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Photoplethysmography-based system for atrial fibrillation detection during hemodialysis

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Introduction (1)

Hemodialysis:

- 350 000 people in the EU
- 5400 dialysis centers in the EU
- 60 % of chronic kidney disease patients
- 3 times per week
- 4 hours long

Introduction (2)

Atrial fibrillation (AF):

- The most common arrhythmia
- 33 million people around the world
- Risk of stroke and heart failure

Connection:

- Hemodialysis increases risk of developing AF
- AF occurs during hemodialysis
- Related to changes in fluid balance

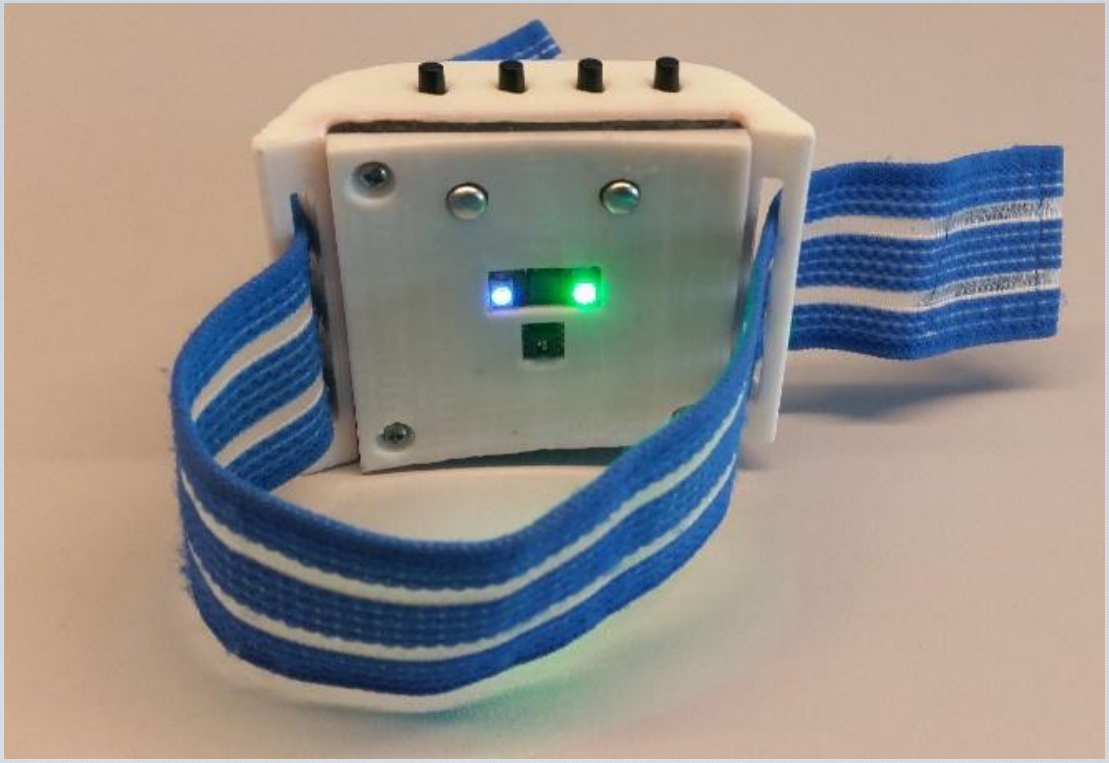
Research question

Can we detect AF during hemodialysis in an unobtrusive and still reliable way?

Proposal

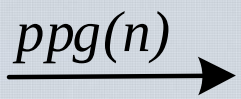
- Electrocardiography is encumbering
- Photoplethysmography might be a solution
  - Definitely less obtrusive!
  - Also less reliable...
- A system consisting of:
  - Specialized low power device
  - Embedded algorithm to run the detection

