A data-driven approach to nocturnal diagnosis of hypertension from continuous Photoplethysmography time series

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Introduction

- Systolic Blood Pressure (BP) is the heart's force exerts on arteries wall when the heartbeats
- For continuous BP monitoring, invasive intravascular central monitoring is used which requires medical presence and contains potential risks for patient.
- Cardio Vascular Disease (CVD) like Hypertension have risen around the world making BP non invasive continuous monitoring a clinical priority
- Photoplethysmography (PPG) measures the amount of light absorbed or reflected by blood vessels close to the skin
- PPG can be measured continuously in a non invasive way and can be used to measure BP

Blood Pressure Categories

BLOOD PRESSURE CATEGORY	SYSTOLIC mm Hg (upper number)		DIASTOLIC mm Hg (lower number)
NORMAL	LESS THAN 120	and	LESS THAN 80
ELEVATED	120 – 129	and	LESS THAN 80
HIGH BLOOD PRESSURE (HYPERTENSION) STAGE 1	130 – 139	or	80 – 89
HIGH BLOOD PRESSURE (HYPERTENSION) STAGE 2	140 OR HIGHER	or	90 OR HIGHER
HYPERTENSIVE CRISIS (consult your doctor immediately)	HIGHER THAN 180	and/or	HIGHER THAN 120

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Goals

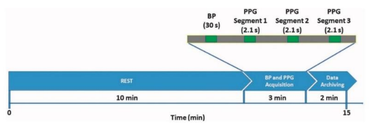
- Use PPG to monitor effectively BP continuously in a non invasive way using machine learning
  - Extracting digital biomarkers from PPG time series
  - Build a machine learning regression model to predict BP on PPG-BP database
- Apply the model on MESA Sleep to diagnose Hypertension

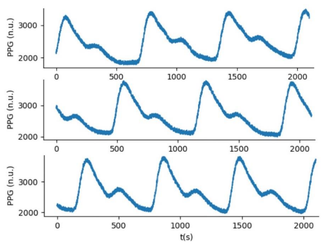
Challenges

- PPG signal non trivial preprocessing
  - Motion artifacts, respiration, age and weight modulates it
- PPG-BP has unbalanced data and few samples of extreme BP values
- Mesa Sleep has no BP values monitored during PPG monitoring

Databases

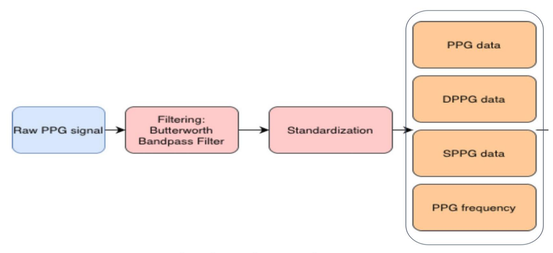
- **PPG-BP**
  - 219 patients (20-89 years old)
  - 3 daily PPG recordings of 2.1s per patients
  - Sampling rate: 1KHz
  - BP measured just before the PPG measurements



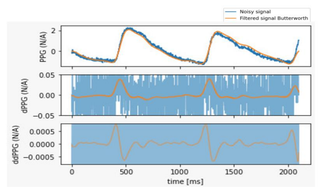


- **Mesa Sleep**
  - 2237 patients (54-95 years old)
  - 16300 hours of overnight PPG monitoring
  - Sampling rate: 250Hz
  - Hypertension labels and BP labels measured weeks before PPG recordings

