A ROBUST FETAL ECG DETECTION METHOD FOR ABDOMINAL RECORDINGS

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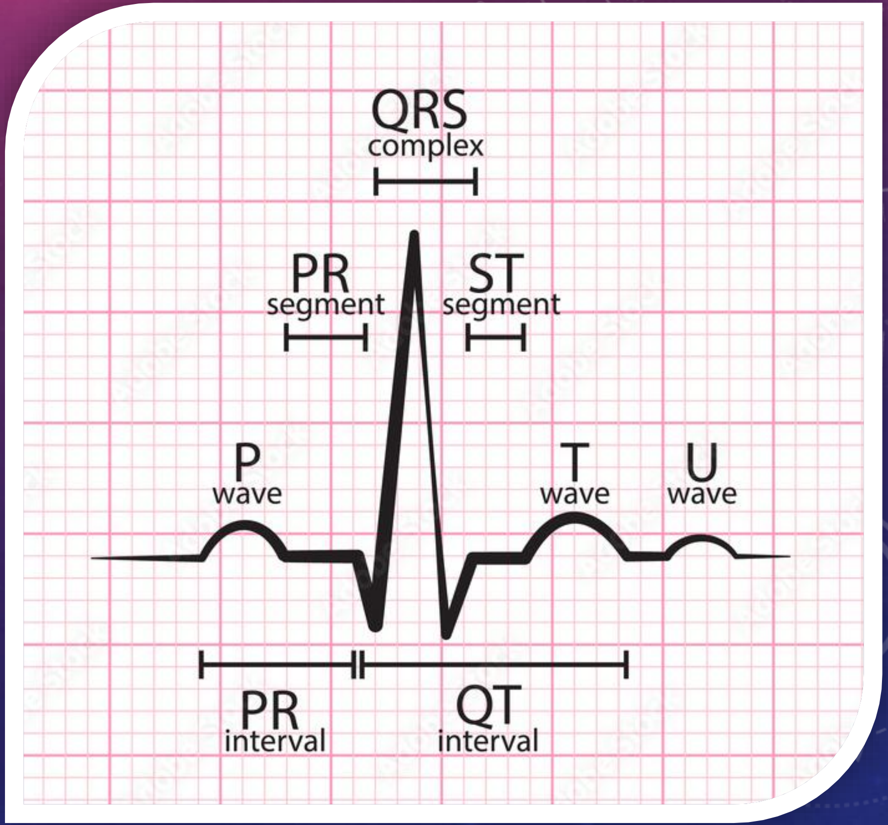
INTRODUCTION

WHY IS FECG IMPORTANT? HOW IS IT DONE?

- Morphological and temporal parameters of the ECG of the foetus during gestation can provide information about the fetal well-being, e.g. level of fetal oxygenation

- FECG can be obtained by placing electrodes on the mother's abdomen

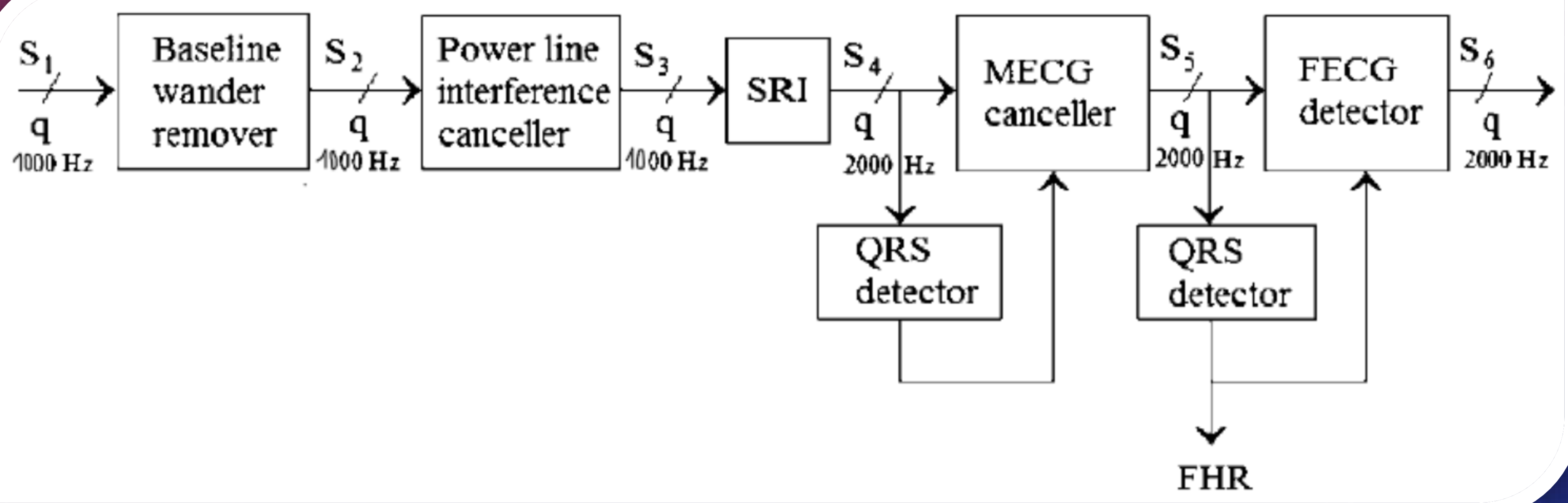
- FECG detection = detection of a small amplitude fetal signal overwhelmed by a large number of interference signals and noise



METHODOLOGY

APPROACH: SEQUENTIAL ANALYSIS (SA)

- Estimating and removing the interference signals step-by-step, using *a priori* information about the interference signals and the signal of interest