We have built a device

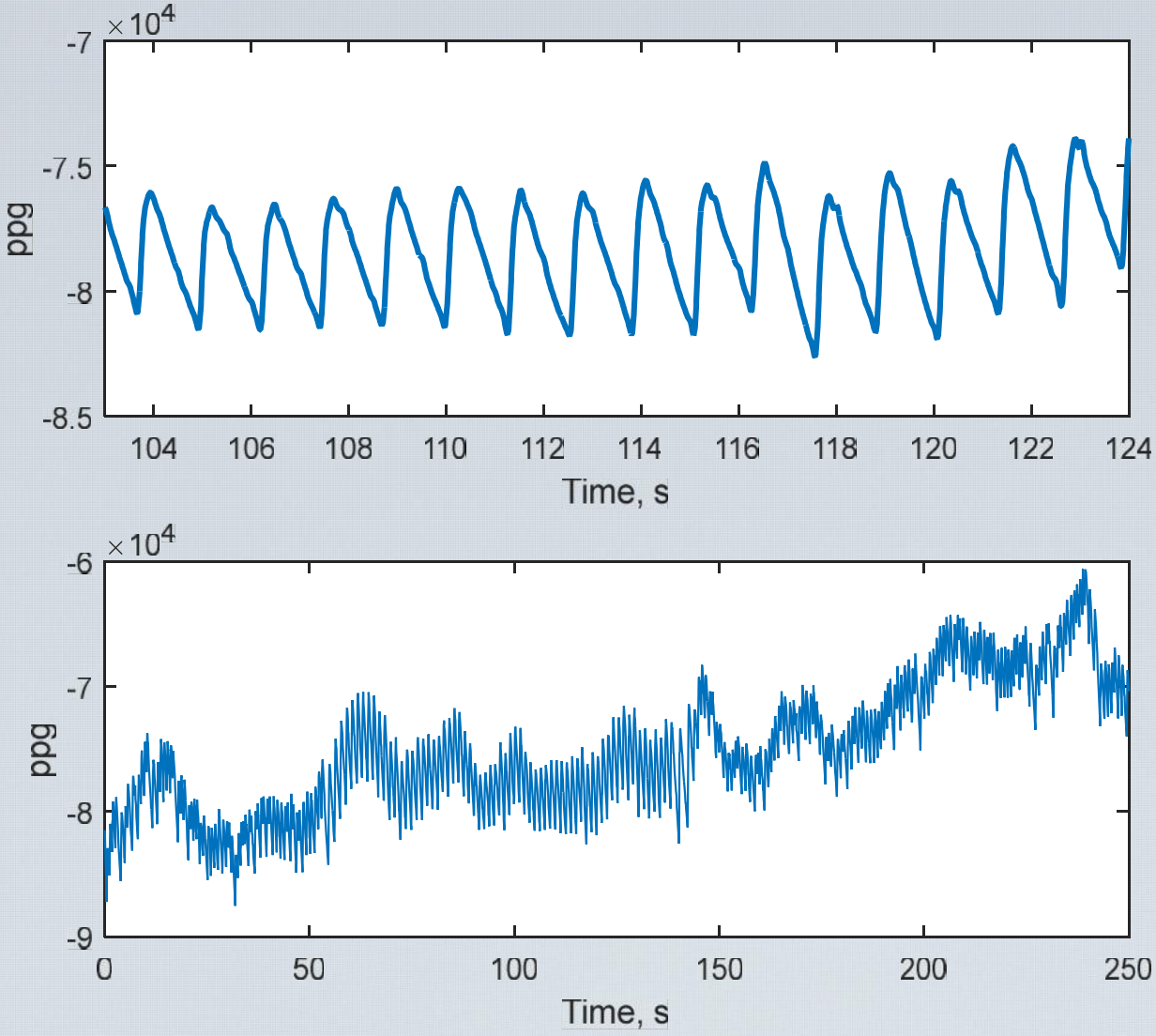


- ARM Cortex-M0, 16 MHz, 16 kB SRAM
- PPG sampling at 250 Hz
- 24-hour battery life

