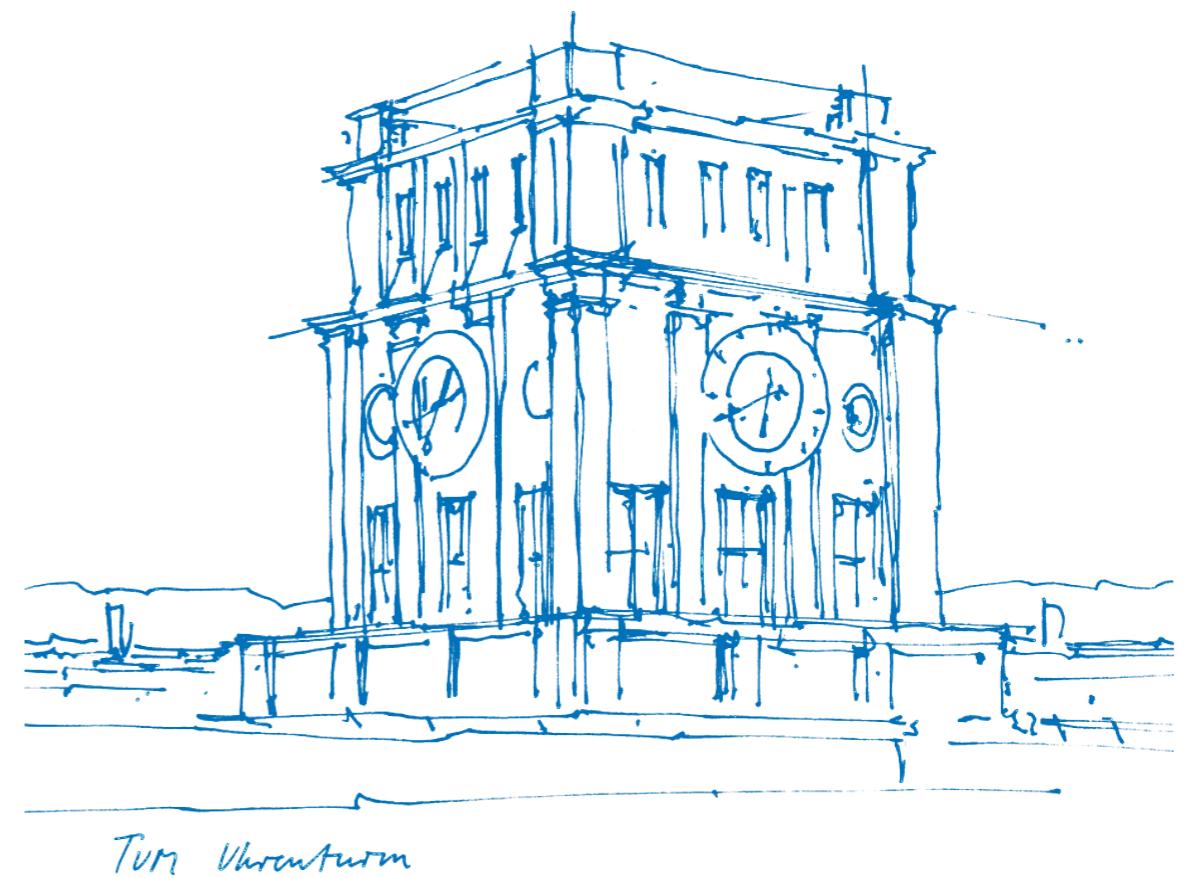


# Realtime detection of Freezing of Gait algorithm and implementation

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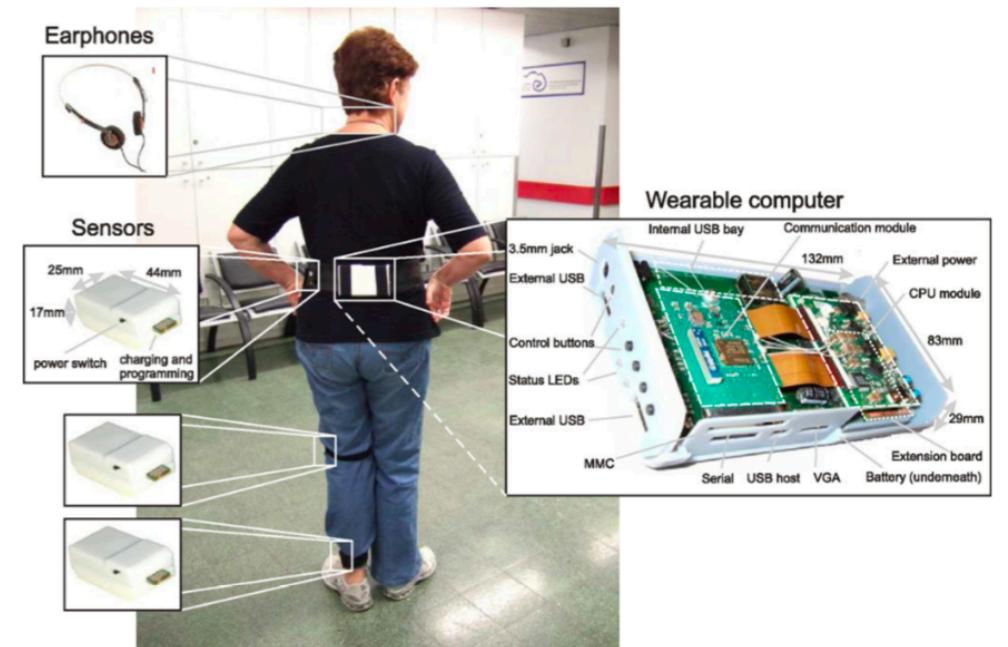
# Motivation

## Freezing of gait



Rhythmic auditory stimulation (RAS)

## Wearable-Based Methods

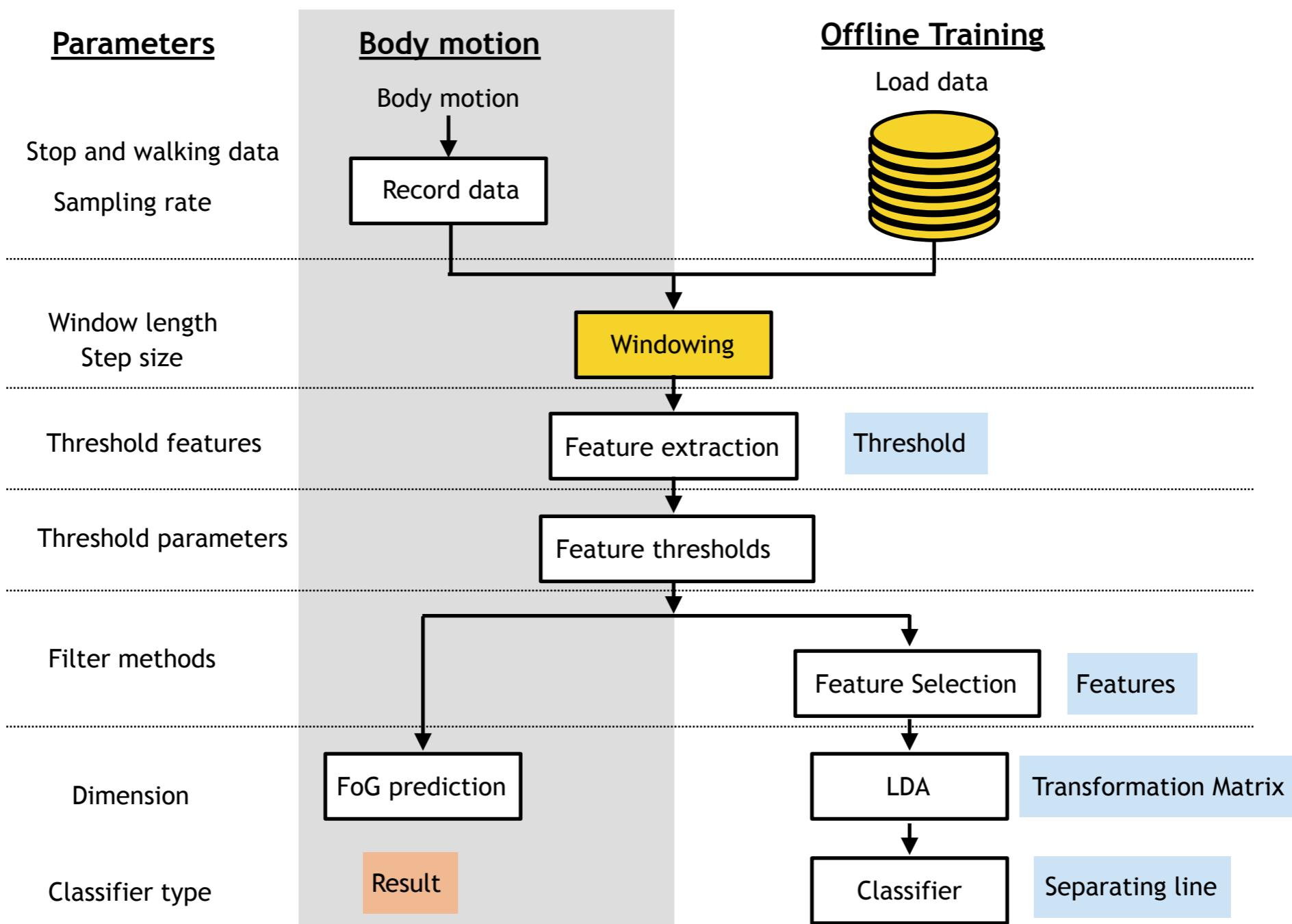


- Mobile system, realtime detection
- Provide RAS only during an actual or impeding FOG event.

