PHOTOPLETHYSMOGRAPH SIGNAL RECONSTRUCTION BASED ON A NOVEL HYBRID MOTION ARTIFACT DETECTION – REDUCTION APPROACH.
PART I: MOTION AND NOISE ARTIFACT DETECTION

Alice Sansoni Biomedical Signal Processing a.a. 2020-2021

PPG and MNA

- Photoplethysmograph (PPG): device to monitor blood volume changes on peripheral tissues. It is used to obtain HR, RR and SPO_2.
- Motion and Noise Artifacts (MNA): serious obstacles for PPG recording, difficult to filter.
- Sources:
  - *Environmental artifacts*
  - *Physiological artifacts*
  - *Experimental artifacts*
- Causes:
  - *Movement of venous blood and other non-pulsative components along with pulsatile arterial blood*
  - *Variations in the optical coupling between the sensor and the skin*

MNA detection difficulties and how the paper approaches the problem

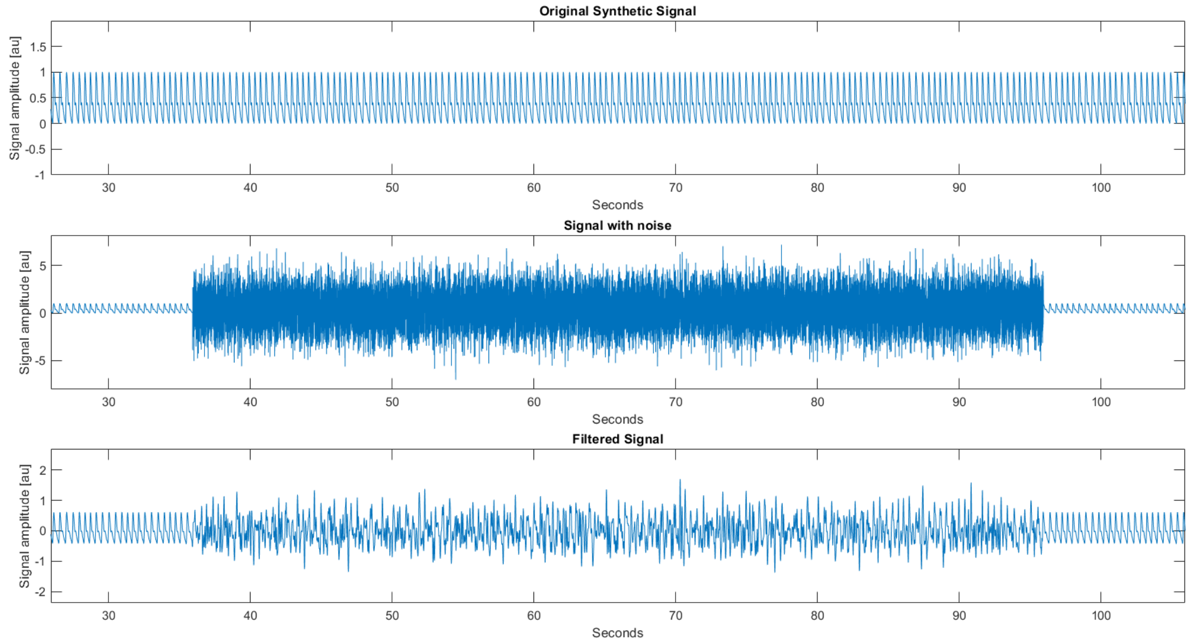
- They don’t have a predetermined frequency band
- Overlapped spectrum with the desire PPG signal
- Use of 4-time domain parameters to quantify MNA as input of a SVM because there are noticeably differences between the values of clean and corrupted parts.
- First step in order to later reconstruct the detected corrupted segments without compromising the clean part of the signal.

Dataset

- Synthetic Dataset for Respiratory Rate Estimation which simulates PPG signals.
- Three respiratory modulations:
  - *Baseline Wander (low frequency artifact in the ECG)*
  - *Amplitude Modulation (proportional to the amplitude of the signal)*
  - *Frequency Modulation (proportional to the frequency of the signal)*
- Sampling Frequency (Fs) = 500 Hz
- Number of samples = 105 000 → 210 s
- Data split by respiratory modulation and then divided into training and test phase.