FILTERING

- ***LINEAR INTERPOLATION***

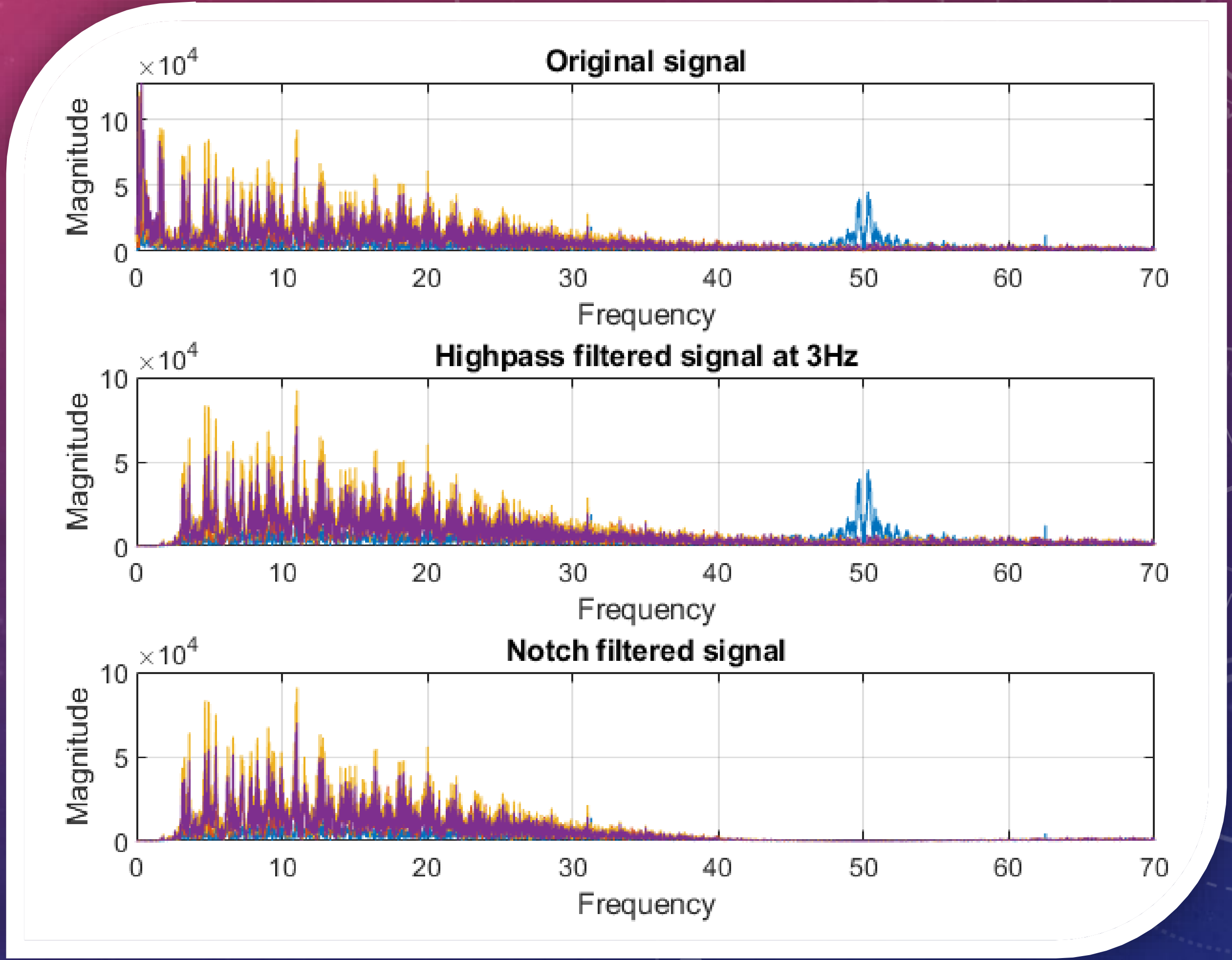
  To replace NaN values

- ***BASELINE WANDER REMOVER***

  Highpass filter at 3 Hz

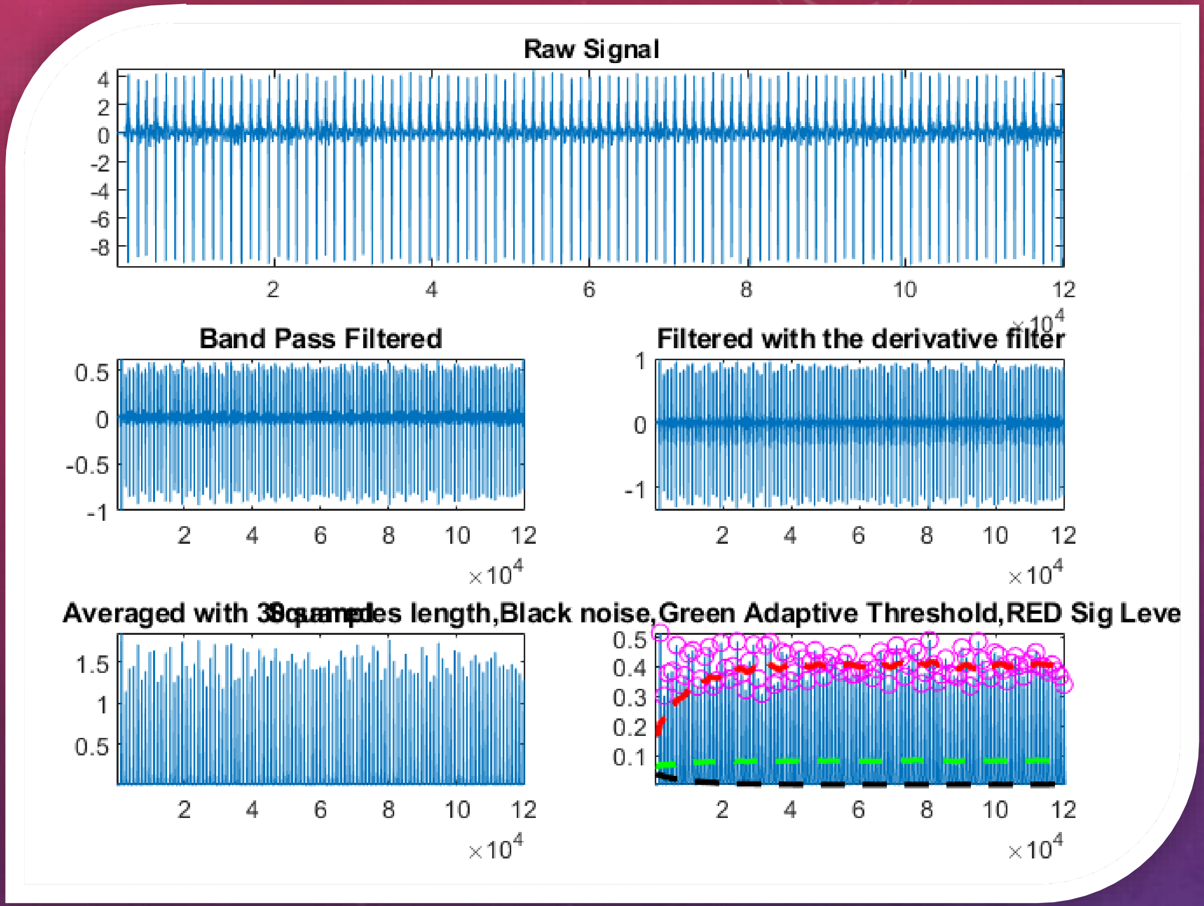
- ***POWER – LINE INTERFERENCE CANCELLER***