<https://www.researchgate.net/>

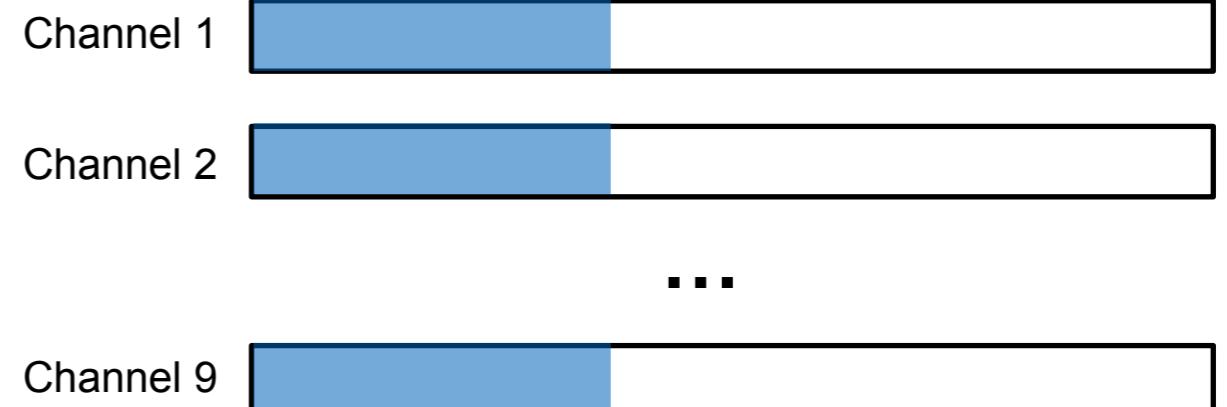
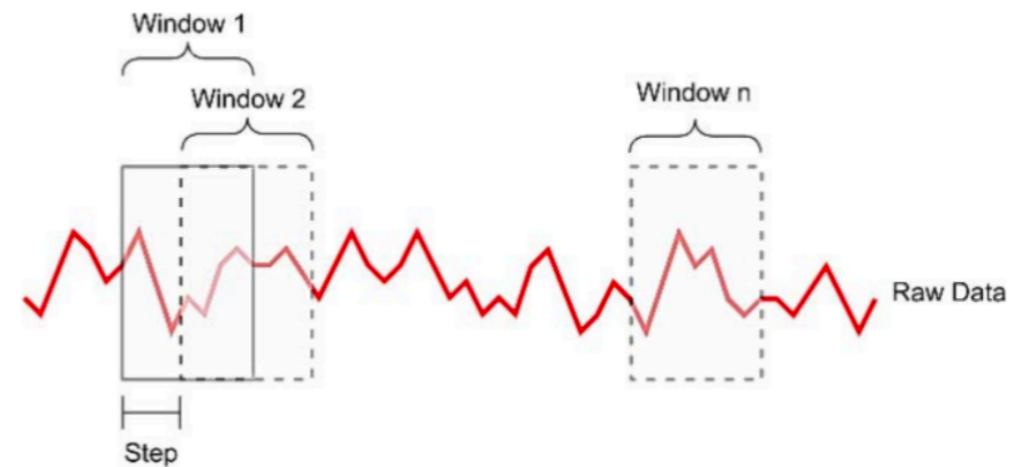
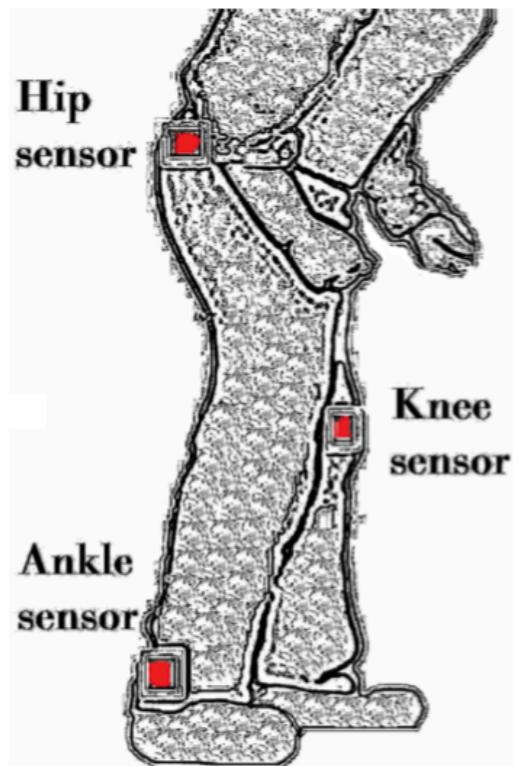
[M. Bachlin, M. Plotnik, D. Roggen, I. Maidan, J. M. Hausdorff, N. Giladi, and G. Troster, "Wearable assistant for parkinson's disease patients with the freezing of gait symptom," ]

# Method overview



# Dataset

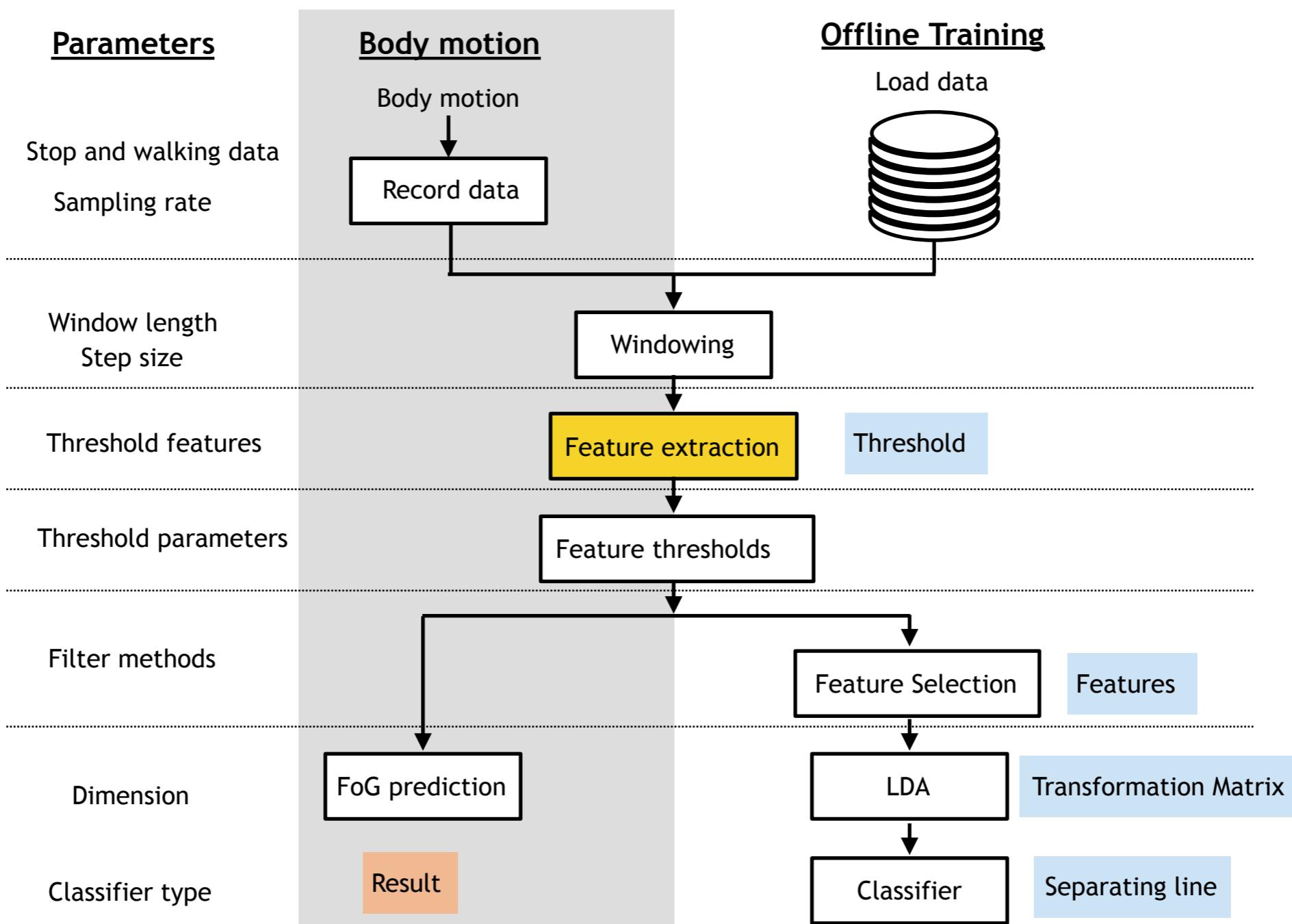
**DAPHNET dataset**



Thuy T. Pham\*, Freezing of Gait Detection in Parkinson's Disease  
: A Subject-Independent Detector Using Anomaly Scores

