysmography

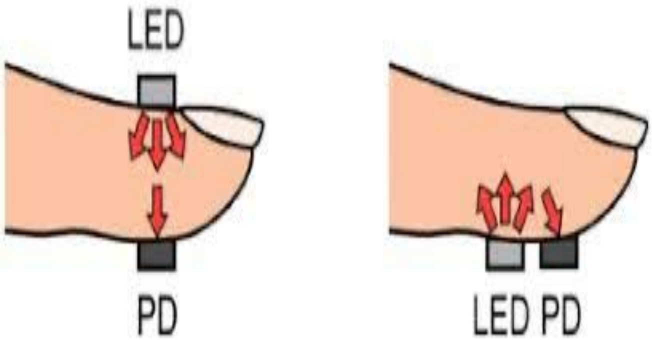
Plethysmography is the volumetric measurement of an organ, resulting from fluctuations in the amount of blood or air it contains. The change in blood volume is synchronous to the heart beat, so it can be used to detect heart rate.

Photoplethysmography

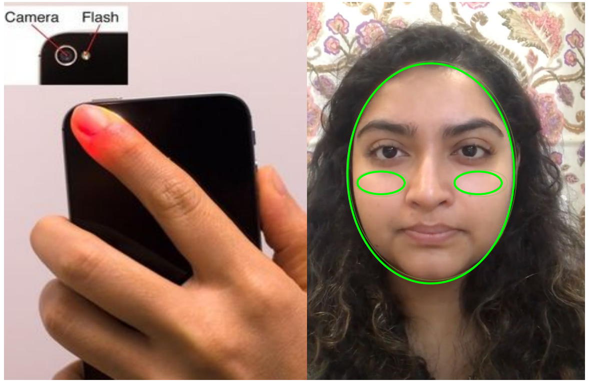
Photoplethysmography is just a means of plethysmography that uses optical techniques. There are two basic types of photoplethysmography: transmittance and reflectance. Another classification may be contact and contactless photoplethysmography.

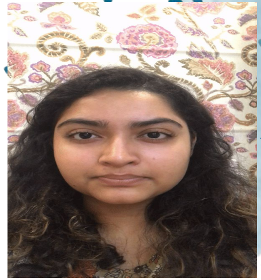
The Photoplethysmography Distinctions

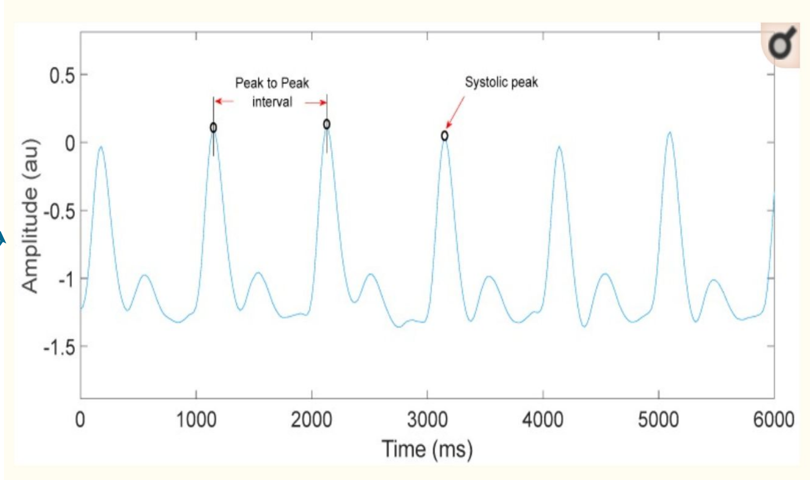
Transmittance (left) and
Reflectance (right)



Contact (left) and
Contactless (right)







Heart Rate

SpO2

Blood Pressure

Technology Stack

Python

NumPy, SciPy, Dlib, OpenCV, Matplotlib, etc.

MATLAB

For preliminary signal processing

Deep Learning

U-Nets and Residual Neural Networks for BP.