Common procedure for each signal

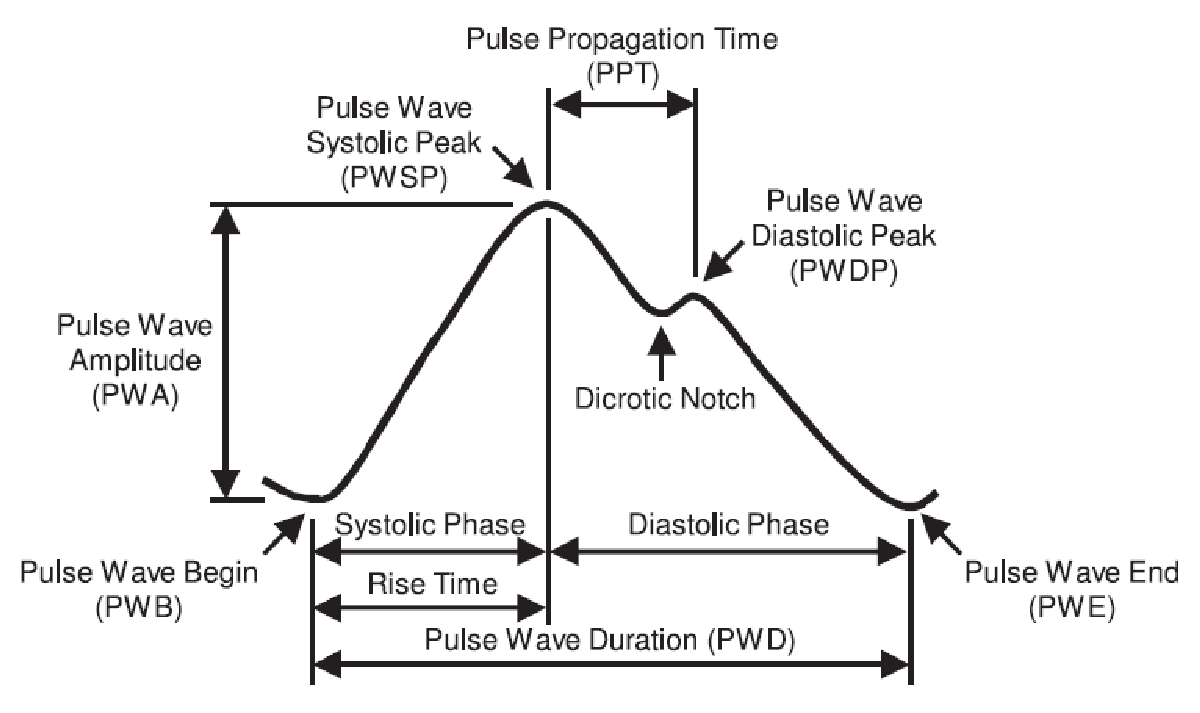
- Adding gaussian white noise
  - $Noisy\ Signal\ =\ Orginal\ Signal\ +\ \sigma(Signal)\ \cdot random\ value$
  - *To the whole signal with* $SNR\ =\ 25\ dB$
  - *To 30 000 samples (60 s), around the 29% of the total, with* $SNR\ \in [-25\ -10\ dB]$
- Applying a 3^{rd} order Butterworth bandpass filter with cutoff frequencies of 0.5 and 12 Hz
- Applying a zero phase and reverse filtering
- Splitting the signal into 7-seconds long segments, 30 in total.
- For each segment:
  - *Computing 4 parameters*
  - *Computing labels: 0 = clean, 1 = corrupted (if less than 85% of the segment is free from noise)*



Example of **a)** Syntetic Signal **b)** Signal with white gaussian noise, SNR = -15 **c)** Filtered signal using 3-rd order Butterworth and forward and reverse Zerophase filter