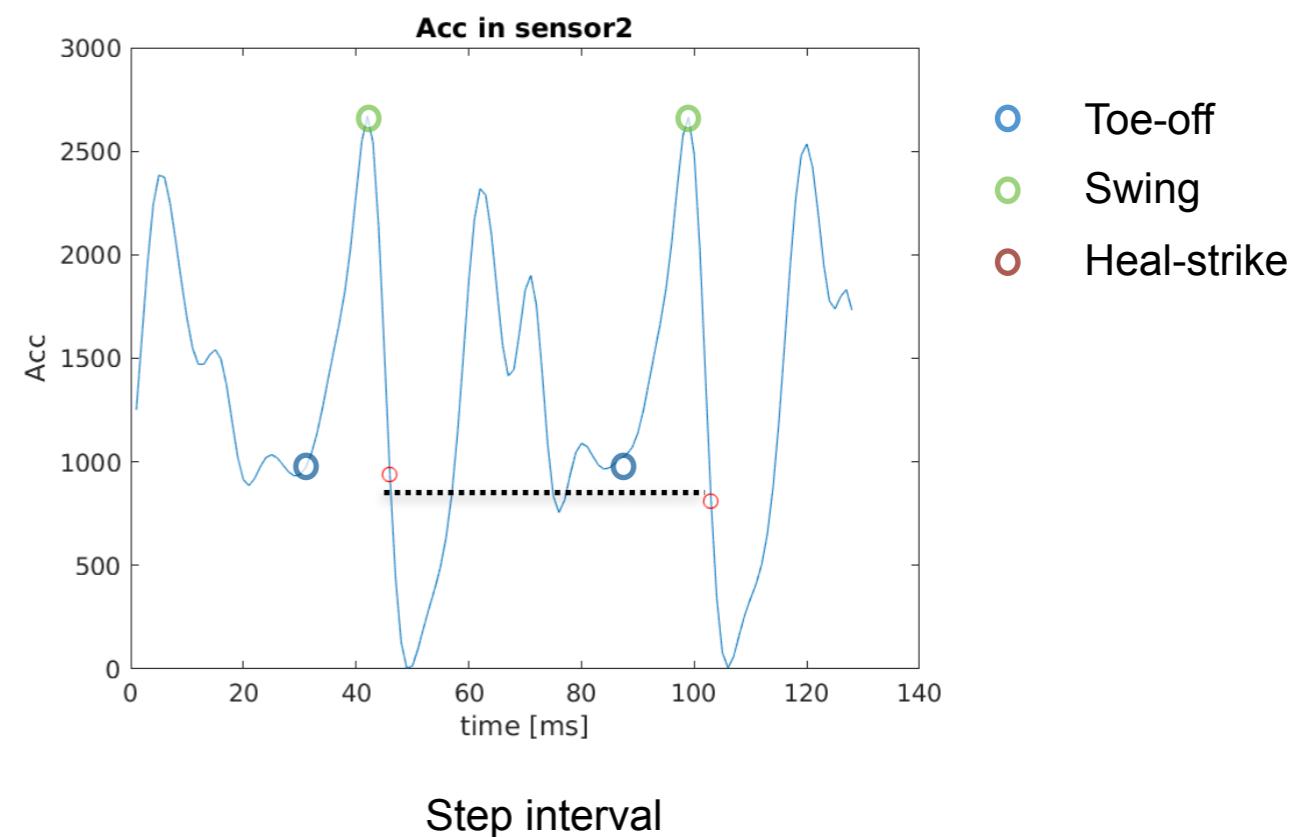
**9 x window\_size x sample\_rate**

# Feature extraction

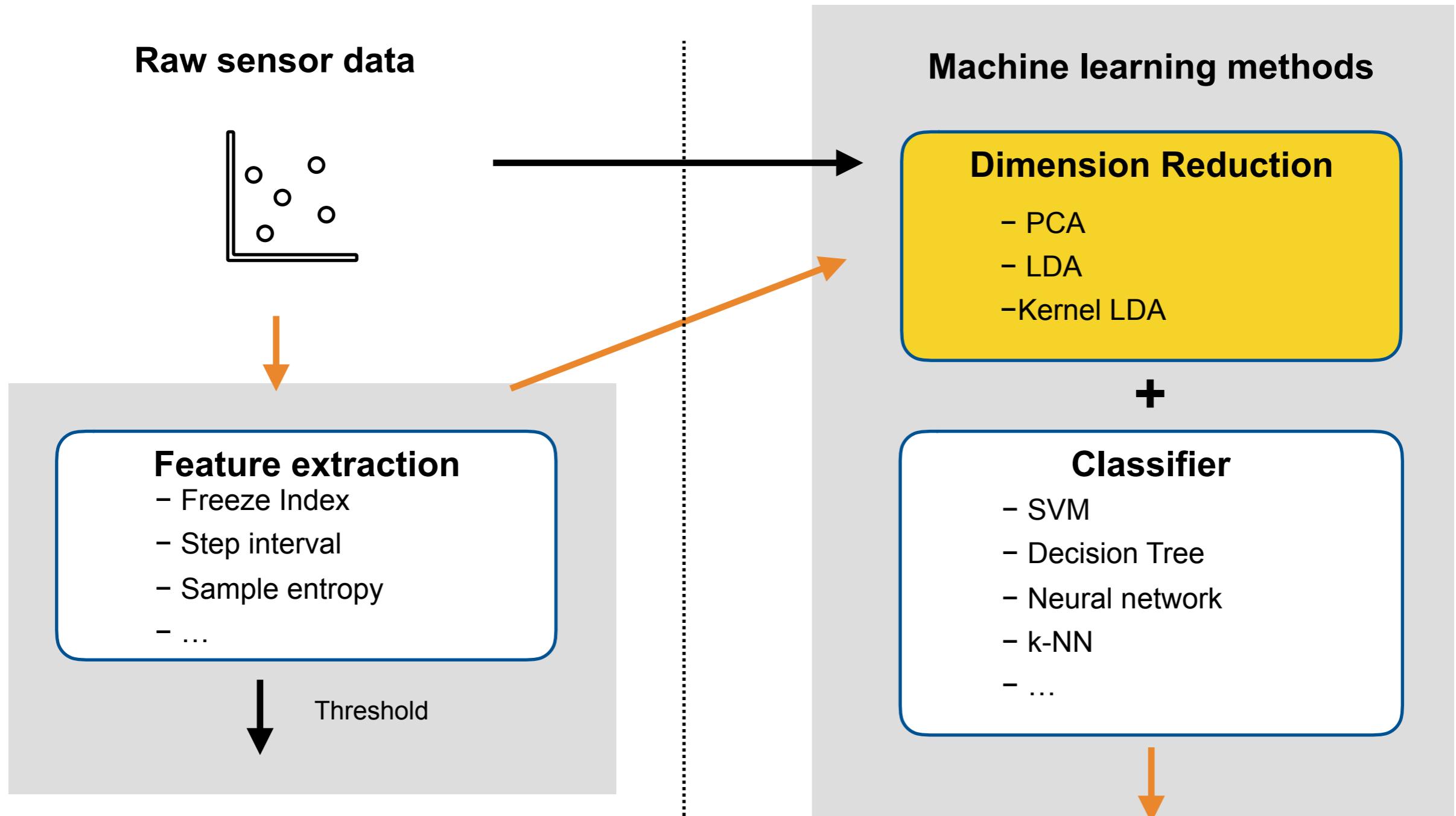


# Feature extraction

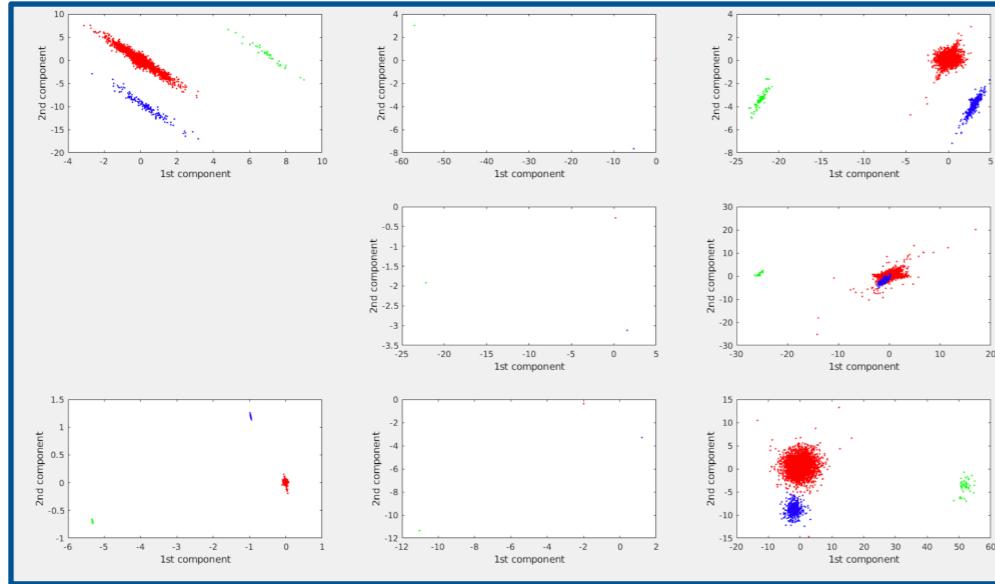
Features in time domain	
Features	Description
sample entropy	Measures repeatability or predictability within one window :
step interval	Time interval between two steps in one window
max correlation	Measures the periodicity in one window
step depth	Difference between max and min value in one window
step counts	Counts of steps in one window
variogram	The measure of smoothness of data in time series
portion above mean	The proportion above the mean of the observations within the window whose values are greater than the mean of the window
Features in frequency domain	
Features	Description
loco-band energy	energy in [0.5-3Hz] frequency band
loco-band+freeze-band energy	energy in [0-8Hz] frequency band
freezing index	The power in the 3-8Hz band divided by the power in 0.5–3 Hz band
dominant frequency	The frequency with maximal Power Spectral Density (PSD)
wavelet mean	the mean of coefficient of DWT in the third level, which represents energy in freeze band



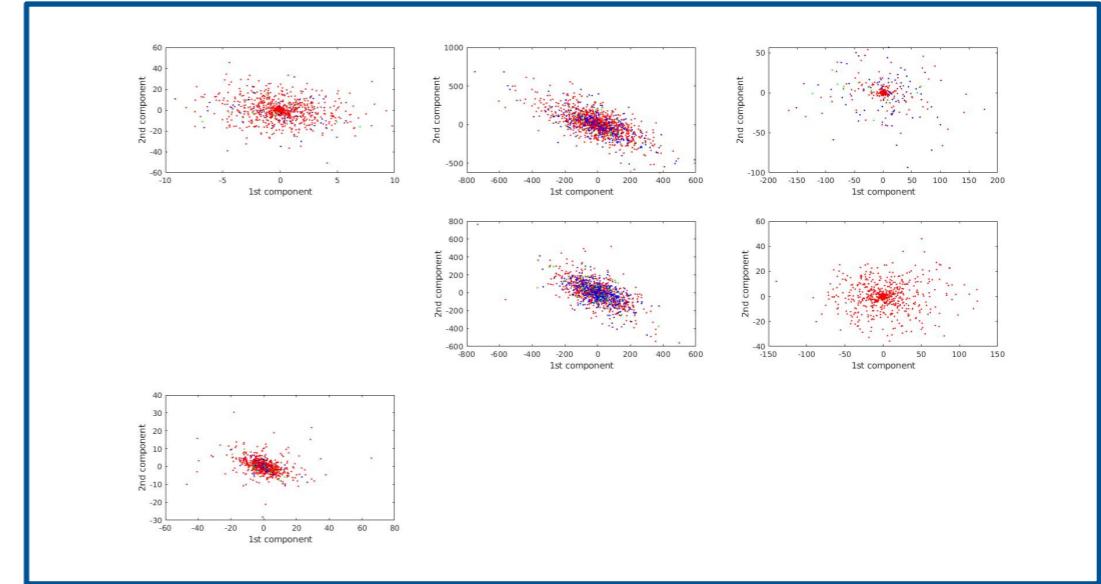
# Classification of sensor measurement



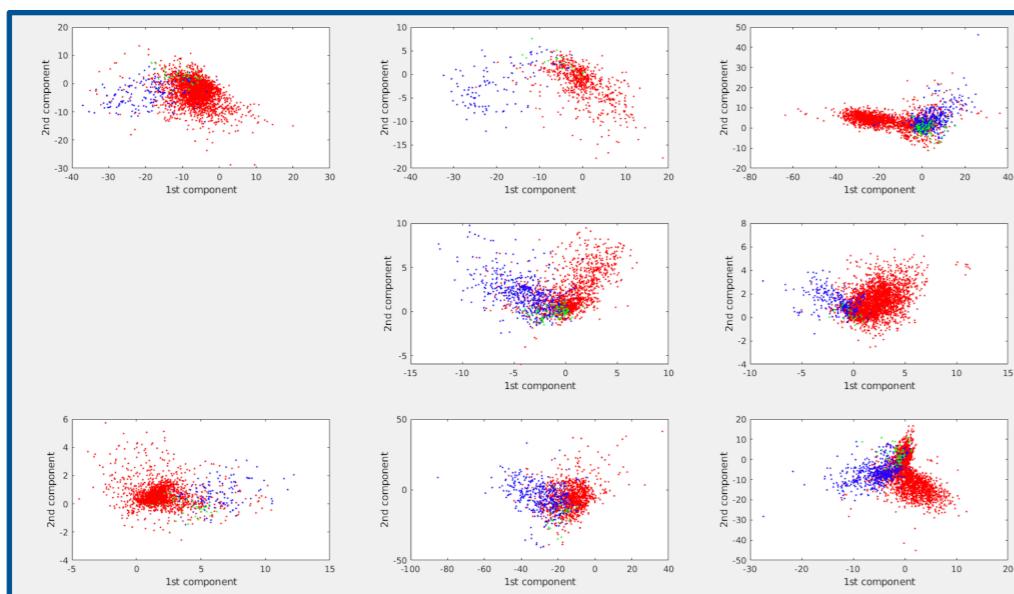
# Dimension reduction using LDA



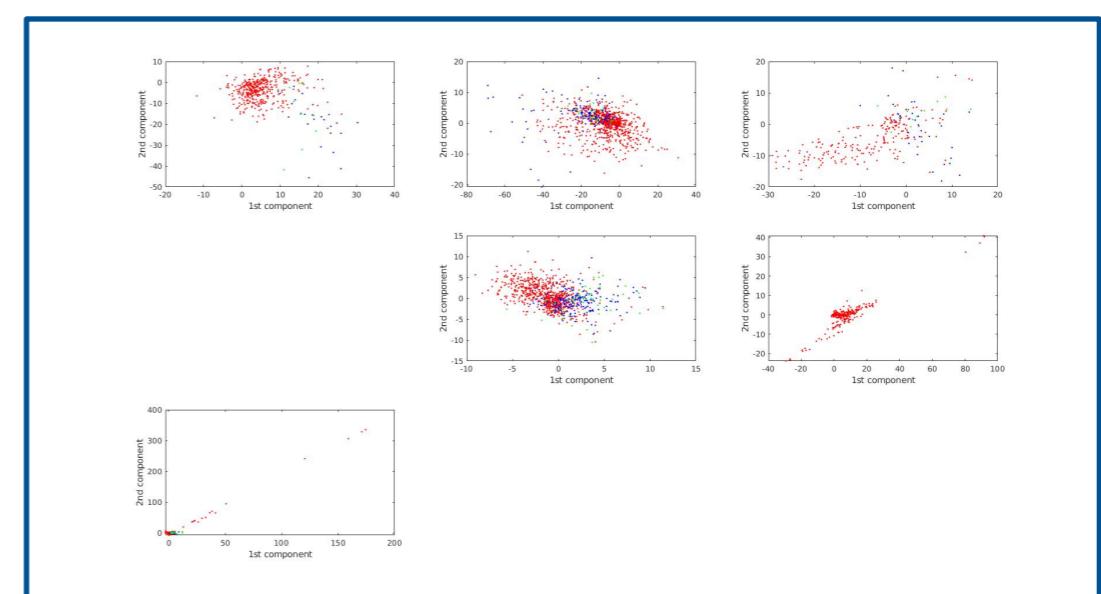
(a) LDA with raw data (Training)