The Project

Three vital parameters: Heart Rate, SpO2, Blood Pressure

Model 1: Heart Rate Measurement

Obtaining the PPG

The photoplethysmograph is taken from a video of the fingertip between length 10-30 seconds

Filtering the signal

Band pass filtering + squaring + determination of areas of interest

Detection of Parameter

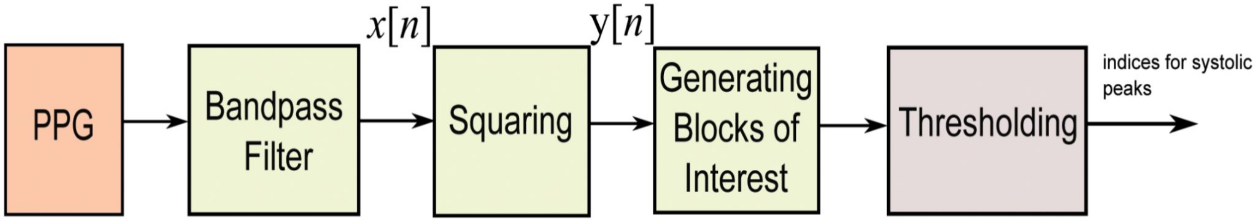
Peaks are detected in the area of interest and the overall estimation of the heart rate is made

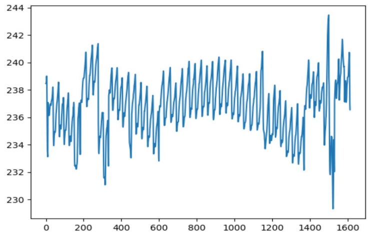
Salient Features & Advantages

- Origin Independent: The video can be from the face or the fingertip, the computation methodology from the second stage onwards, i.e, bandpass filtering remains the same.

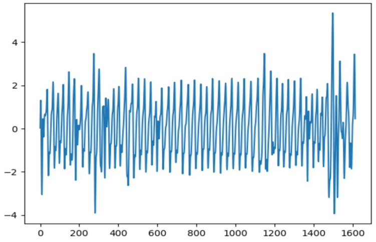
- Event-related moving averages with dynamic threshold.

- Signal adaptive and noise robust.

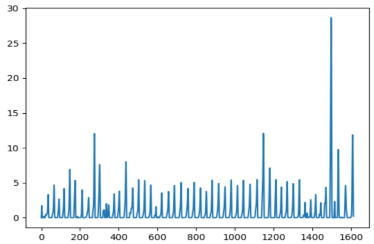




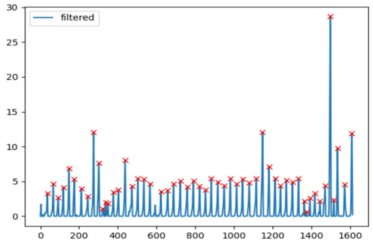
Raw PPG signal



Band pass filtering



Squaring



Thresholding and detection

Video Name	Actual BPM	Predicted BPM	Error	Error Percentage	Mean Error
102ajay	102	97.88	4.12	4.04	
104ajay	104	91.44	12.56	12.07	
106ajay	106	92.12	13.88	13.09	
20210616finger_80bpm	80	74.71	5.29	6.61	
20210616finger_85bpm(1)	85	75.18	9.82	11.55	
20210616finger_85bpm	85	78.96	6.04	7.11	
64hr_12rr_98spo2_ft	64	58.78	5.22	8.16	
65karan	65	67.23	2.23	3.43	
66karan	66	63.28	2.72	4.12	
70karan	70	66.30	3.70	5.28	
71karan	71	66.58	4.42	6.23	
93ajay	93	87.77	5.23	5.62	
98spo2_70bpm	70	63.87	6.13	8.76	
HC_10	85	76.30	8.70	10.24	
HC_3	83	78.68	4.32	5.21	
HC_4	80	72.71	7.29	9.12	
HC_5	75	74.84	0.16	0.22	
HC_6	80	77.17	2.83	3.54	6.80
HC_7	70	63.87	6.13	8.76	
HC_Dro_2	96	86.54	9.46	9.86	
HC_nit_1	85	81.97	3.03	3.57	
HC_shr_1	107	56.19	50.81	47.49	
HC_Son_2	68	60.48	7.52	11.06	
hr100	100	87.77	12.23	12.23	
hr65+	65	66.58	1.58	2.42	
hr65_2	65	67.23	2.23	3.43	
hr65_3	65	63.28	1.72	2.65	
hr70	70	66.30	3.70	5.28	
KL_rj_1	54	60.52	6.52	12.08	
KL_sha_1	64	63.51	0.49	0.77	
video2	72	75.73	3.73	5.18	
video3	80	71.77	8.23	10.29	
video4	77	73.82	3.18	4.13	
video5	80	77.07	2.93	3.66	
video6	85	75.18	9.82	11.55	