Preprocessing

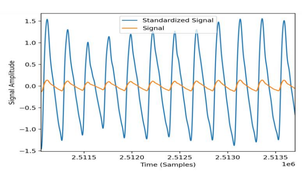


Filtering: PPG and derivatives



PPG and derivatives plot using Butterworth filter 4th order

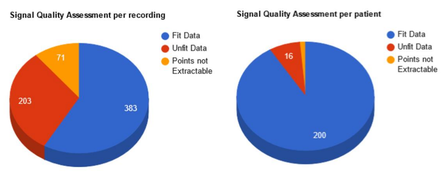
Standardization



PPG segment with standardized data

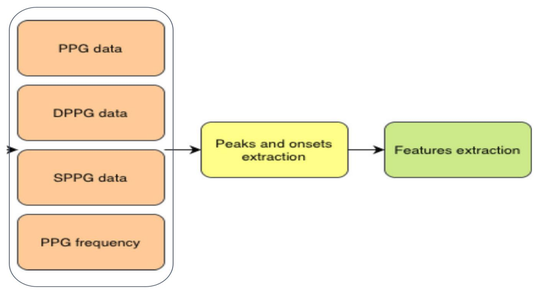
Signal Quality Assessment

- Skewness Signal Quality Index method used

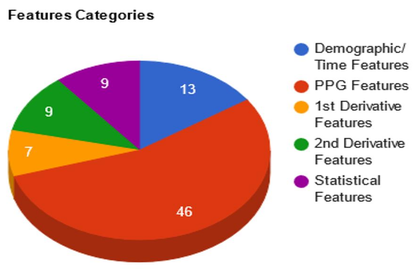


Pie charts of signal quality assessment per patient and per recording

Features Extraction

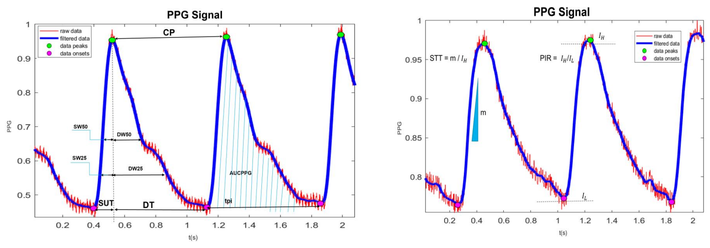


Features

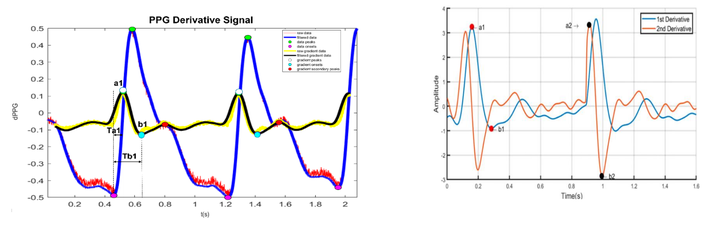


Pie chart of features categories

- PPG toolbox created containing 85 features



Examples of PPG features



Examples of DPPG and SPPG features

Machine Learning Pipeline

- Gaussian Process Regressor (GPR) and Random Forest Regressor (RF) models built
- Feature selector algorithm: Generic Univariate K best, 30 features selected
- 10 fold cross validation
- Hyperparameters tuning with Bayes optimizer

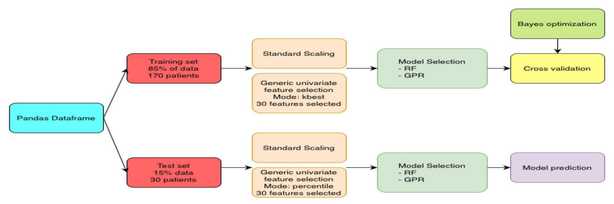


Diagram of machine learning pipeline

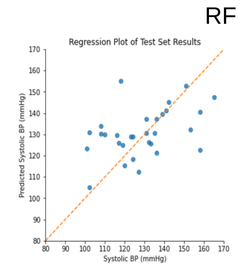
Models Performance

Feature Selection	Performance	GPR	RF	Unit
Generic Univariate Selector, mode KBest, 30 features	MAE	12.17	11,98	mmHg
	MeAE	6.22	6.76	mmHg
	MSE	278.61	252.08	mmHg2
	RMSE	16.69	15.87	mmHg

GPR

- Best performance on GPR model

RF



Observations

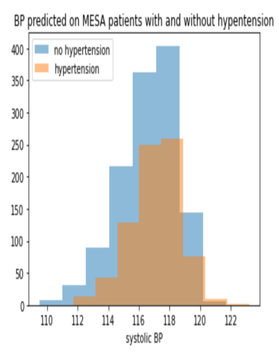
- Models predict mostly BP between 110 and 140 mmHg
- Performance influenced by unbalanced data

Experiment on Mesa

- Same preprocessing steps were applied on the Mesa dataset and same features were extracted
- The data was then split using the hypertension labels (1 or 0) and the trained machine learning models were applied on both groups

Observations and Discussion

- No shift spotted in the model prediction of both groups
- Trained models does not generalized well on noisier and bigger dataset
- PPG taken overnight while model trained with day PPG



Conclusions

- Successfully build a PPG toolbox containing 85 features
- Two models were trained, optimized and tested on PPG-BP database to predict systolic BP
- Experiment conducted on Mesa not successful due to differences between the two databases.
- Possibility to boost and improve results by adding more features to the toolbox

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