(b) LDA with raw data (Test)

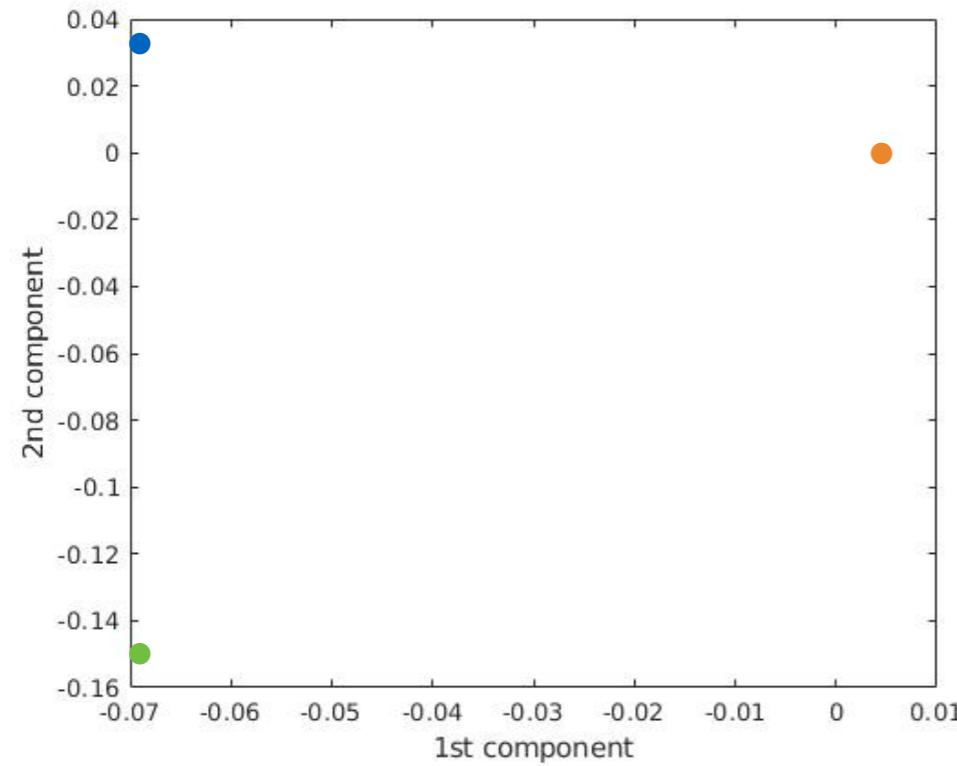


(c) LDA with features (Training)

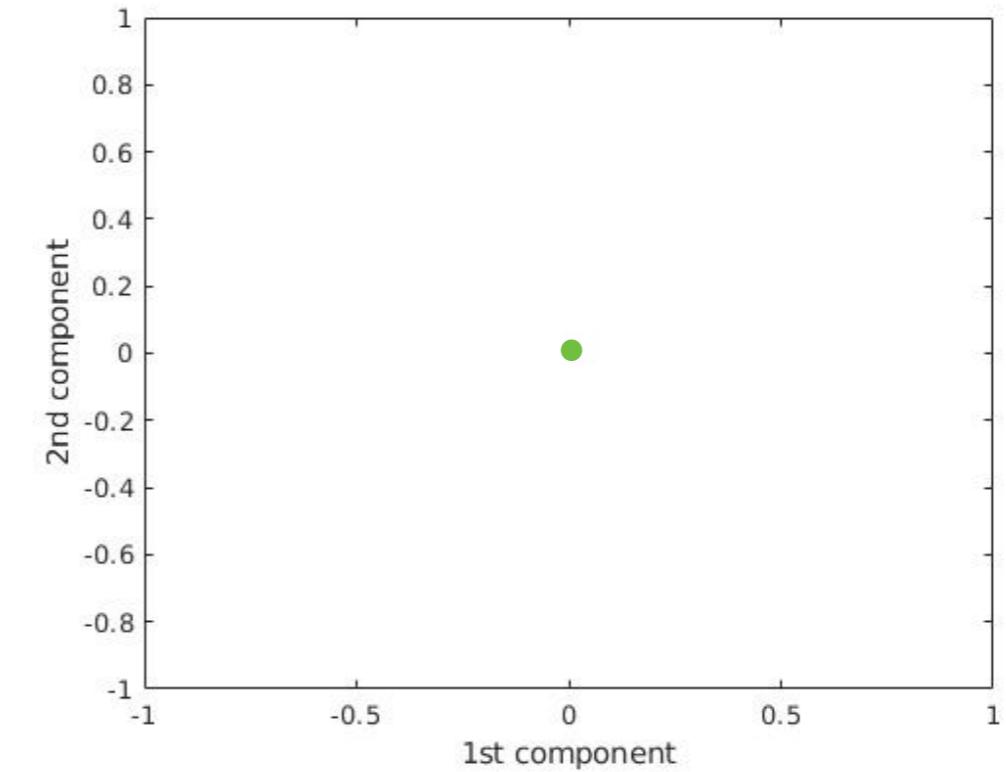


(d) LDA with features (Test)

# Dimension reduction using kernel LDA



(a) Training result



(b) Training result

# Potential problem with dataset



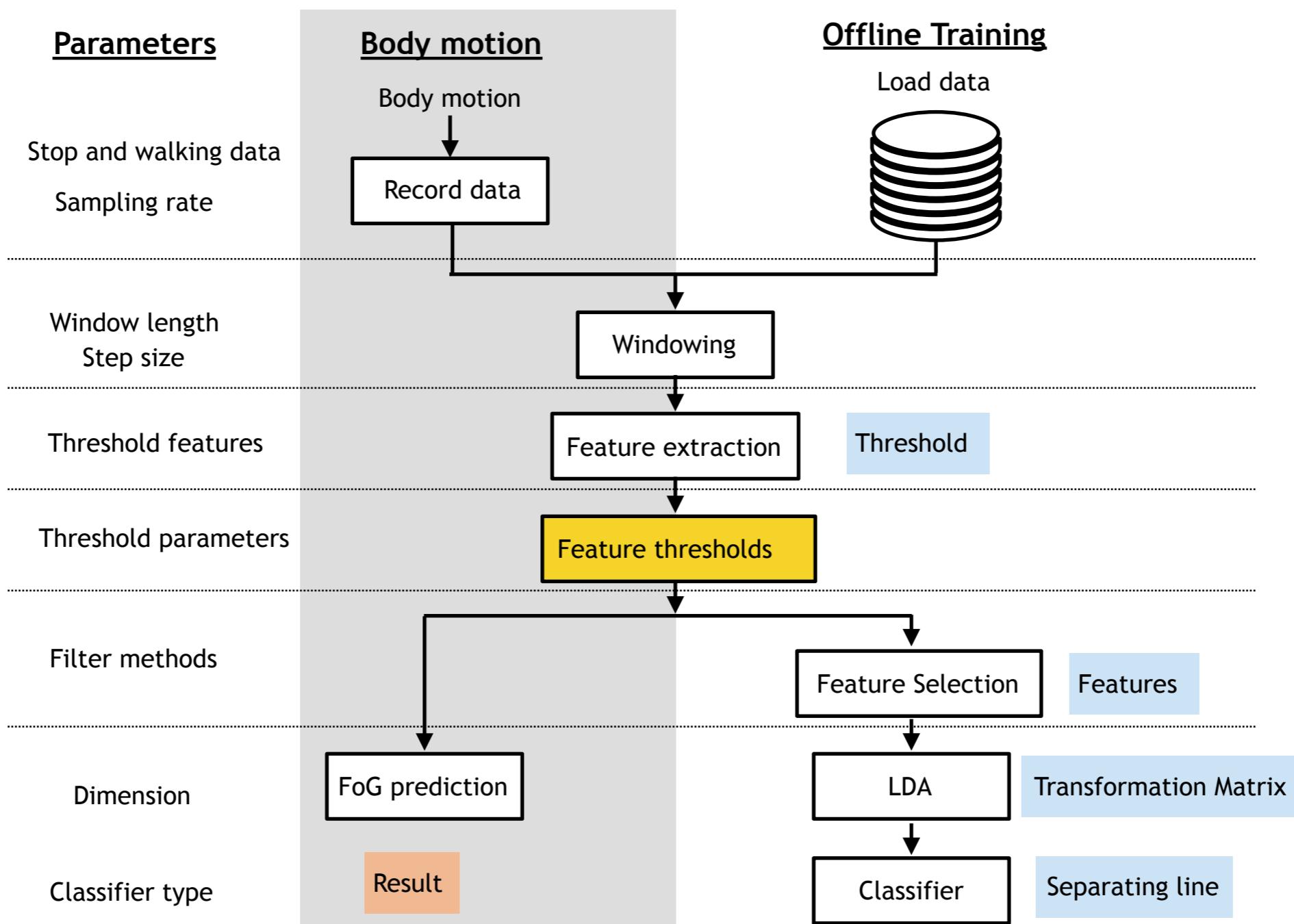
**Assumption 1 : There are some period that are not correctly labeled.**