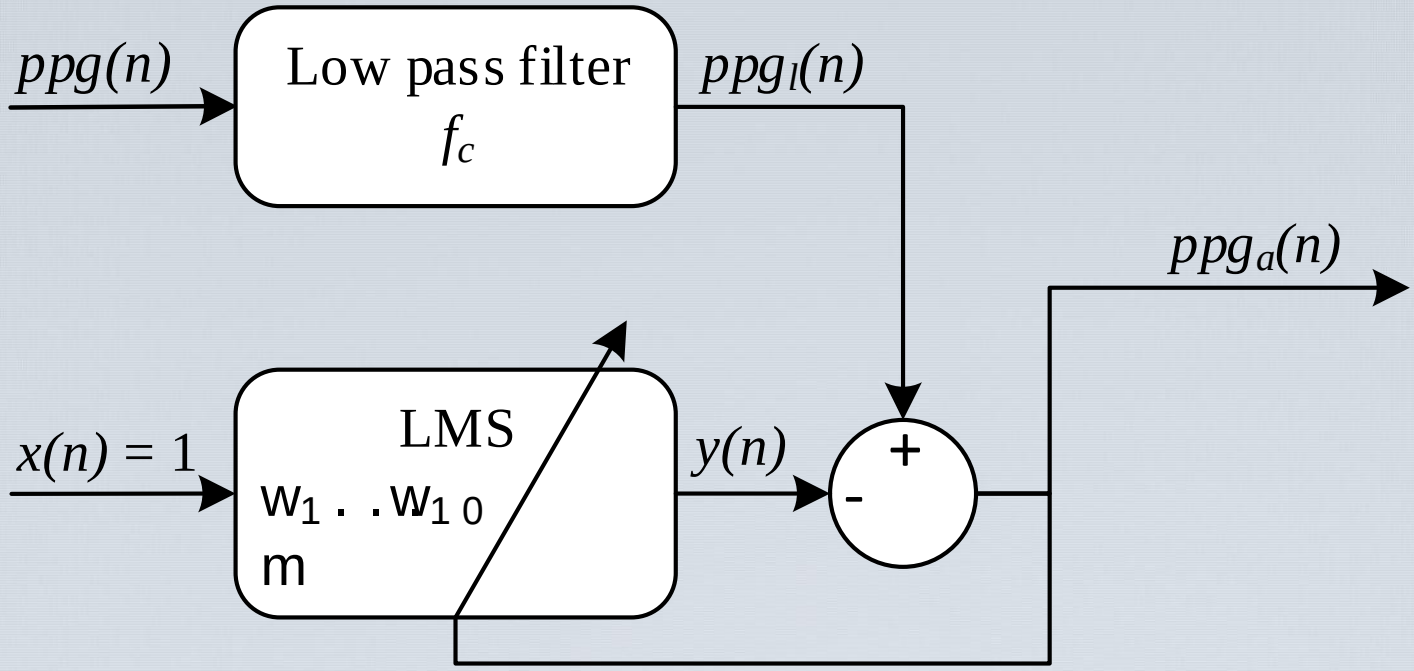
Methodology: Start



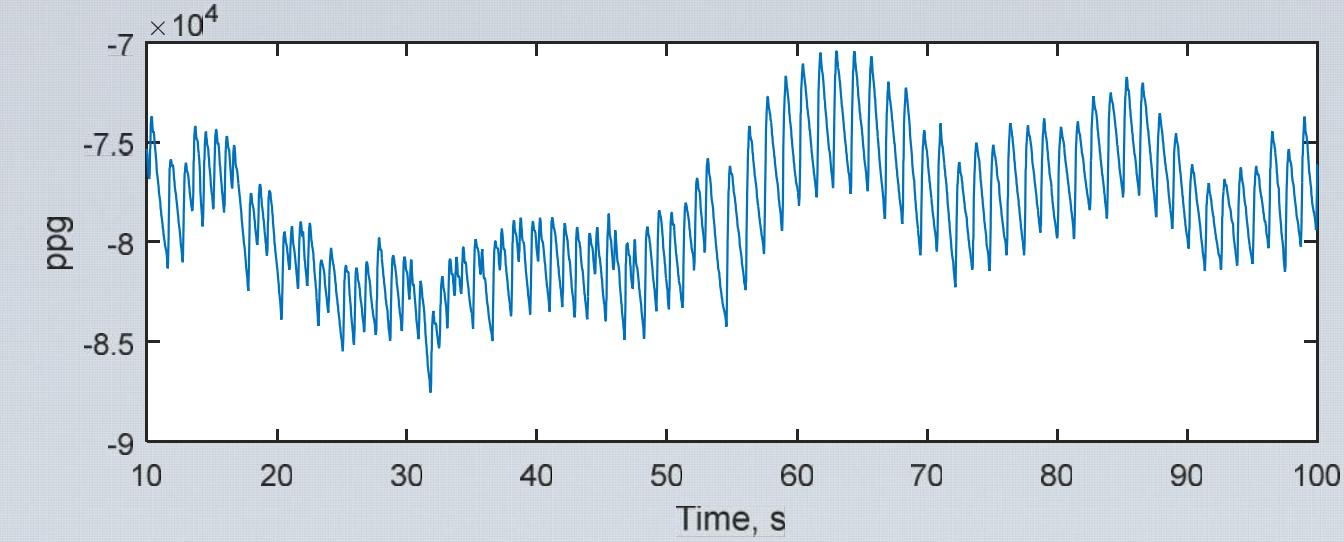
Raw PPG

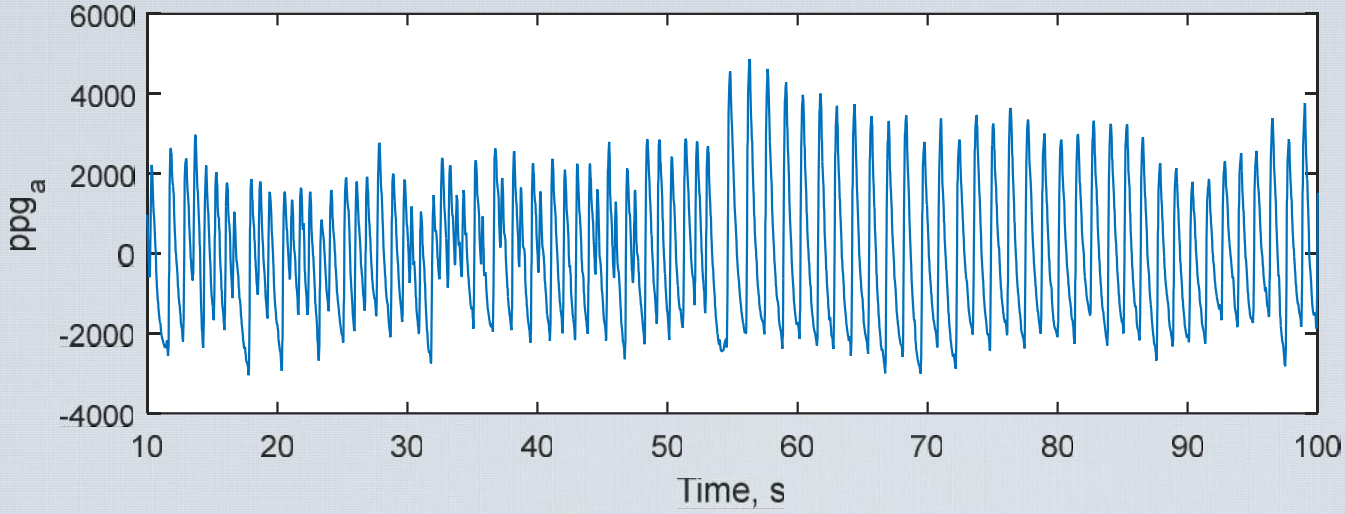

×10^4
-7
-7.5
-8
-8.5
ppg
104
106
108
110
112
114
116
118
120
122
124
Time, s
×10^4
-6
-7
-8
-9
ppg
0
50
100
150
200
250
Time, s