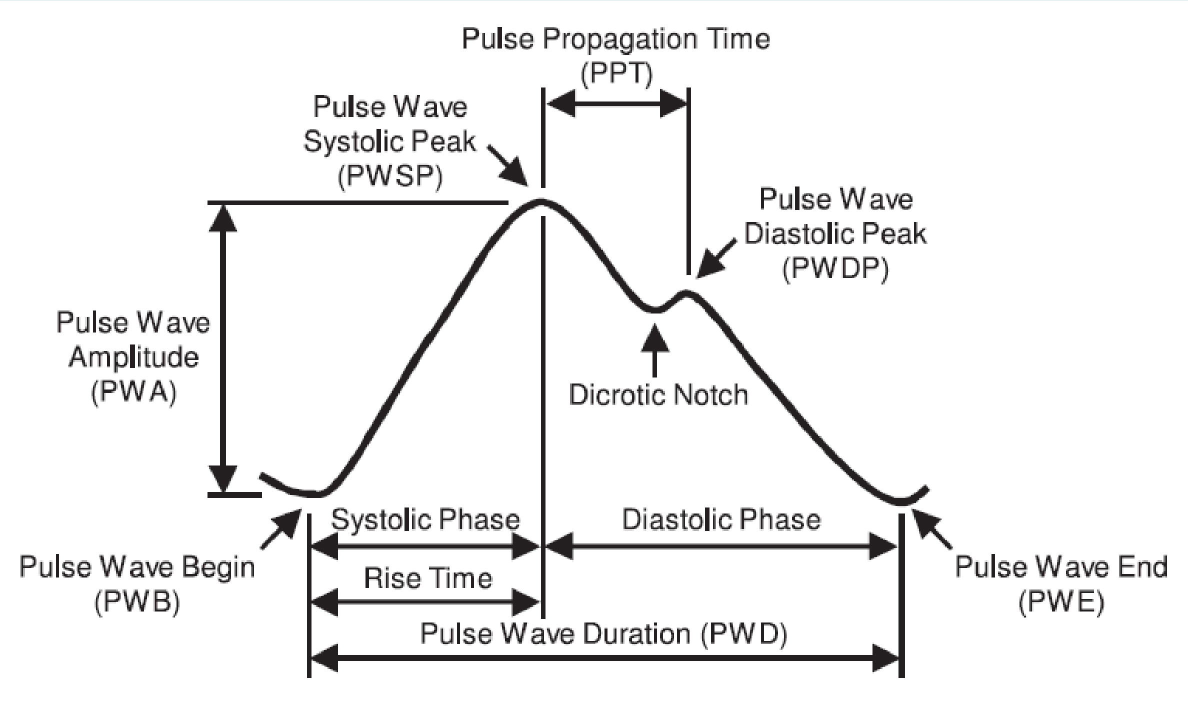
Time-Domain Parameters

- Standard Deviation of Peak-to-Peak Interval
  - $STD_{HR} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(D_{n,i} - \overline{D_n})^2}$
  - $D_{n,i} = T_{peak.n,i} - T_{peak.n,i-1}$
  - $\overline{D_n}$ *mean peak-to-peak interval of the nth segment*