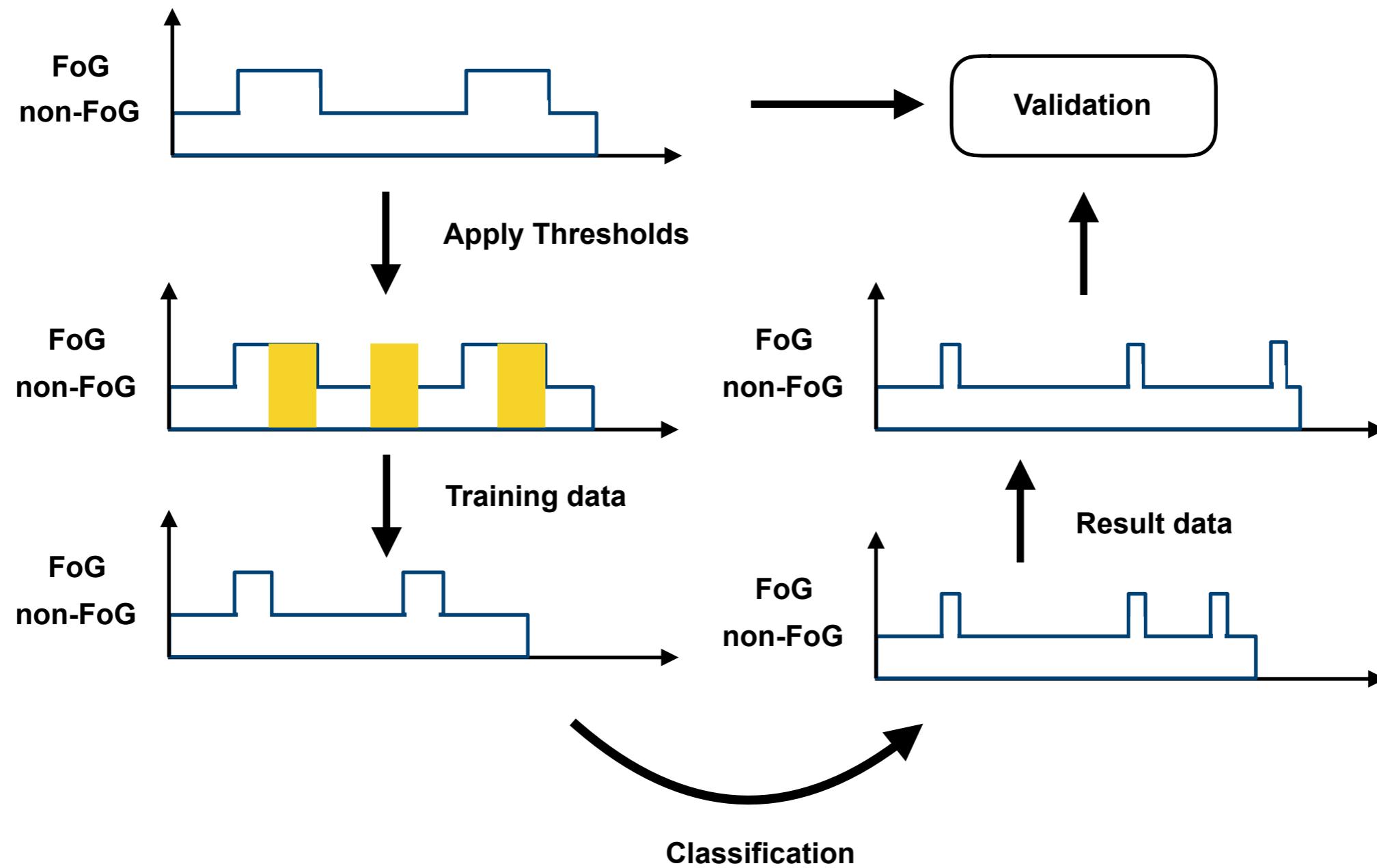
(a) raw acceleration data of patient 8 with labels

**Solution 1 : Data cleaning**

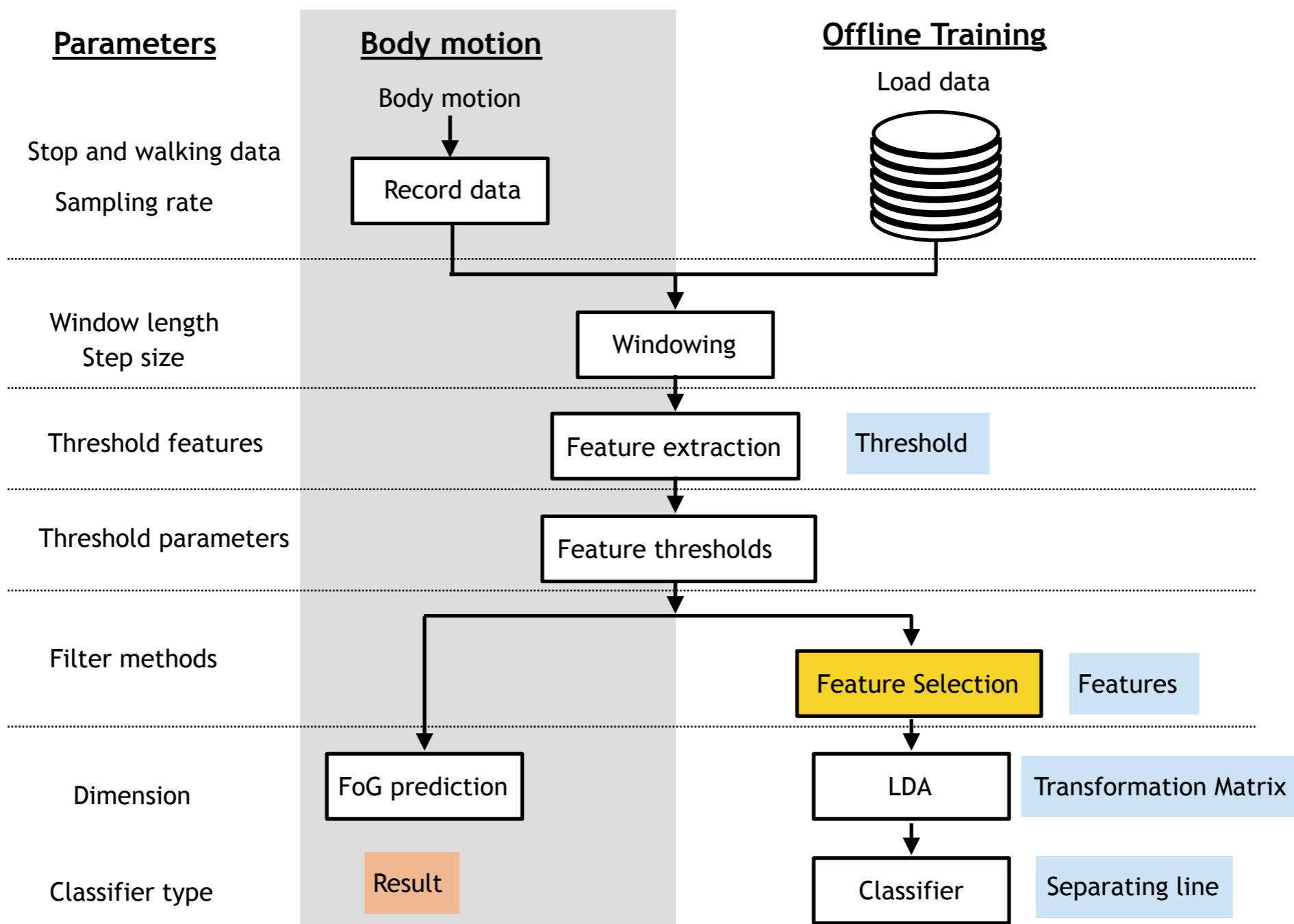
# Feature thresholds



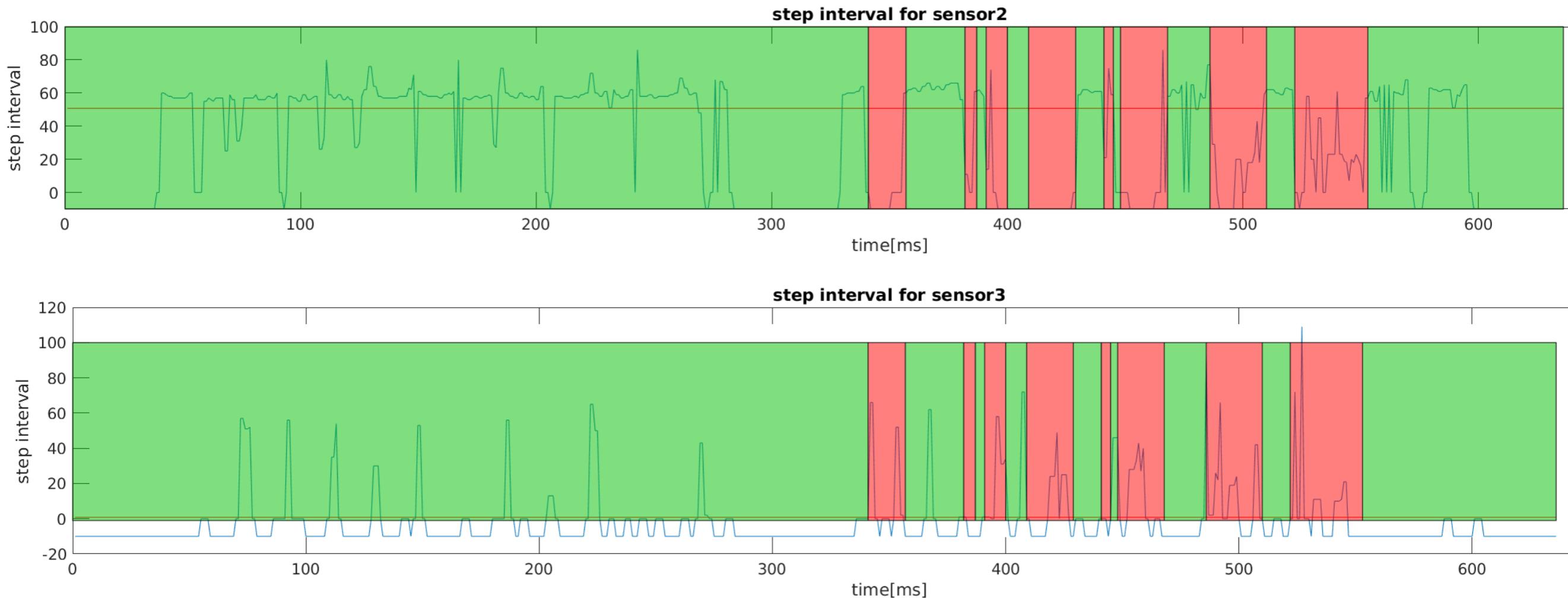
# Data cleaning step



# Feature selection



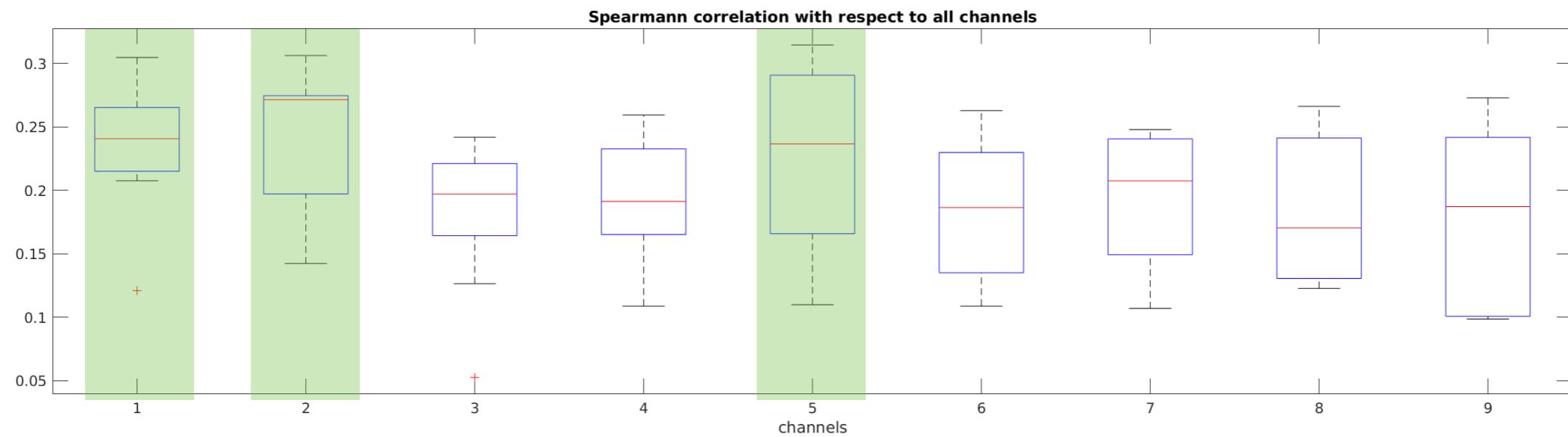
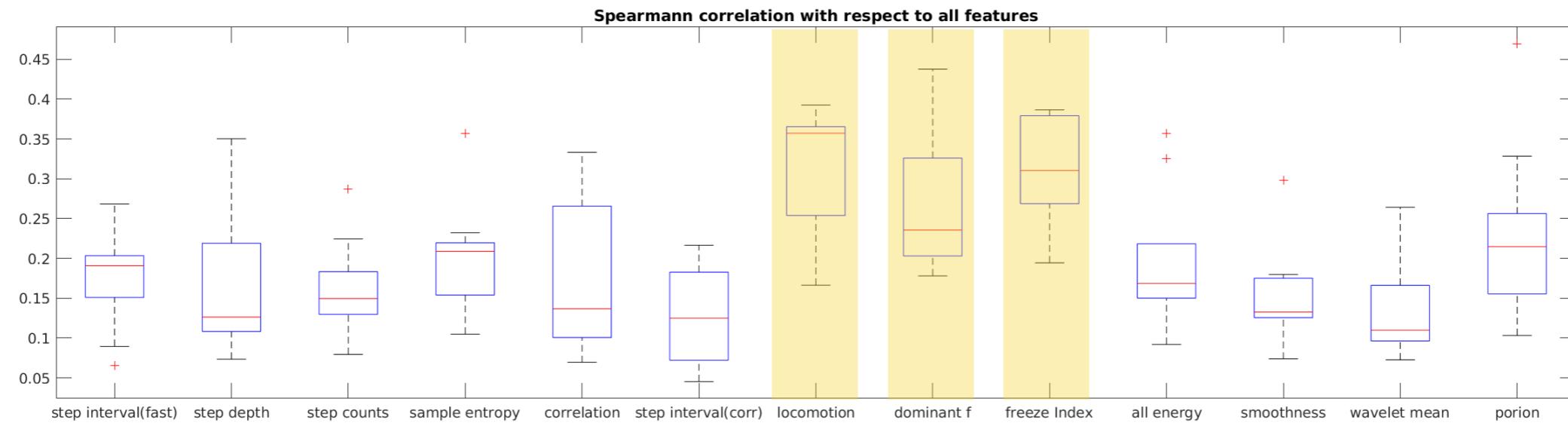
# Feature selection