Methodology: Preprocessing

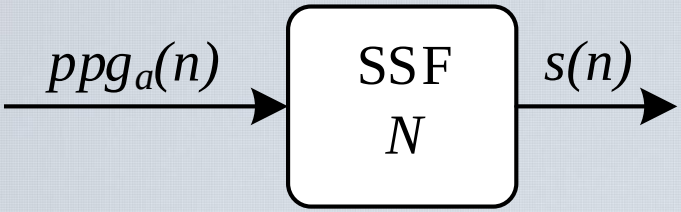


Raw & Preprocessed PPGs





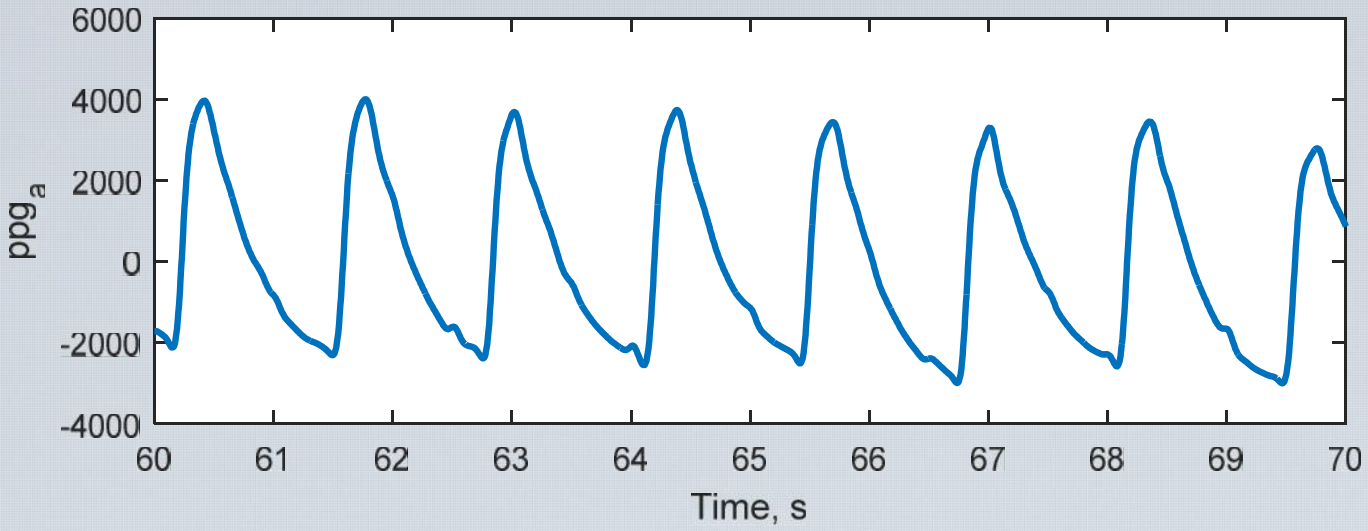
Methodology: SSF

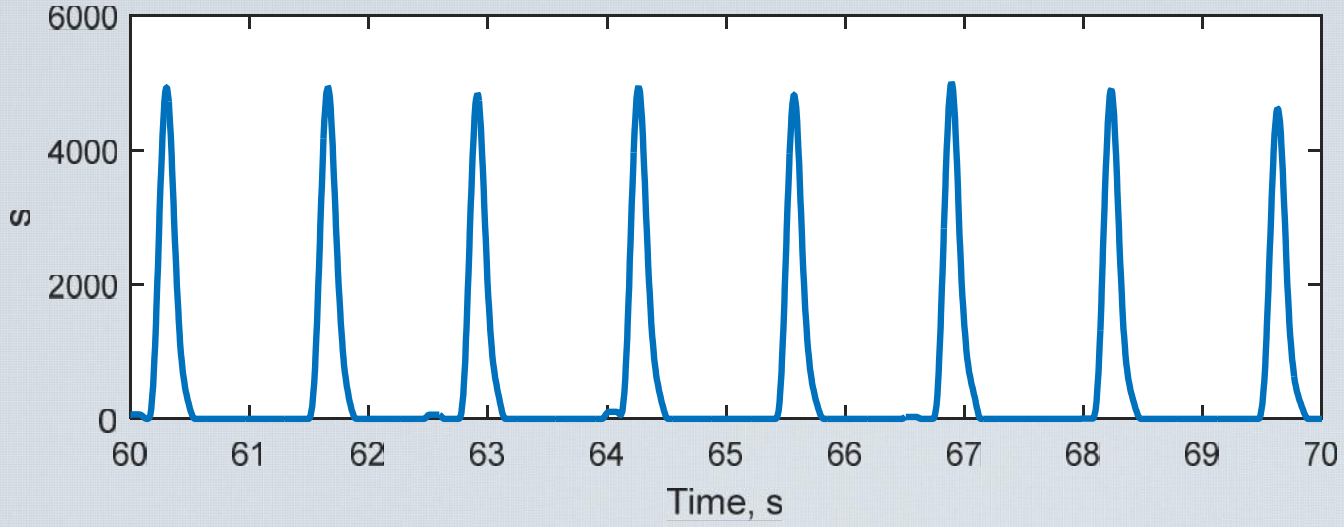


Slope Sum Function (SSF):