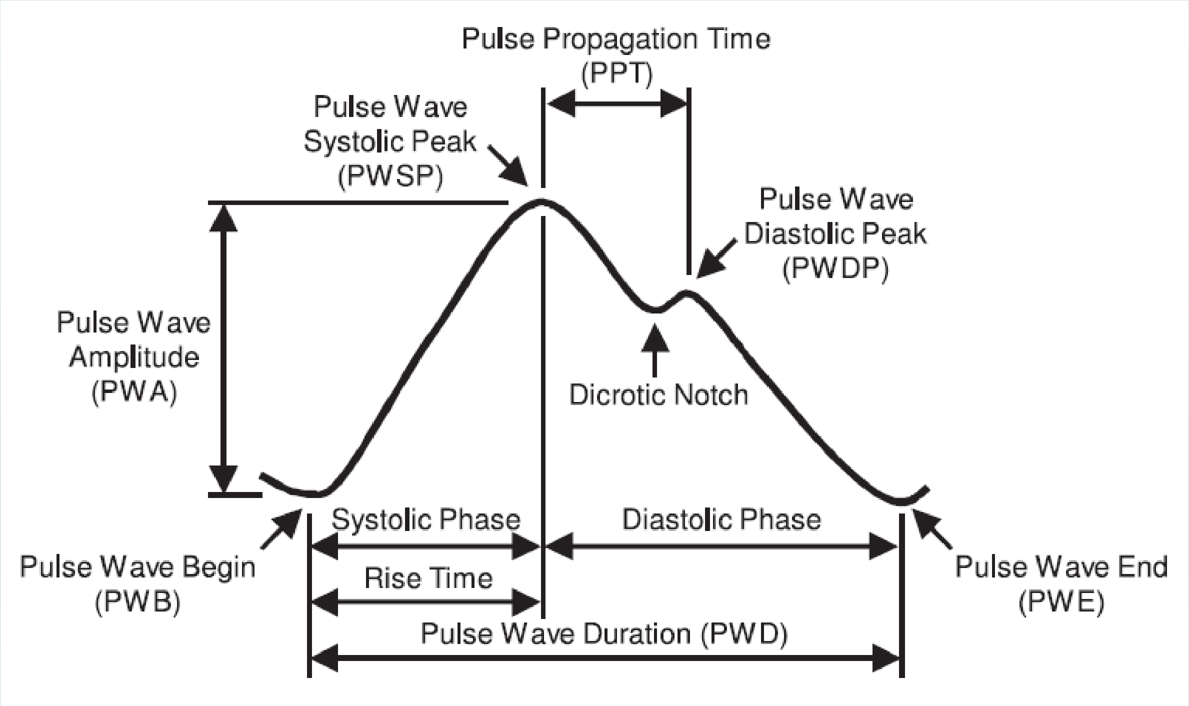
Time-Domain Parameters

- Standard Deviation of Peak-to-Peak Amplitude
  - $STD_{AMP} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(A_{n,i} - \overline{A_n})^2}$
  - $A_{n,i} = A_{peak.n,i} - A_{trough.n,i+1}$
  - $\overline{A_n}$ *mean peak-to-peak interval amplitude of the nth segment*



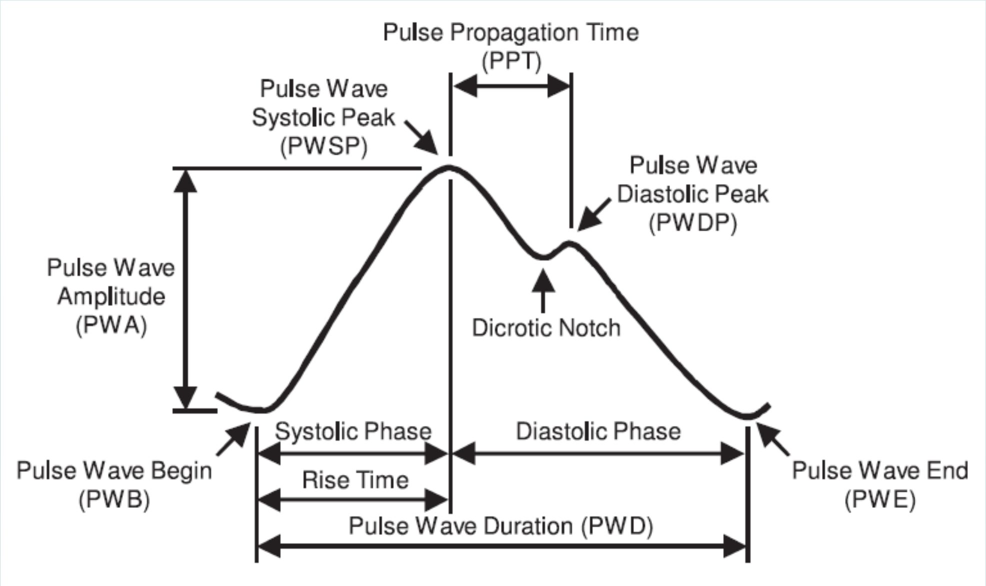
Time-Domain Parameters

- Standard Deviation of Systolic and Diastolic Ratio
  - $STD_{SD} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(R_{SD,n,i} - \overline{R_{SD,n}})^2}$
  - $R_{SD,n,i} = (T_{trough,n,i} - T_{peak,n,i})/(T_{peak,n,i} - T_{trough,n,i-1})$
  - $\overline{R_{SD,n}}$ *mean systolic and diastolic time interval ratio of the nth segment*