Model 2: SpO2 Measurement

Obtaining the PPG

The photoplethysmograph is taken from a video of the fingertip or face greater than 15 seconds.

Ac and Dc Component extraction

Done by taking up mean and standard deviation values of the red and blue components per frame.

Detection of Parameter

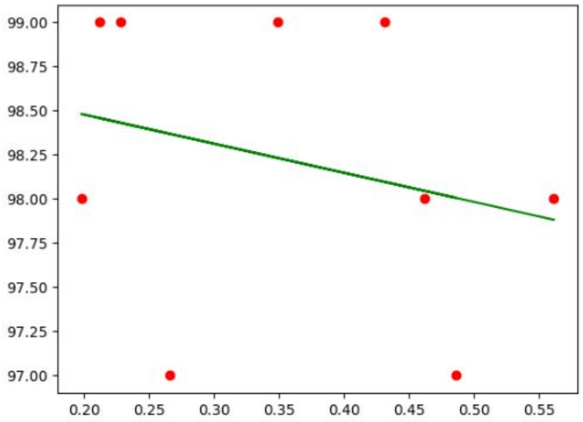
$$SpO_2 = A - B\frac{AC_{RED}/DC_{RED}}{AC_{BLUE}/DC_{BLUE}}$$

Equations Used

$$RR = \frac{AC_{\lambda 1}/DC_{\lambda 1}}{AC_{\lambda 2}/DC_{\lambda 2}}$$

$$SpO_2 = \alpha \cdot RR + \beta$$

Getting α and β



Salient Features & Advantages

- Approach works for both face and fingertip SpO2 detection.
- The noise reduction and filtering stages can be eliminated with no comparable reductions in result quality reducing the algorithm complexity.
- The videos have to be at least 15 seconds long for suitable detection.
- The α and β parameters are calibration constants that can be obtained using ground truth values for available training data set. This can be done by fitting a simple linear regression model.

Test Results

Fingertip Videos

NAME	Actual SpO2	Predicted SpO2	Error Percentage	Mean Error
HC_4.mp4		97		1.0125
104ajay.mp4		98		
HC_5.mp4		97		
HC_6.mp4		97		
20210616finger_80bpm.mp4		97		
HC_7.mp4		97		
20210616finger_85bpm(1).mp4		97		
HC_Dro_1.mp4	99	97	2.02	
20210616finger_85bpm.mp4		97		
HC_Dro_2.mp4	98	98	0	
64hr_12rr_98spo2_ft.mp4		98		
HC_Son_1.mp4	99	97	2.02	
65karan.mp4		97		
HC_Son_2.mp4	99	98	1.02	
66karan.mp4		98		
HC_Sum_1.mp4		97		
70karan.mp4		98		
HC_nit_1.mp4		98		
71karan.mp4		97		
HC_shr_1.mp4		97		
KL_rj_1.mp4	98	98	0	
98spo2_70bpm.mp4		97		
KL_sha_1.mp4	97	97	0	
HC_1.mp4		97		
VID_20210615_180226264.mp4		98		
HC_10.mp4	98	97	1.02	
HC_13.mp4		98		
hr65+.mp4		97		
hr65_2.mp4		97		
HC_2.mp4		97		
hr65_3.mp4		98		
HC_3.mp4	99	97	2.02	
hr70.mp4		98		

Face Videos

Video Name	Sctual SpO2	RR value for signal	Predicted SpO2	Error Percentage	Mean Error
video1.mp4	98	0.05712976607	100	2.04	1.27
video2.mp4	99	0.05453523164	100	1.01	
video3.mp4	98	0.0915427457	99	1.02	
video4.mp4	99	0.03758427041	100	1.01	

Model 3: Blood Pressure Measurement

Obtaining the PPG

Subsection of Physionet's MIMIC II dataset is used as photoplethysmograph sample

Approximation Network

One-dimensional deep supervised U-Net model

Refinement Network

One-dimensional MultiResUNet model and it outputs the desired ABP waveform

Salient Features & Advantages

- Instead of using mathematical approach like in case of previously discussed parameters, here a deep learning based approach is used.