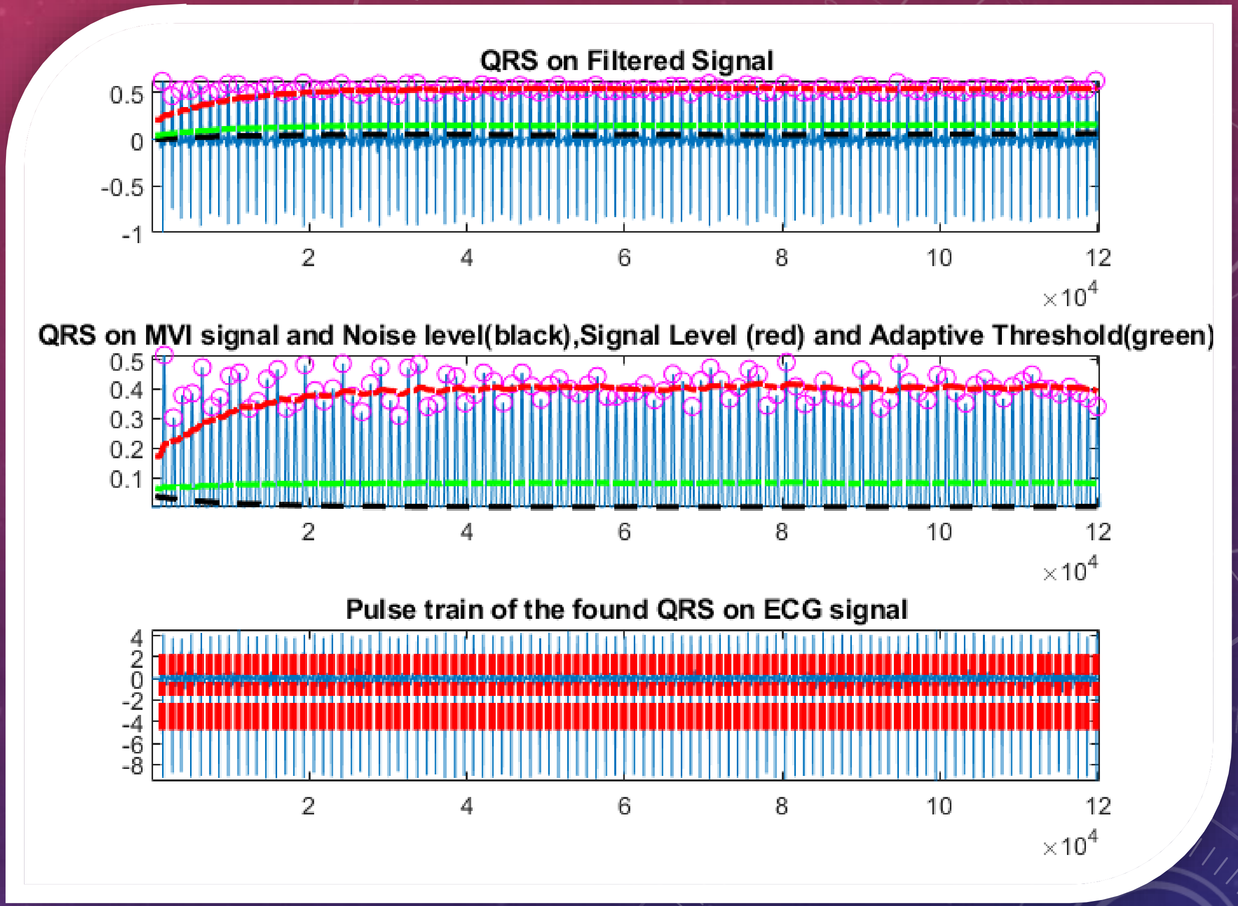
  Notch filter at 50 Hz

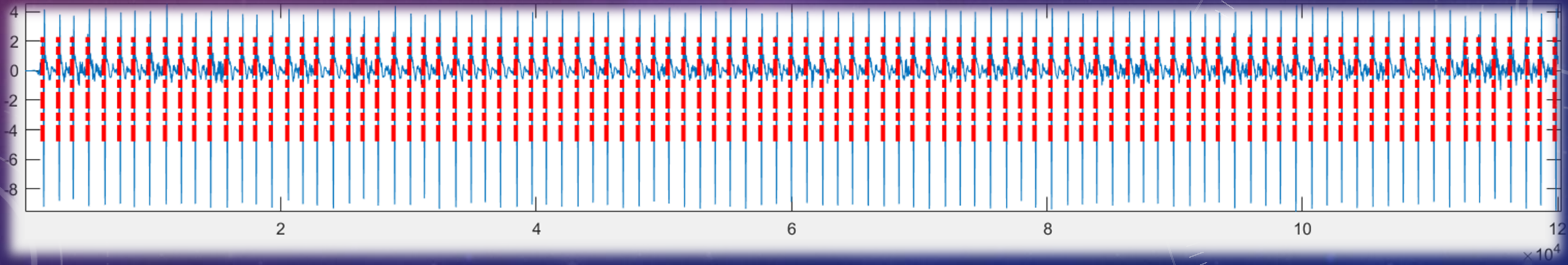


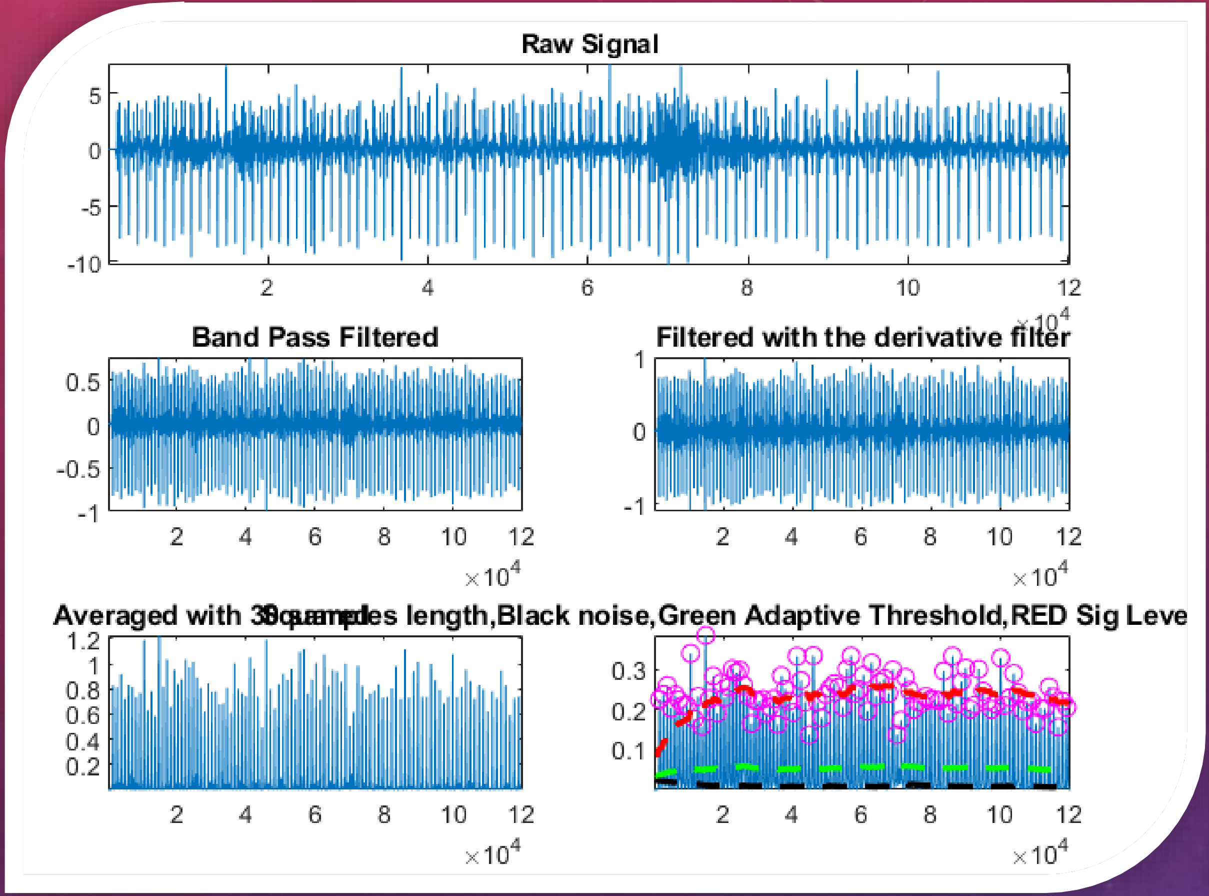
MQRS DETECTOR

1. *MULTI- CHANNEL QRS ENHANCEMENT METHOD* → using **PCA**
2. *UPSAMPLING* up to 2000 Hz
3. *PAN TOMPKINS QRS DETECTOR*
   - Additional filtering
     - band pass 5 – 15 Hz → noise cancellation
     - derivative filter → emphasizing R peaks
     - moving average (150 ms window) → get smooother signal
   - R-peaks detector
     - adaptive thresholds and decision rules


Raw Signal
Band Pass Filtered
Filtered with the derivative filter
Averaged with 30 samples length,Black noise,Green Adaptive Threshold,RED Sig Leve
Squared


QRS on Filtered Signal
QRS on MVI signal and Noise level(black),Signal Level (red) and Adaptive Threshold(green)
Pulse train of the found QRS on ECG signal