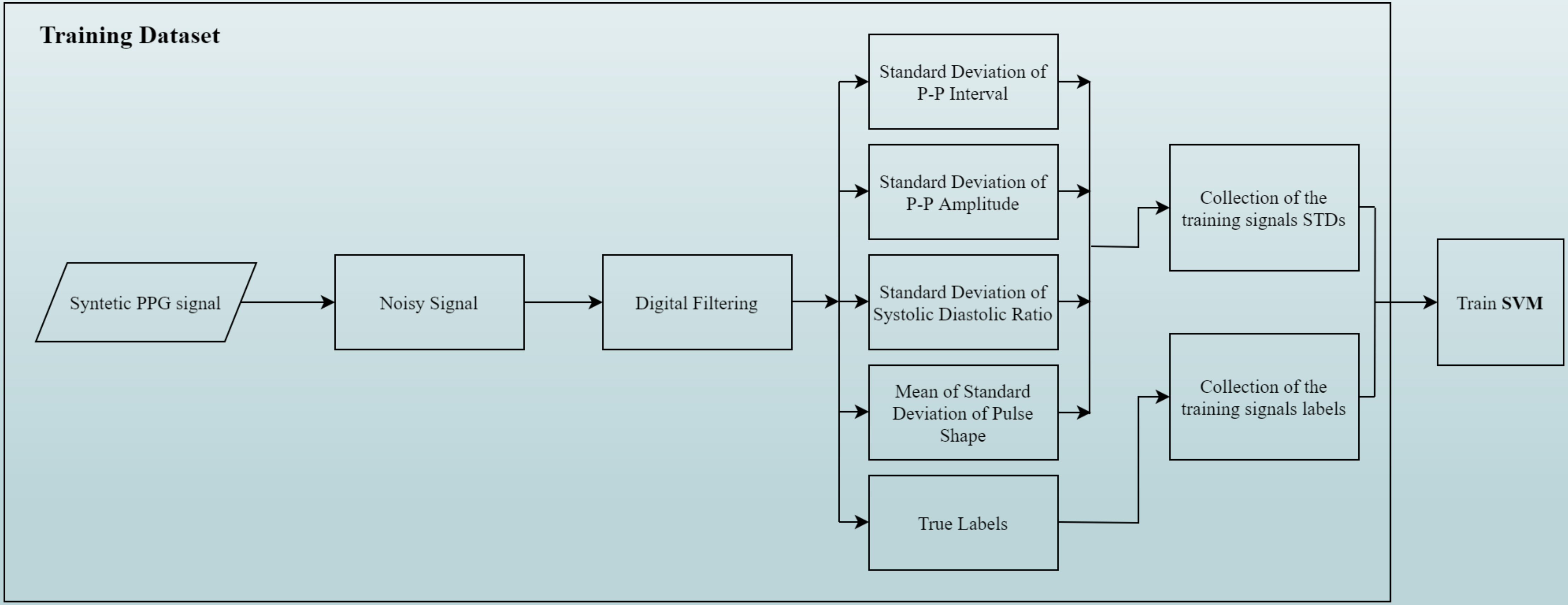


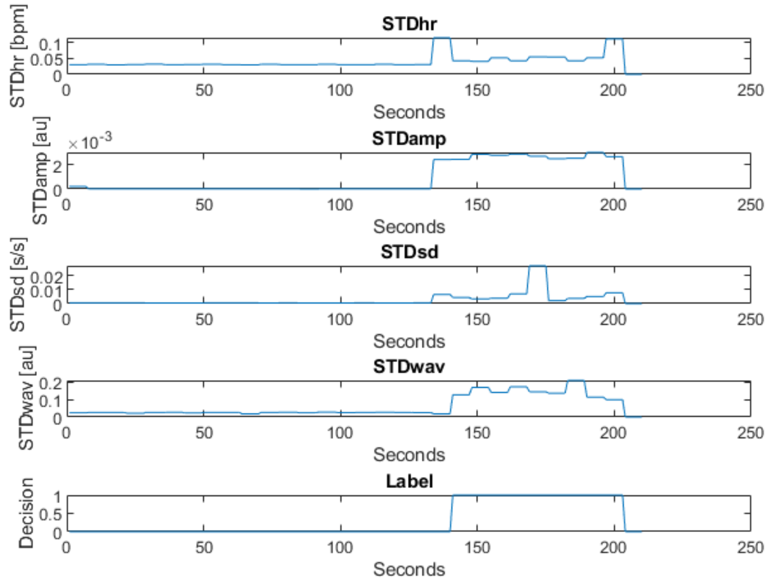
Time-Domain Parameters

- Standard Deviation of Peak-to-Peak Amplitude
  - $STD_{WAV,n} = E[STD_{WAV,n,m}]$
  - $STD_{WAV,n,m} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(q_{n,i}(m) - \overline{q_{n(m)}})^2}$
  - $q_{n,i}(m)$ *mth sample [of* N_{samp} *taken from a pulse] at the ith pulse of the nth segment*
  - $\overline{q_{n(m)}}$ *mean at the mth sample of the nth segment*