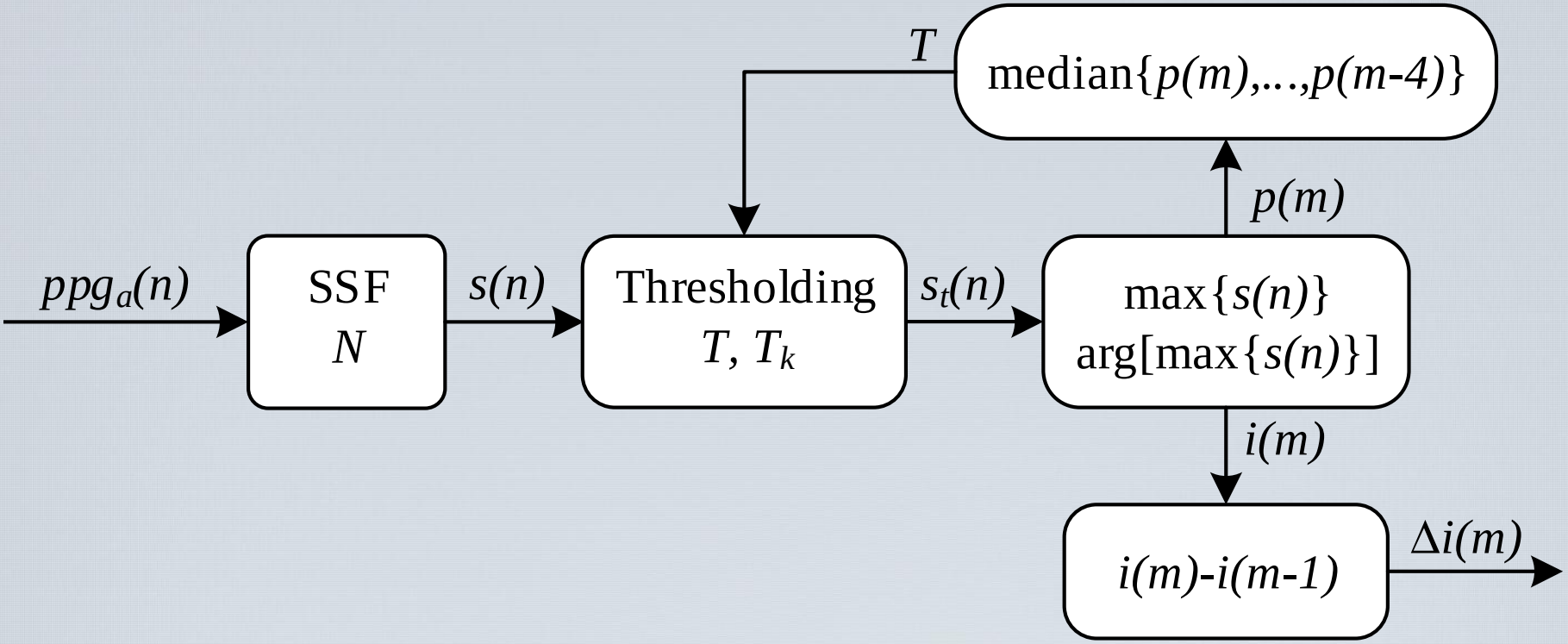
$$SSF_i = \sum_{k=i-w}^{i} \Delta x_k, \qquad where \qquad \Delta x_k = \begin{cases} \Delta s_k & when \quad \Delta s_k > 0 \\ 0 & when \quad \Delta s_k \leq 0 \end{cases}$$