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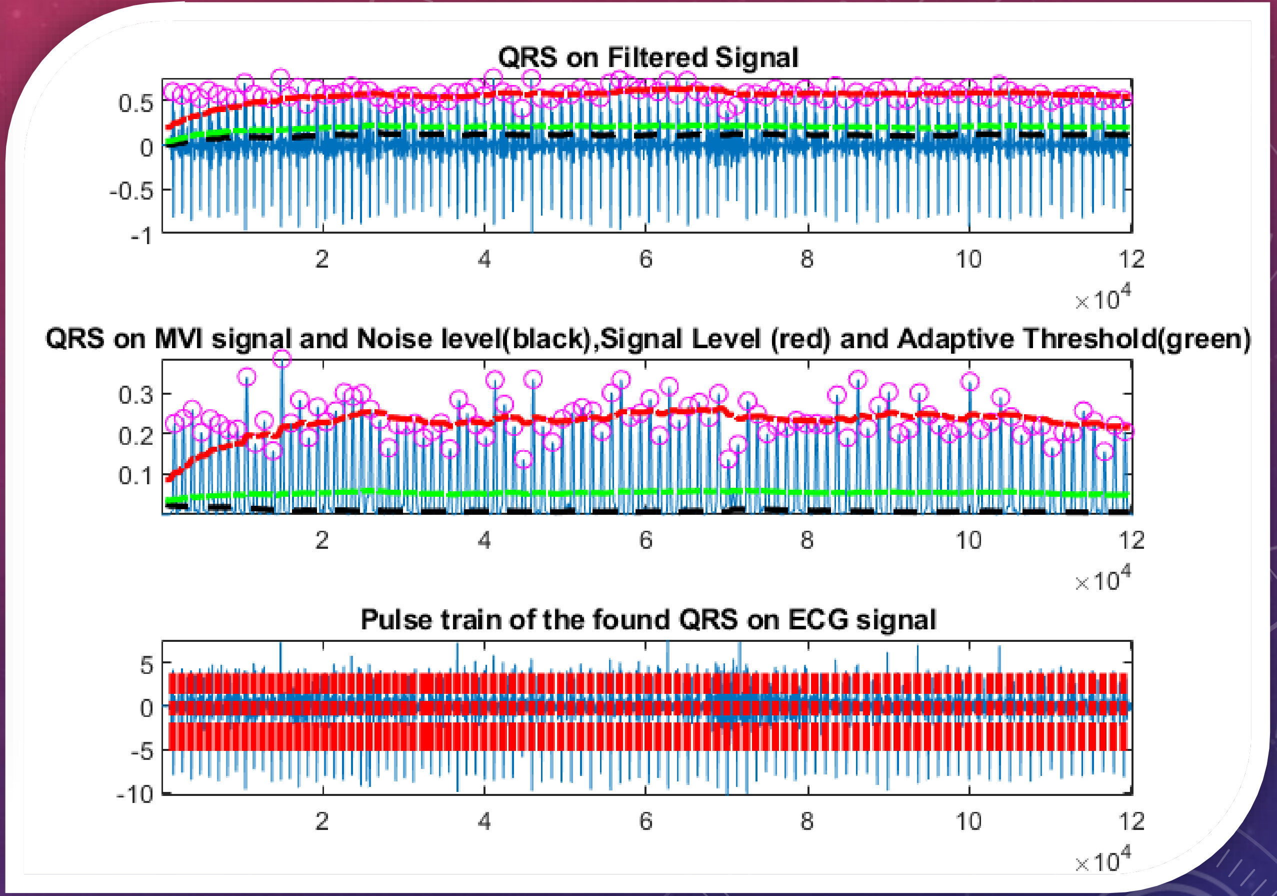
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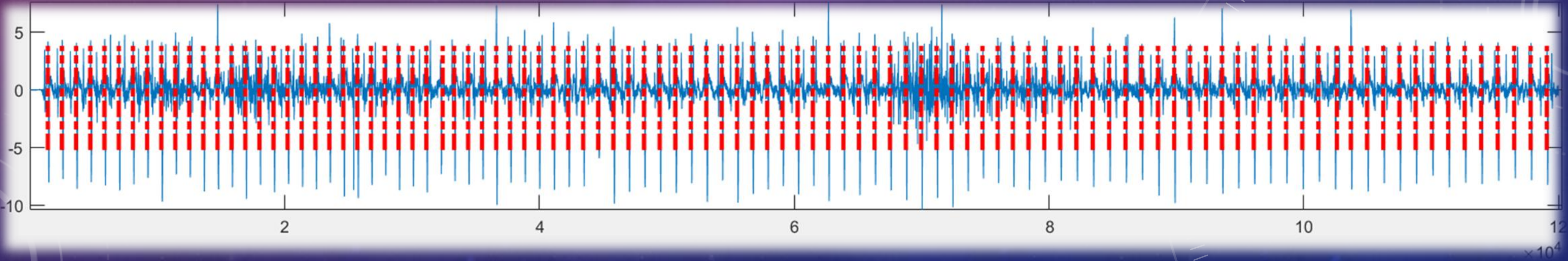
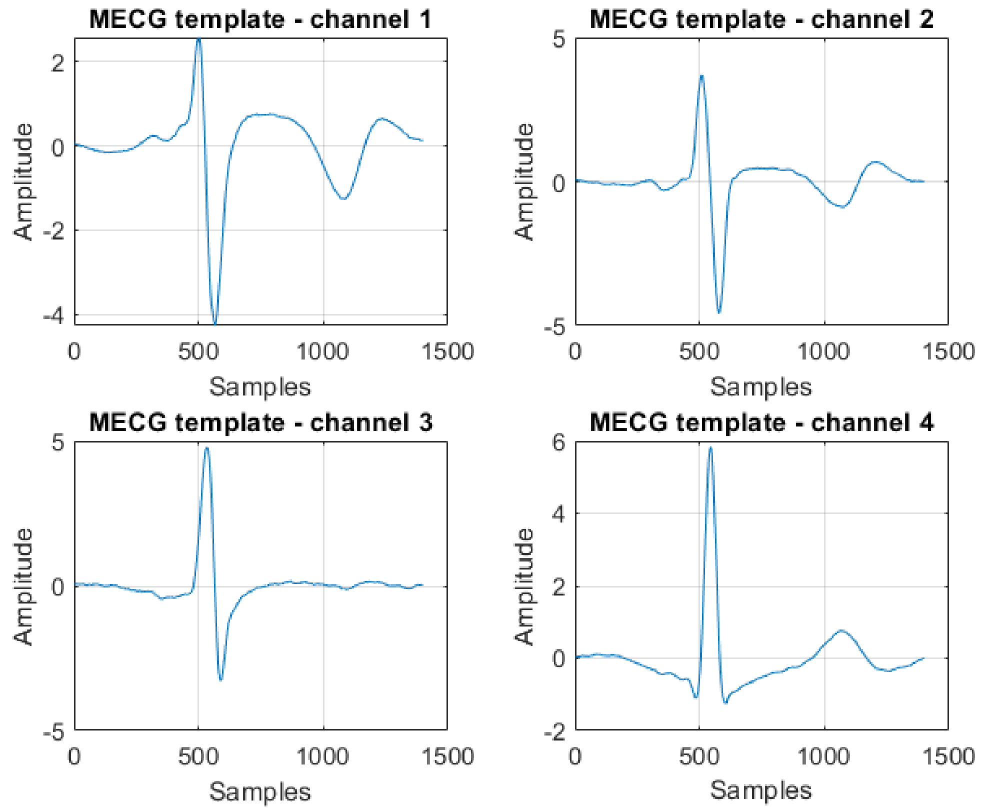