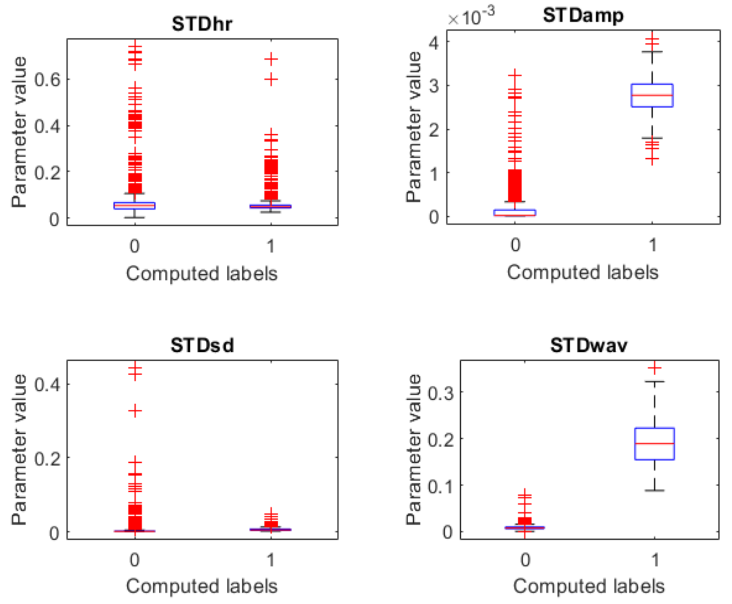


Training Procedure

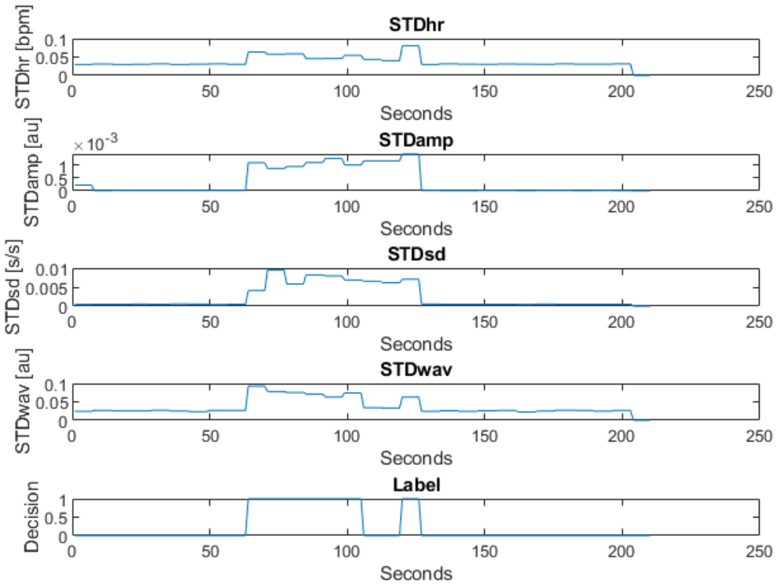




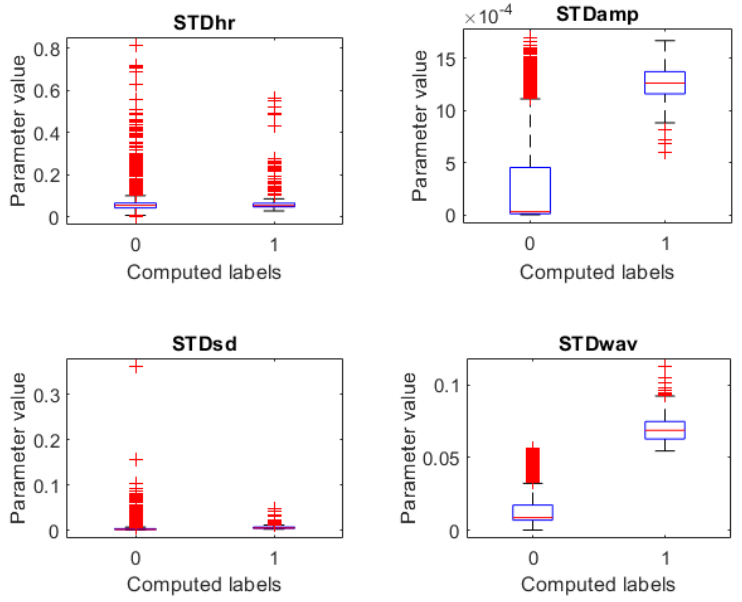
a,b,c,d) Computed STDs and **e)** Predicted Labels with SNR = -25 dB