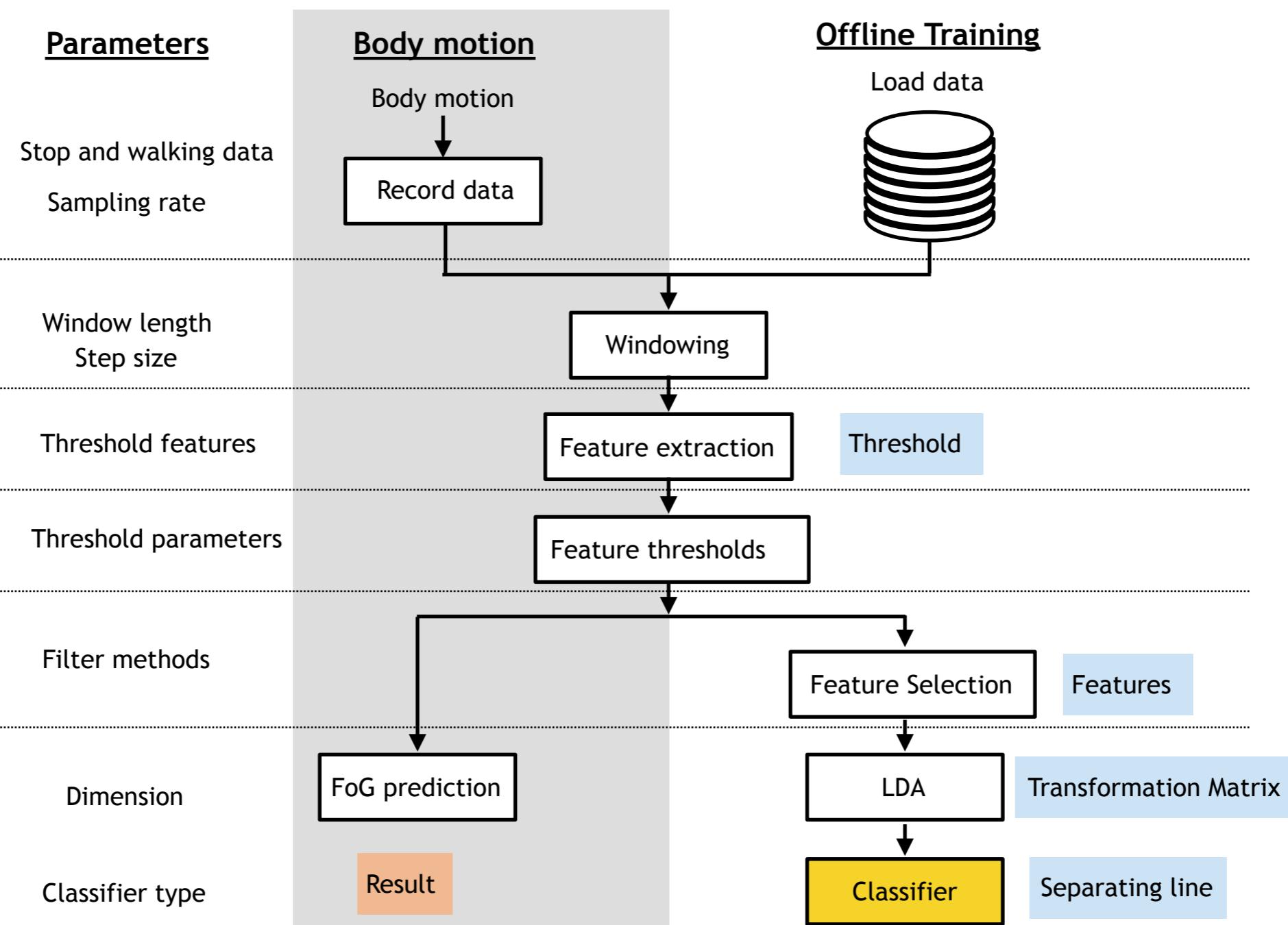
**Problem :** Different features and acceleration channels have difference correlation with FoG period.

**Solution :** Measure the correlation and filtering.

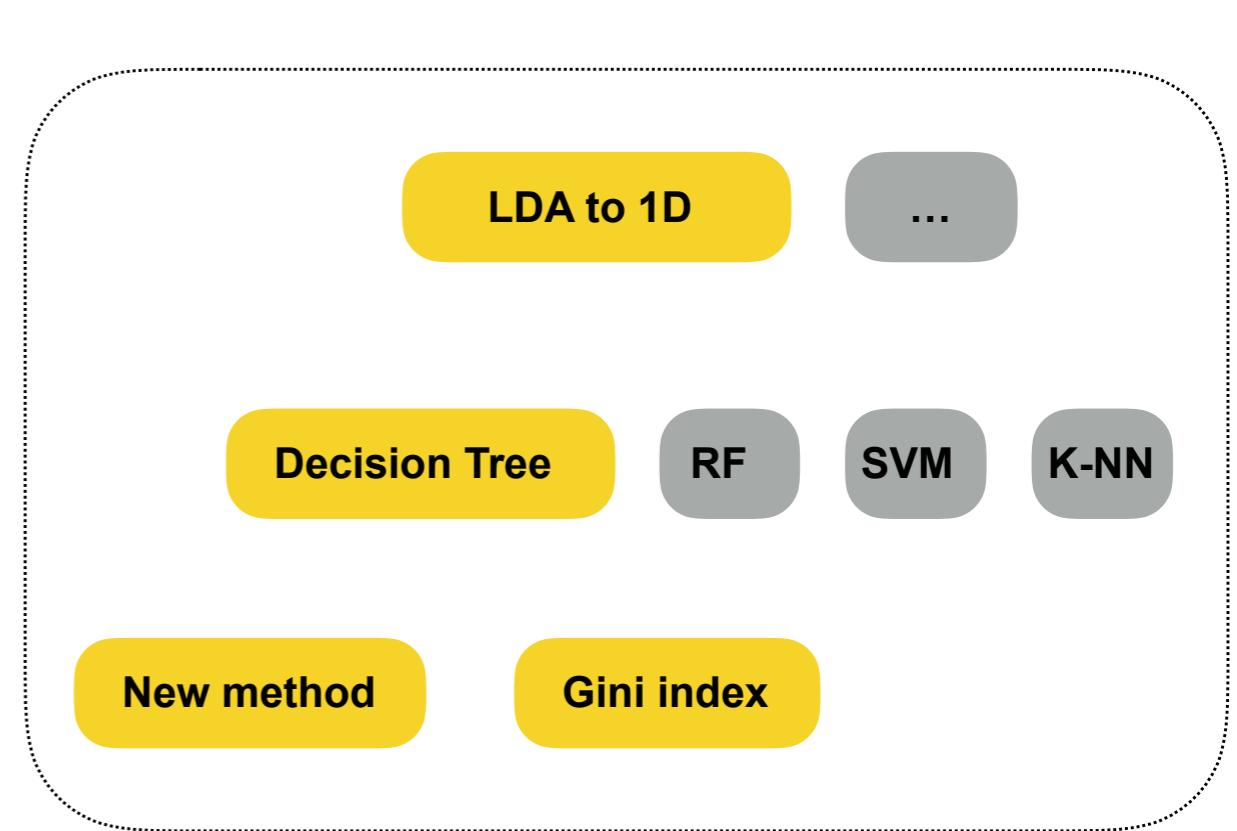
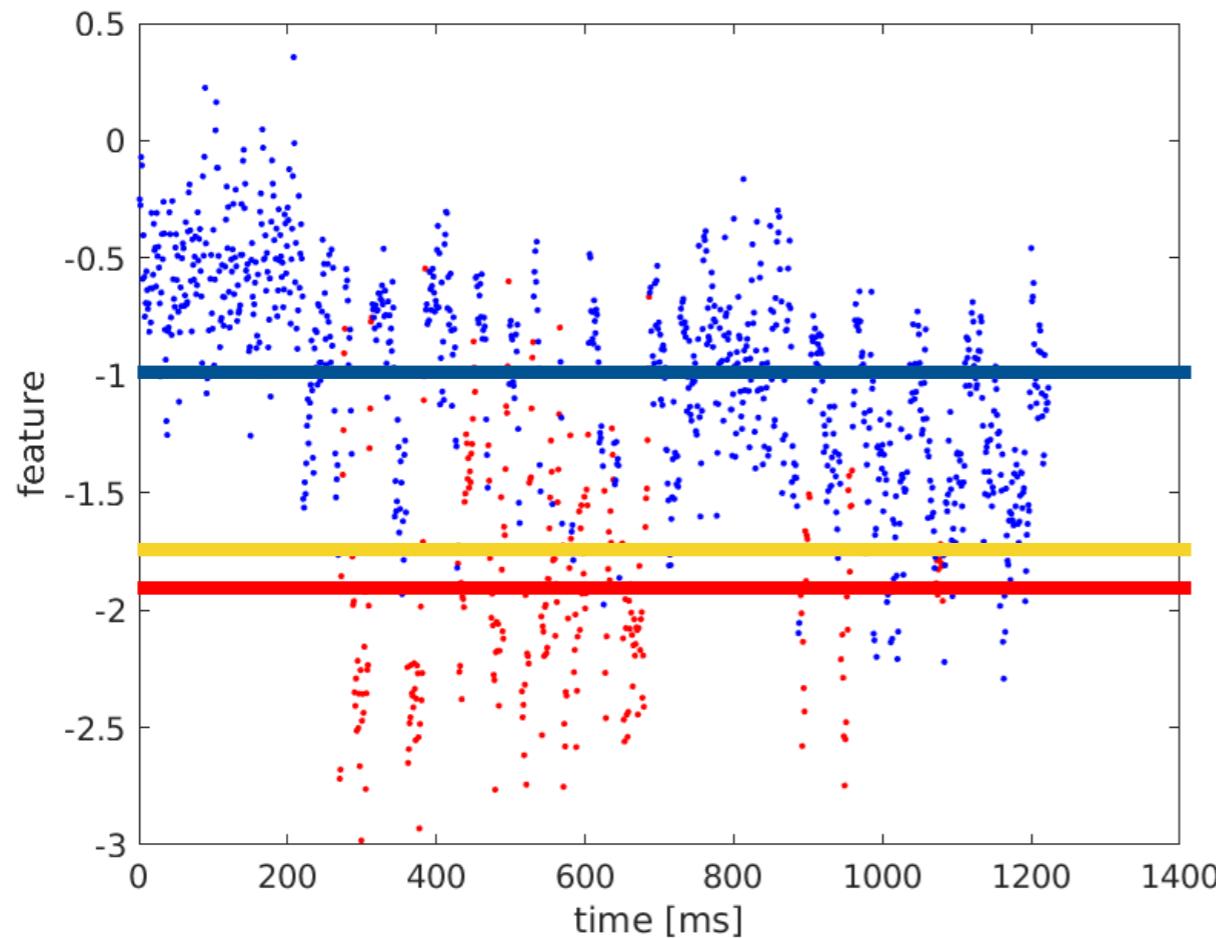
# Feature selection