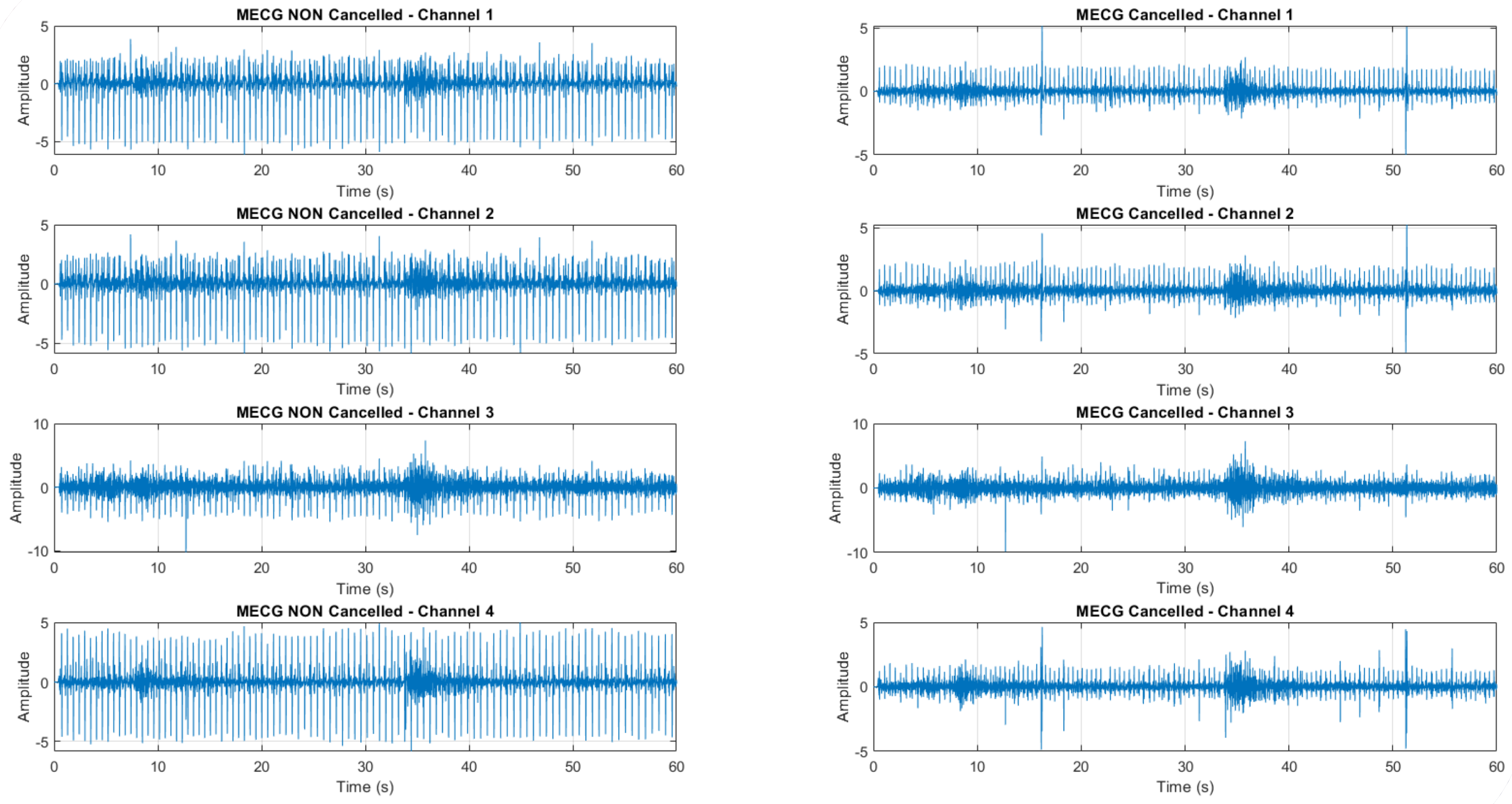
MQRS TEMPLATE

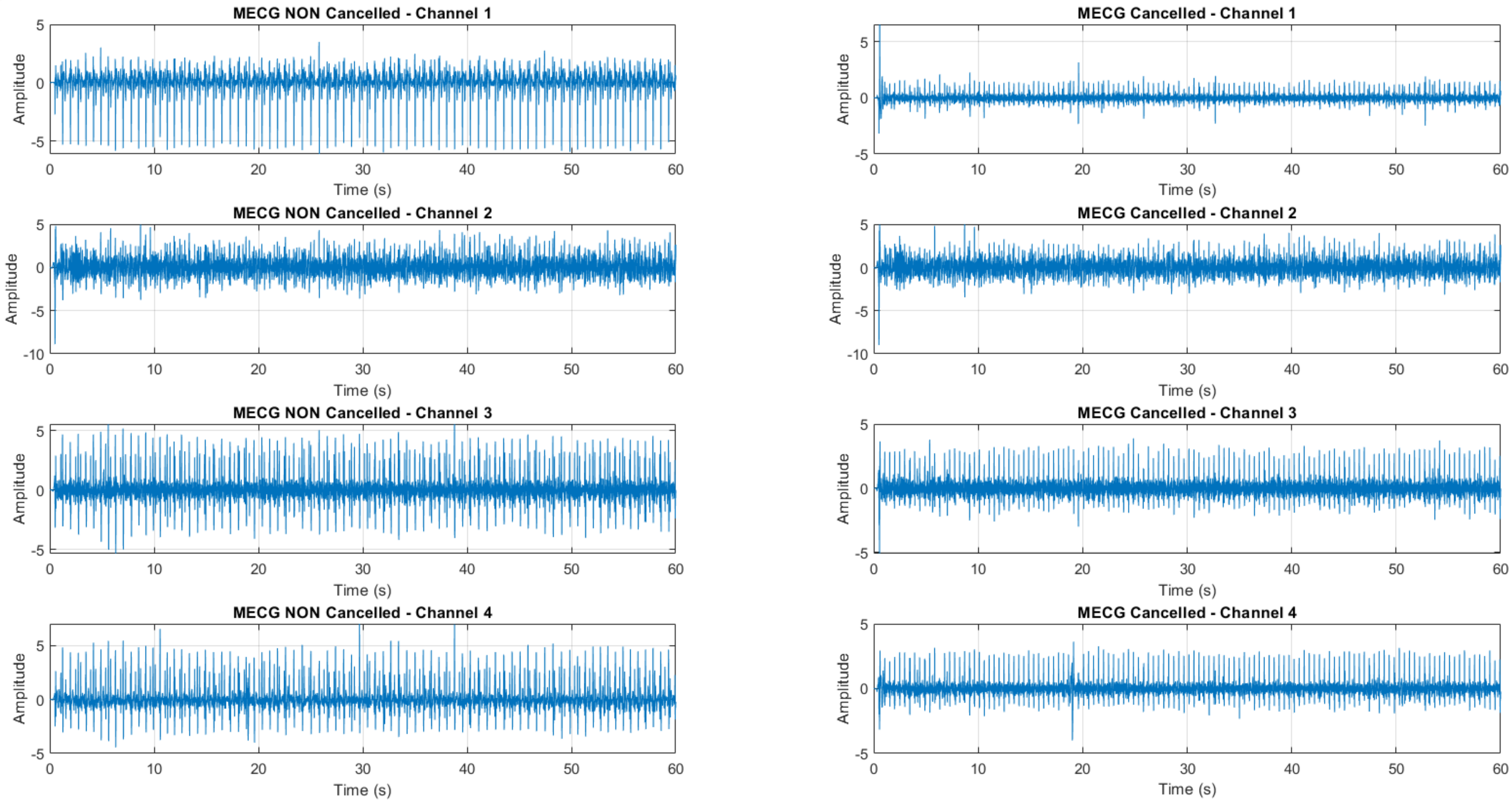
- Extract the found QRS complexes from each channel
  - P wave - 0.20 s
  - QRS complex - 0.10 s
  - T wave - 0.40 s,
- Average the extracted QRS complexes to obtain the average MQRS template for each channel



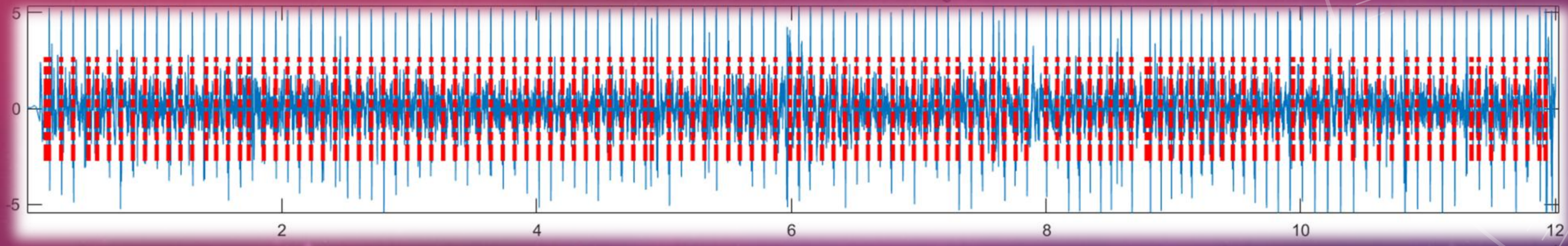
MECG CANCELLER

- For each channel, subtract the average template in the MECG by shifting and subtracting the template at each position detected by the QRS detector