Statistics of STDs values w.r.t. their predicted labels with SNR = -25 dB



a,b,c,d) Computed STDs and **e)** Predicted Labels with SNR = -15 dB



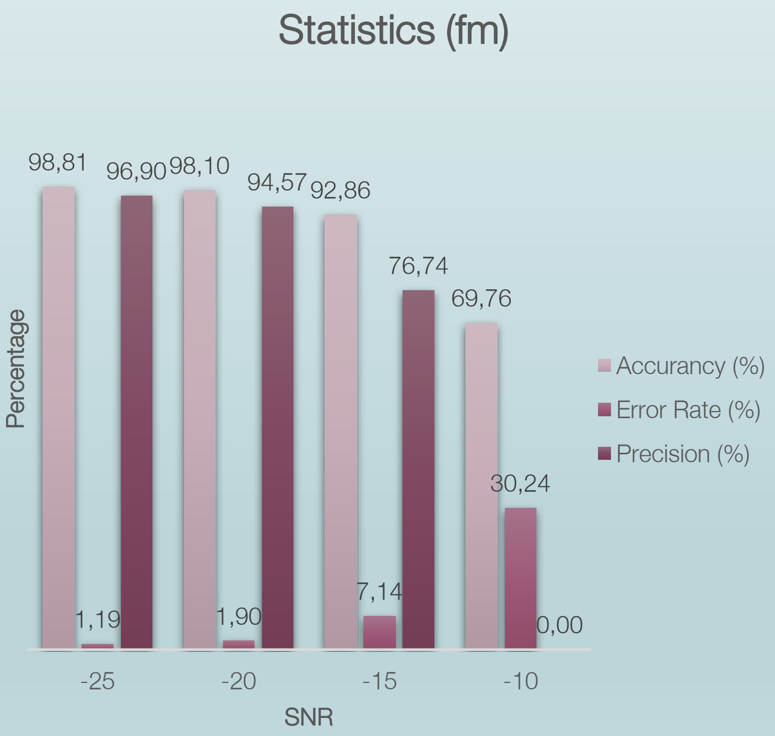
Statistics of STDs values w.r.t. their predicted labels with SNR = -15 dB