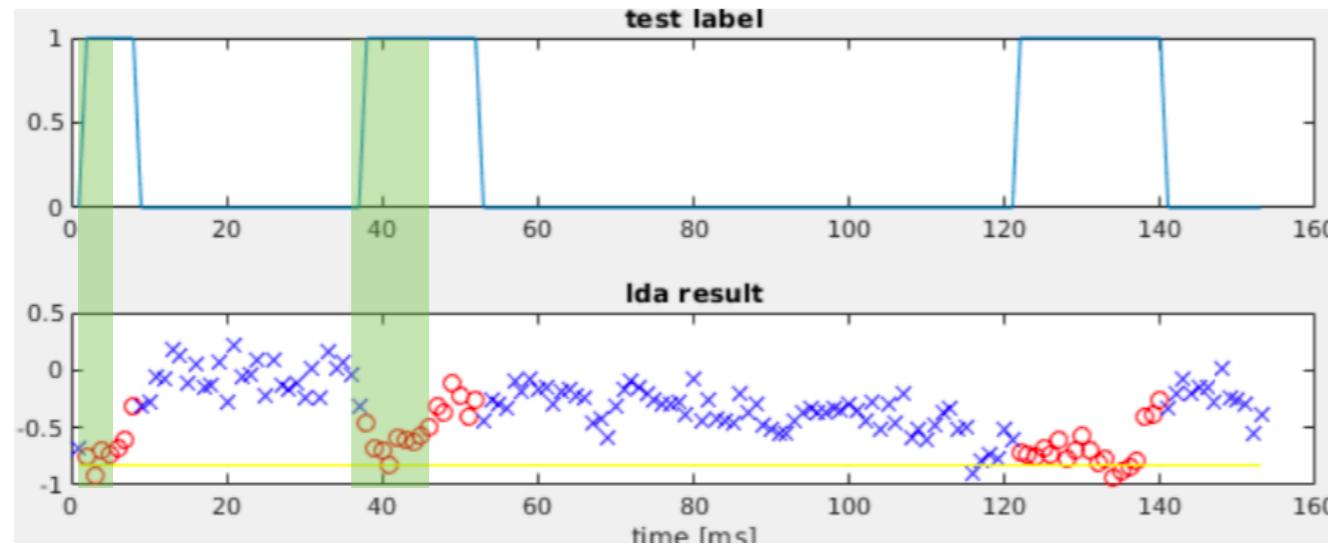
# Classification



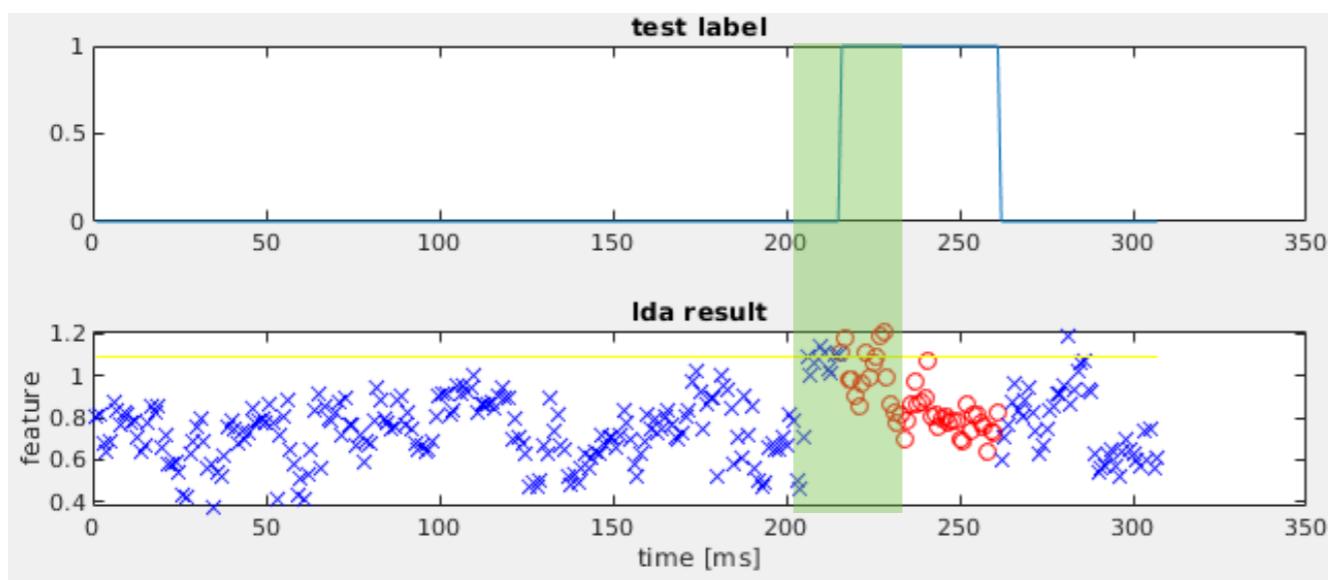
# Classification



# Potential Problem with dataset



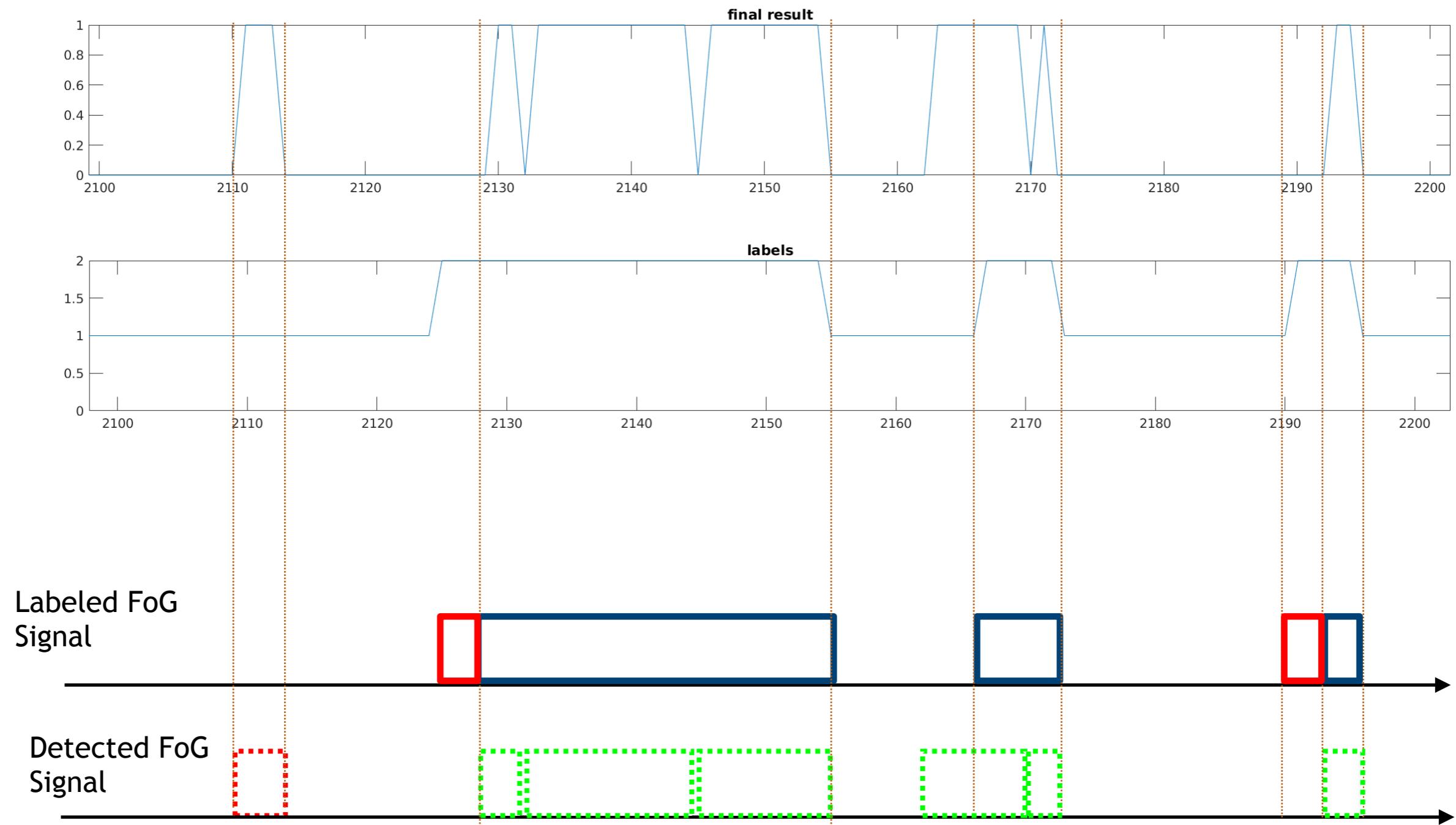
**Assumption 2 : There exists different phases during a FoG episodes, they don't have same importance for classifier**