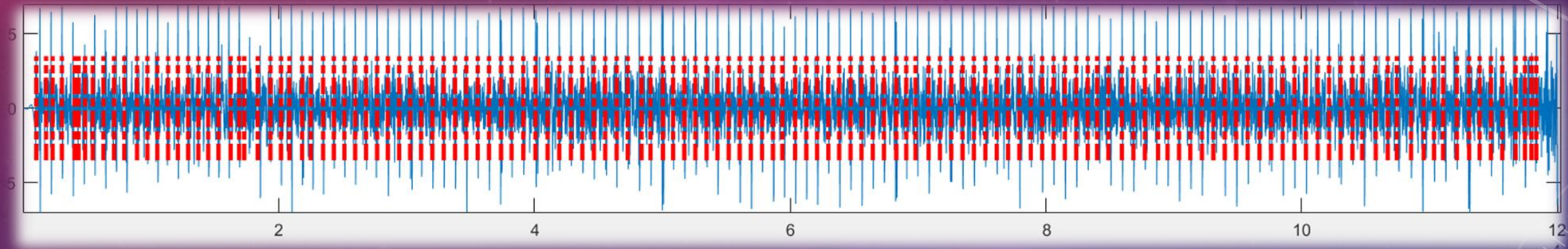



MECG NON Cancelled - Channel 1
MECG Cancelled - Channel 1
MECG NON Cancelled - Channel 2
MECG Cancelled - Channel 2
MECG NON Cancelled - Channel 3
MECG Cancelled - Channel 3
MECG NON Cancelled - Channel 4
MECG Cancelled - Channel 4
Amplitude
Time (s)
0
10
20
30
40
50
60
5
0
-5
-10

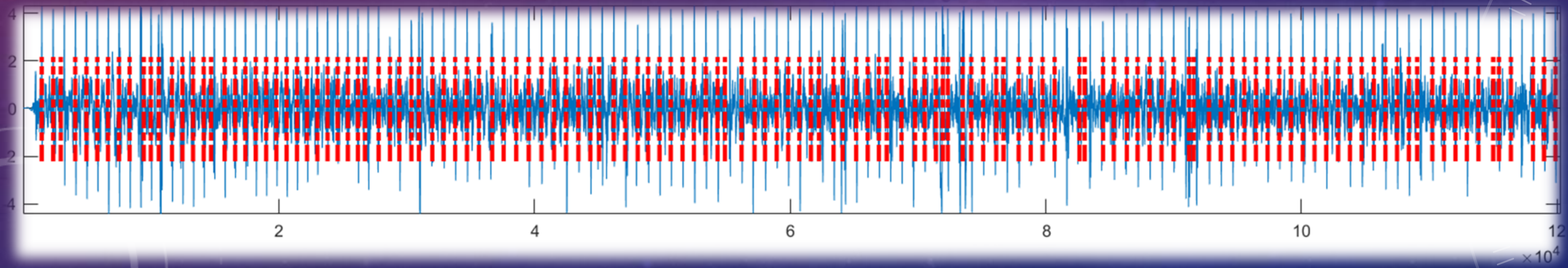
FQRS DETECTOR AND FHR ESTIMATION - SUCCESS