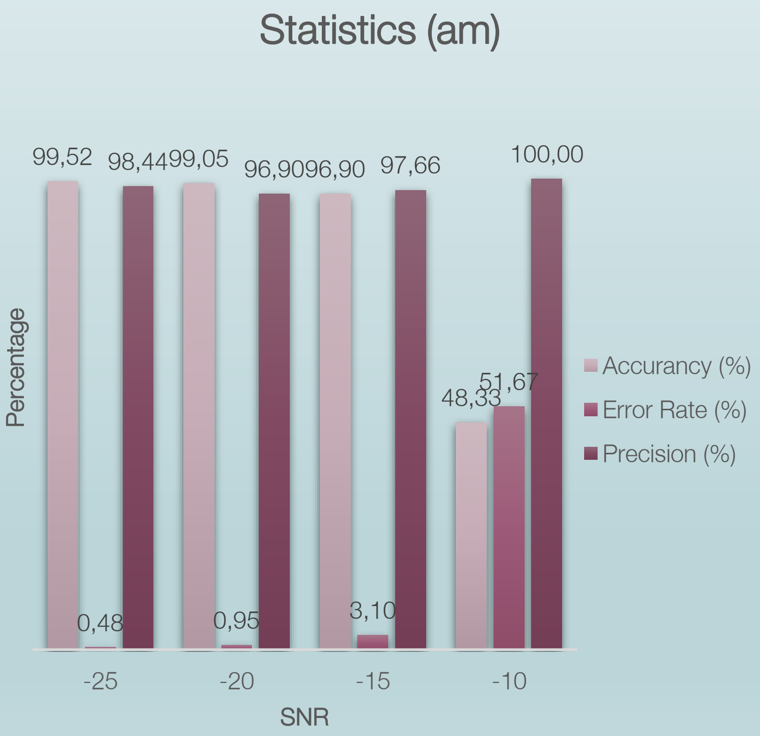
Parameters obtained from the confusion matrix

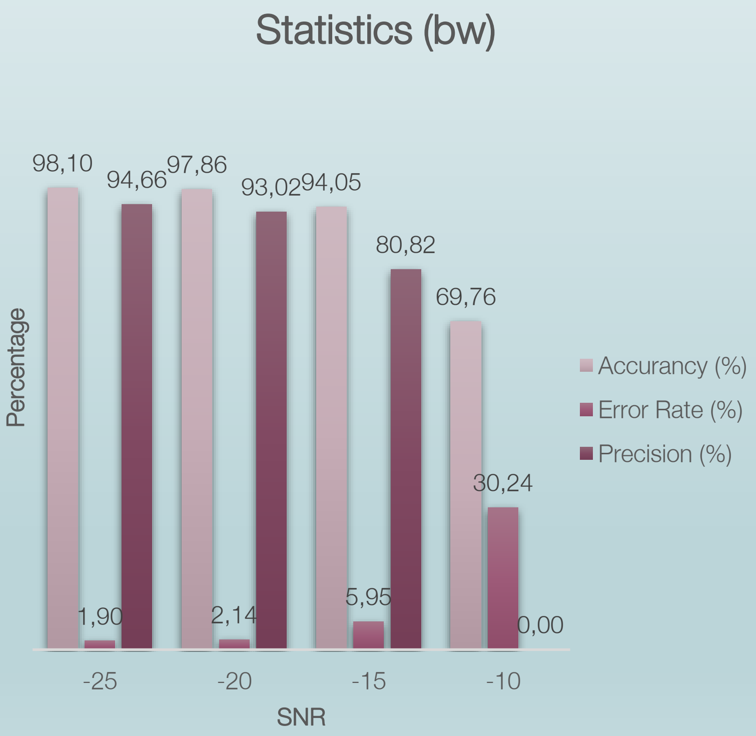
Accuracy = (TP + TN)/Tot
Error Rate = (FP + FN)/Tot = 1 – Accuracy
Precision = TP / (TP+FP)

TP = True Positive
TN = True Negative

FP = False Positive
FN = False Negative







THE END

THANK YOU FOR LISTENING.