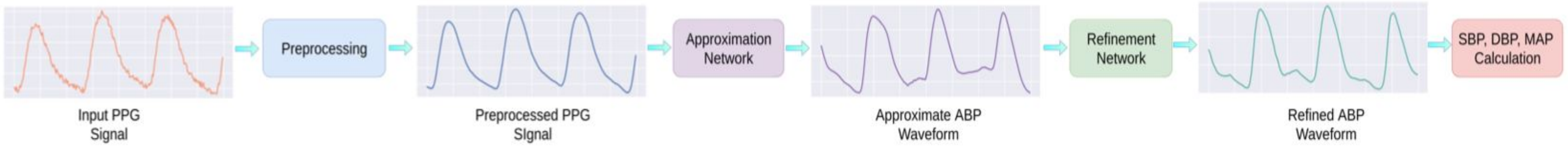
- The ABP (Ambulatory Blood Pressure) waveform is predicted using multi layer U-Net model. A combination of two a refinement and an approximation network is used for optimal results.

- From the predicted ABP waveform, the BP parameters can be calculated using →

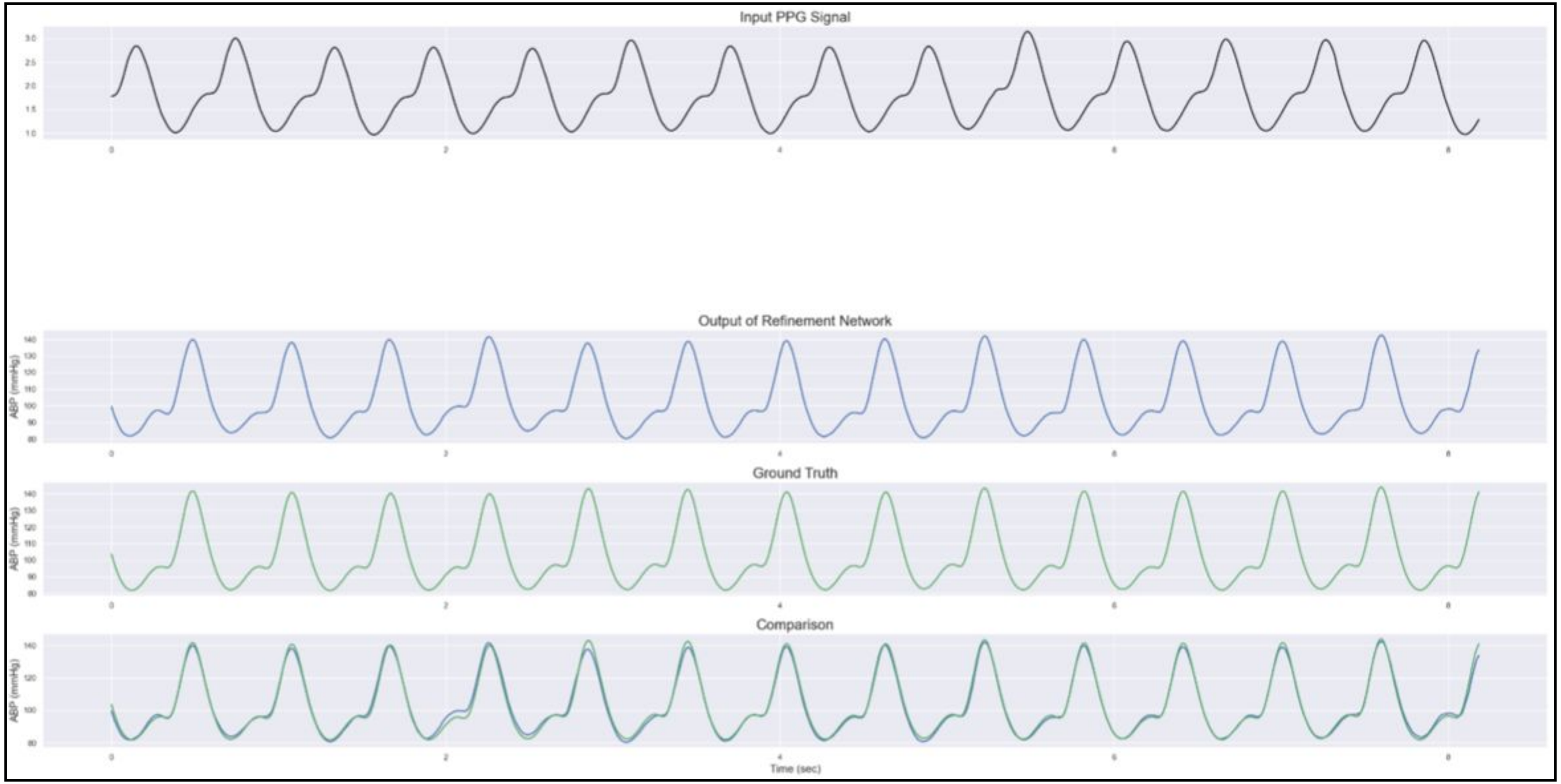
$$SBP = max(ABP)$$

$$DBP = min(ABP)$$

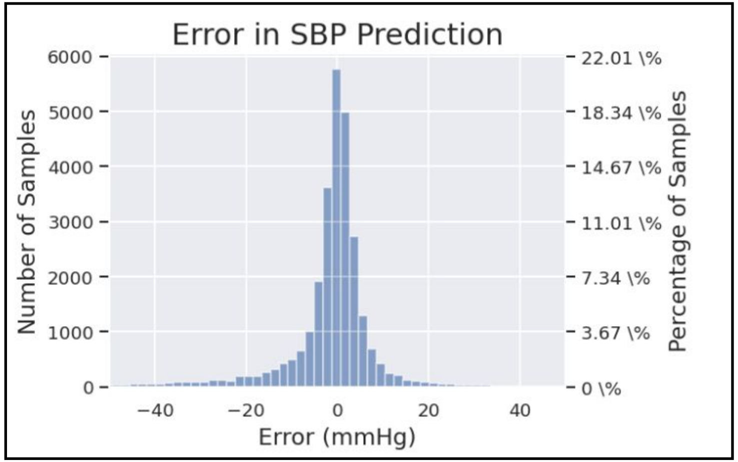
$$MAP = mean(ABP)$$

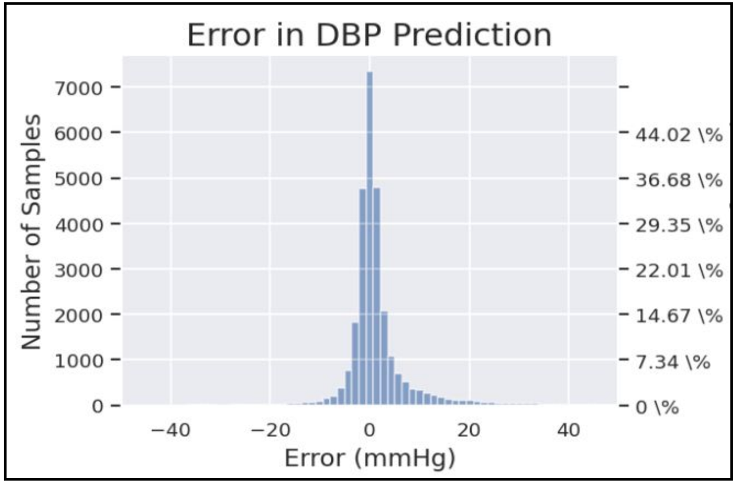


Waveform Plot



AAMI Standard		
	ME	STD
DBP	1.619	6.859
SBP	-1.582	10.688





Here, ME stands for the mean error for the test data and STD is the standard deviation for the computed errors.

Conclusions

Successful detection

All three parameters were suitably detected.

Optimal error rates

The error rates were all below the 10% mark.

Flexible signal duration

Models analysed signals for a variety of time frames without major error induction.

Thanks!

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