**Assumption 3 : Some non-FoG window before a FoG window can also get labeled as FoG**

**Solution 2 : New evaluation standard**

# Evaluation standard



# Result

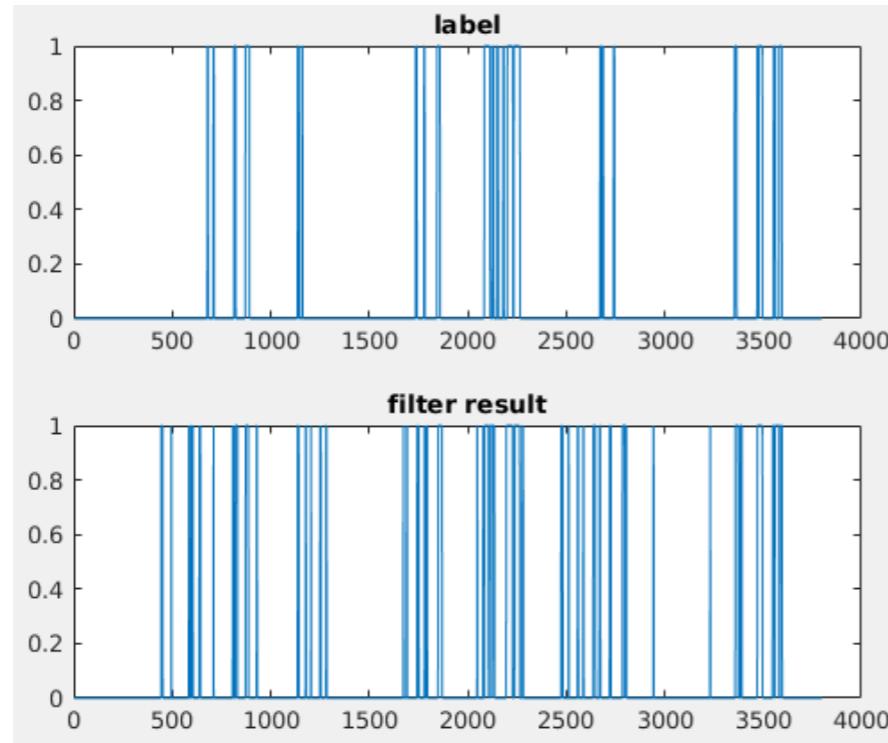
$$\text{New Precision} = \frac{\sum \text{corrrect FoG alarms}}{\sum \text{all FoG alrams}}$$

$$\text{New Recall} = \frac{\sum \text{solved FoG}}{\sum \text{all FoGs exists}}$$

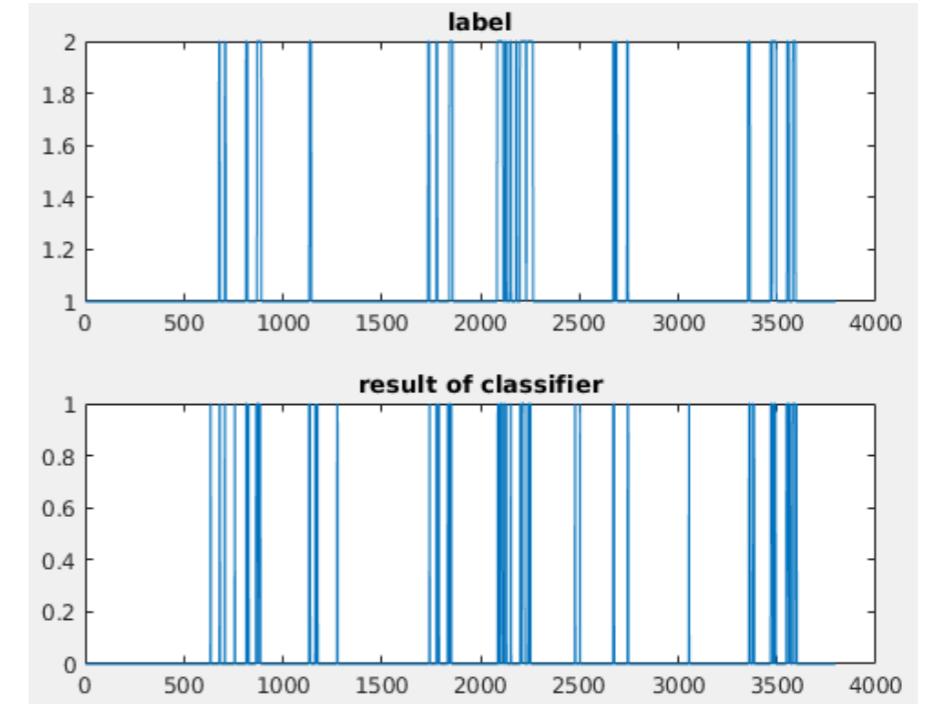
$$\text{New F1 - Score} = 2 * \frac{\text{New Precision} * \text{New Recall}}{\text{New Precision} + \text{New Recall}}$$

Method	Proposed method	Method[7]
ID	F1-score	F1-score
1	0.7724	0.7056
2	0.8553	0.7658
3	0.8272	0.8548
5	0.8470	0.8214
6	0.7560	0.6736
7	0.7325	0.6578
8	0.8695	0.7951
9	0.8877	0.7398

Table 4: detection result



(a) Original Method by Bachelin et al.



(b) New method

# Result

## Data cleaning

Result without thresholds				Energy threshold			Energy+Dominant frequency threshold		
ID	precision	recall	F1-score	precision	recall	F1-score	precision	recall	F1-score
1	0.7358	0.8390	0.7840	0.7222	0.8764	0.7919	0.6905	0.8764	0.7724
2	0.6588	0.7982	0.8277	0.8009	0.9286	0.8141	0.8552	0.8555	0.8553
3	0.7545	0.8873	0.8155	0.7541	0.8802	0.8123	0.7859	0.8730	0.8272
5	0.7288	0.8986	0.8048	0.7903	0.8923	0.8382	0.7753	0.9333	0.8470
6	0.4685	0.8581	0.6061	0.5415	0.6990	0.6102	0.6713	0.8651	0.7560
7	0.6084	0.8130	0.6960	0.6667	0.7609	0.7107	0.6787	0.7957	0.7325
8	0.7380	0.8288	0.7808	0.8317	0.8927	0.8611	0.8170	0.9292	0.8695
9	0.7896	0.7071	0.7460	0.8439	0.9135	0.8774	0.8534	0.9250	0.8877

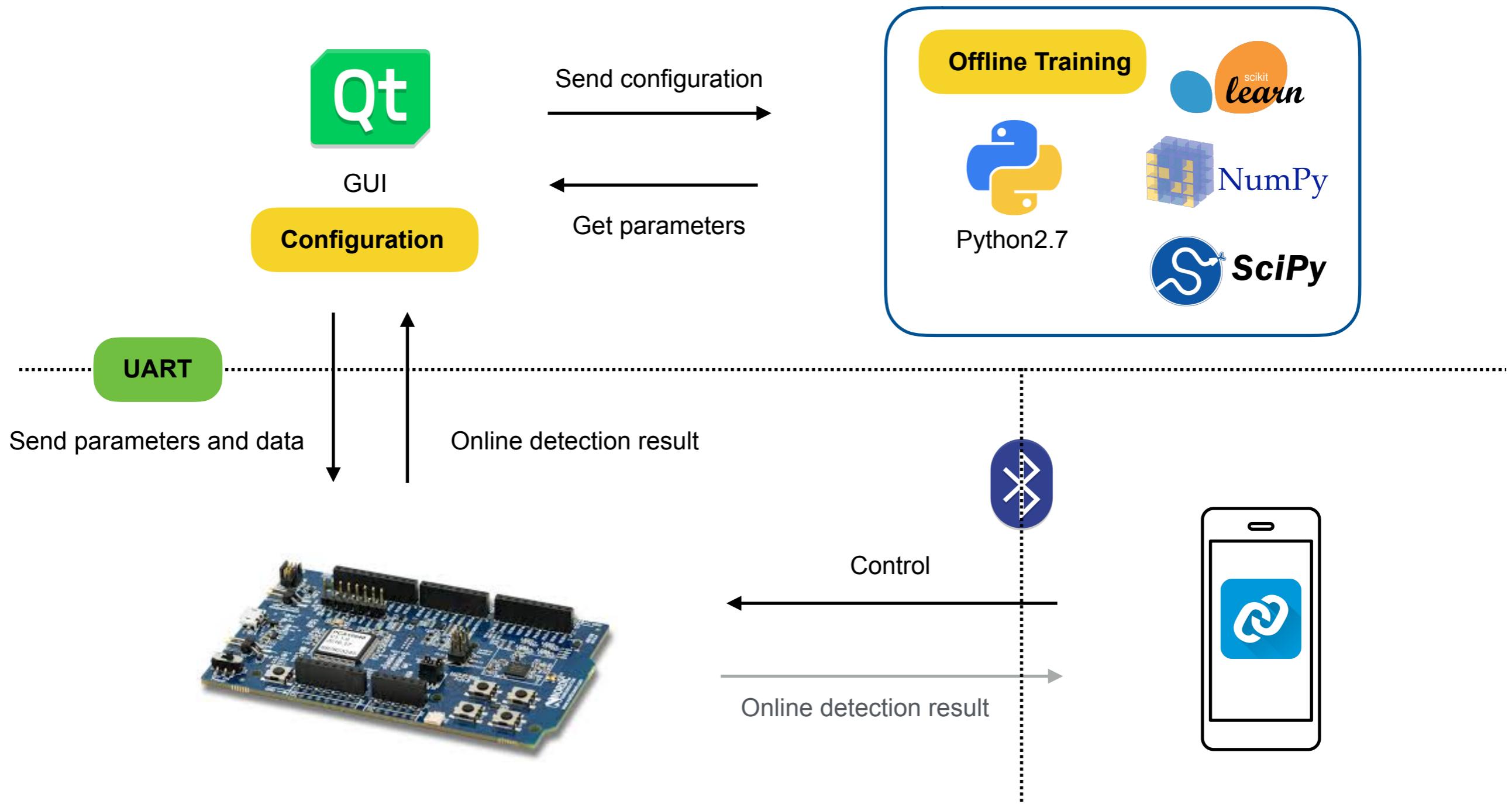
Table 2: Comparison with feature threshold as an additional step

## Feature selection

Without feature selection				With Mutual information			With Spearman's rank correlation		
ID	precision	recall	F1-score	precision	recall	F1-score	precision	recall	F1-score
1	0.7222	0.8764	0.7919	0.6905	0.8764	0.7724	0.7000	0.8090	0.7506
2	0.8333	0.8412	0.8373	0.8552	0.8555	0.8553	0.8469	0.8768	0.8616
3	0.7603	0.8402	0.7983	0.7859	0.8730	0.8272	0.7988	0.8588	0.8277
5	0.8002	0.9270	0.8589	0.7753	0.9333	0.8470	0.7976	0.9101	0.8502
6	0.5347	0.8270	0.6495	0.6713	0.8651	0.7560	0.6230	0.8339	0.7132
7	0.6489	0.7304	0.6873	0.6787	0.7957	0.7325	0.7318	0.8217	0.7742
8	0.7928	0.8105	0.8015	0.8170	0.9292	0.8695	0.8080	0.9178	0.8594
9	0.8676	0.9054	0.8861	0.8534	0.9250	0.8877	0.8568	0.9070	0.8812

Table 3: Comparison between different feature selection methods

# Implementation



# Contribution and future improvement

- 1. Improve the result in compare with Bachelin's method**
  - 2. A data cleaning framework where features can be modified or added**
  - 3. A new evaluation method that consider the characteristic of application**
- 

- 1. More dimension reduction method and classifiers can be applied (SVM)**
  - 2. More advanced evaluation method (score based)**
  - 3. More sensor data can be included (EMG)**
-

# Reference

- [1] [M. Bachlin, M. Plotnik, D. Roggen, I. Maidan, J. M. Hausdorff, N. Giladi, and G. Troster, “Wearable assis- tant for parkinson’s disease patients with the freezing of gait symptom,” ]
- [2] Thuy T. Pham\*,Freezing of Gait Detection in Parkinson’s Disease : A Subject-Independent Detector Using Anomaly Scores
- [3] J. Hausdorff, J. Lowenthal, T. Herman, L. Gruendlinger, C. Peretz, and N. Giladi, “Rhythmic auditory stimulation modulates gait variability in parkinson’s disease,”
- [4] J. Richman and J. Moorman, “Physiological time-series analysis using approximate entropy and sample entropy,”