Sig. no. 4
Found MHR = 79 bpm
Found FHR = 130 bpm
Target FHR = 129 bpm

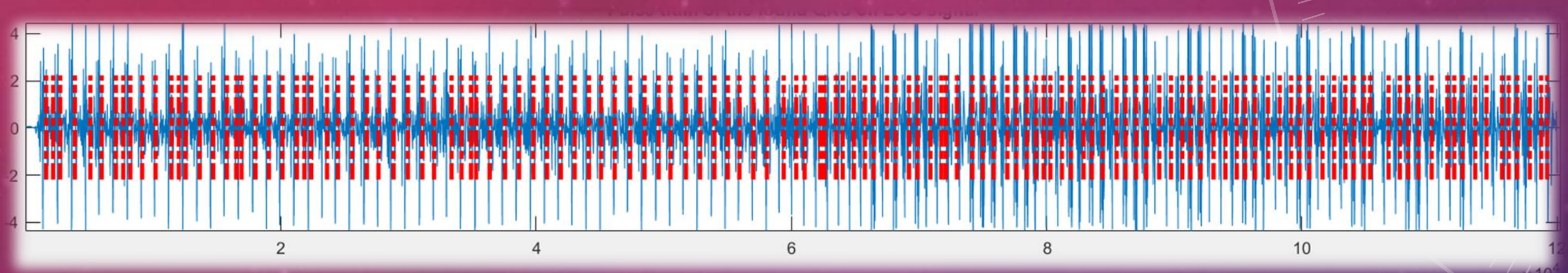


Sig. no. 12
Found MHR = 86 bpm
Found FHR = 138 bpm
Target FHR = 138 bpm

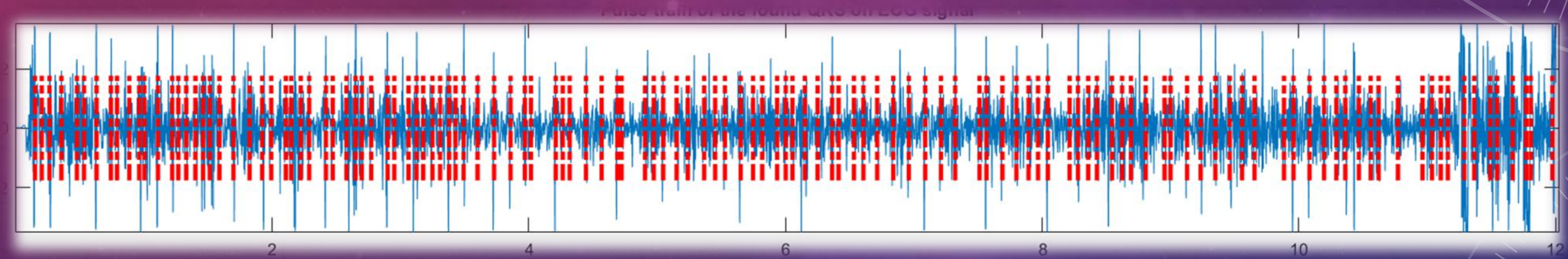


Sig. no. 15
Found MHR = 85 bpm
Found FHR = 133 bpm
Target FHR = 134 bpm

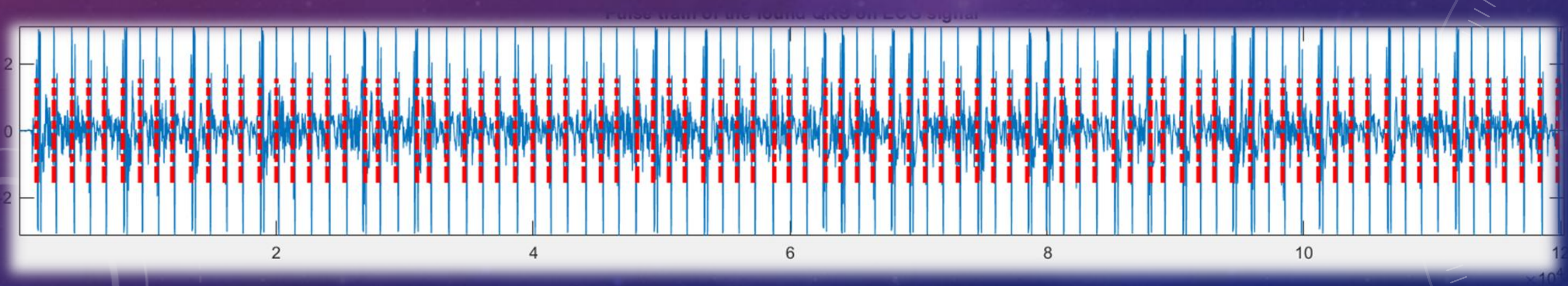
FQRS DETECTOR AND FHR ESTIMATION - FAILURE



Sig. no. 2
Found MHR = 124 bpm
Found FHR = 132 bpm
Target FHR = 160 bpm



Sig. no. 6
Found MHR = 100 bpm
Found FHR = 127 bpm
Target FHR = 160 bpm



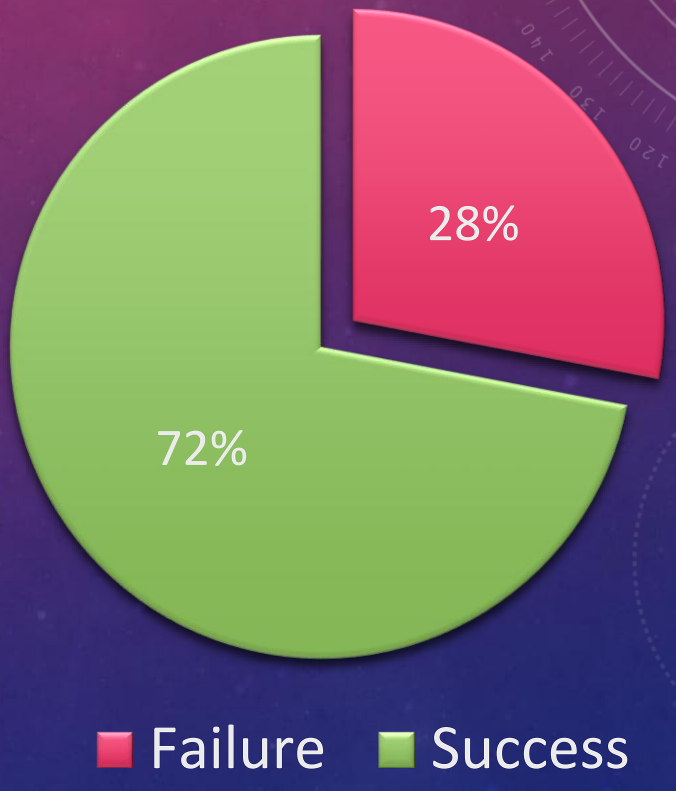
Sig. no. 21
Found MHR = 90 bpm
Found FHR = 90 bpm
Target FHR = 145 bpm

RESULTS AND CONCLUSIONS

OVERALL RESULTS

- No. of samples in the dataset : **25** signals
- No. of correctly estimated FHRs*: **18**
- No. of wrongly estimated FHRs*: **7**

*the error tolerance to consider the prediction correct is 10 bpm



CONCLUSIONS

- Being a sequential analysis, a wrongly executed step generates a chain reaction leading to the wrong estimate of the FHR
  - MHR is the main example: if the MQRS detector calculates incorrectly, it can lead to the deletion of parts of the FECG that should be kept and the retention of parts that should be discarded
- There are particular cases of examples in the dataset containing artifacts or particular noisy areas. In such instances, dedicated preprocessing is necessary, including clipping and adjustment of parameters (e.g., signal threshold in the QRS detector).

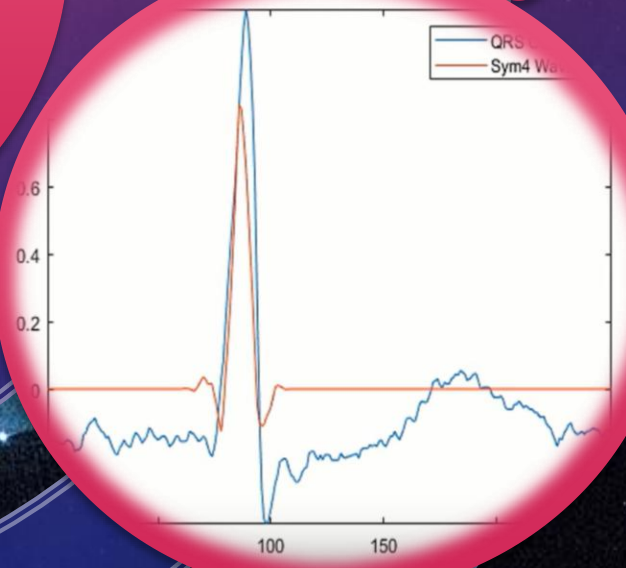
ANOTHER IMPLEMENTED STEP BUT NOT USED

QRS detection using wavelet is excellent in cases of clean ECG (e.g. electrodes on the chest), but when the ECG is noisy (e.g. FECG), the wavelet can emphasize artifacts and noise in addition to the ECG itself

WAVELET

as band pass filter

The **sym4** wavelet resembles the QRS complex



THANK YOU FOR YOUR ATTENTION!