PPG and SSF

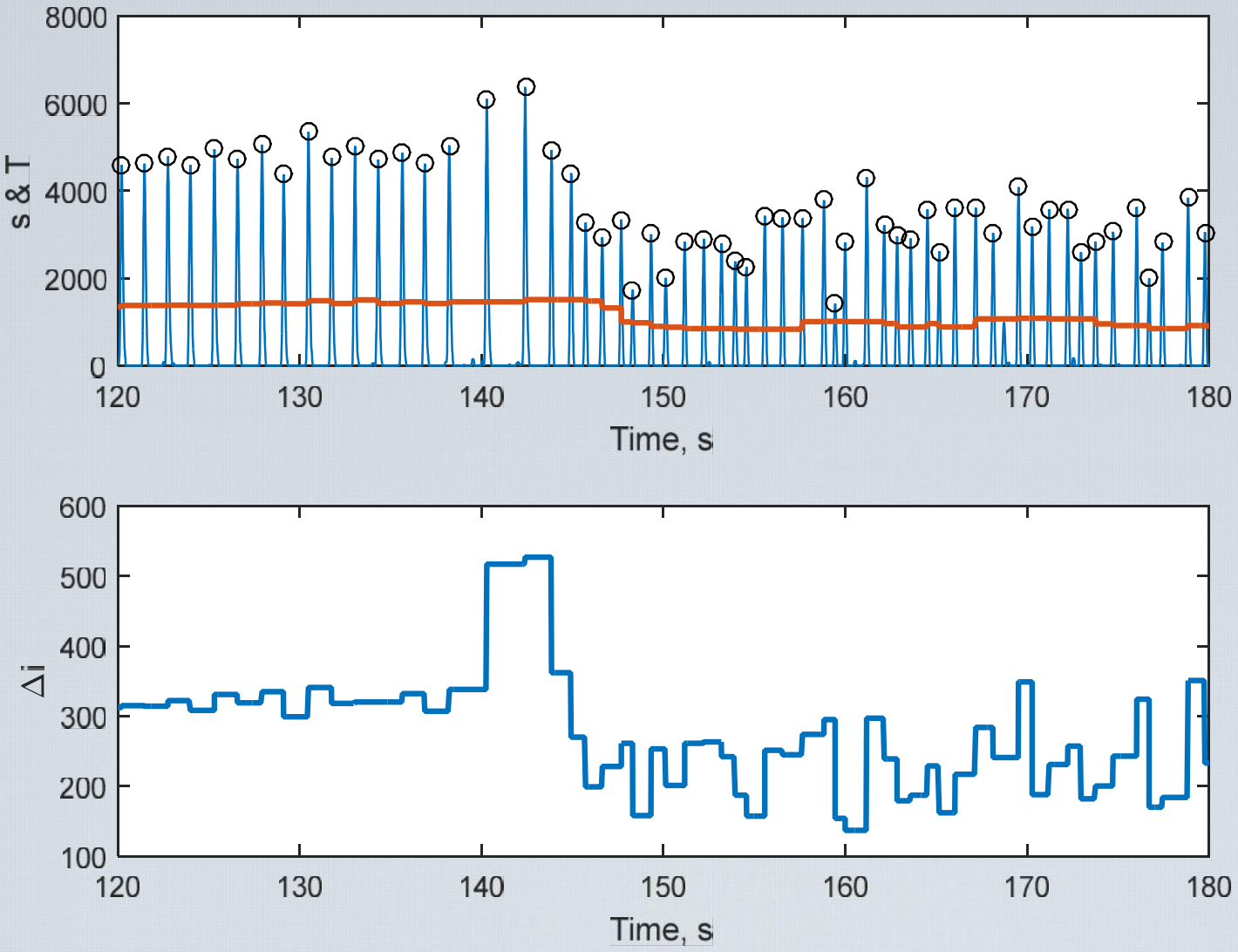

6000
4000
2000
0
-2000
-4000
ppg_a
60
61
62
63
64
65
66
67
68
69
70
Time, s


6000
4000
2000
0
s
60
61
62
63
64
65
66
67
68
69
70
Time, s

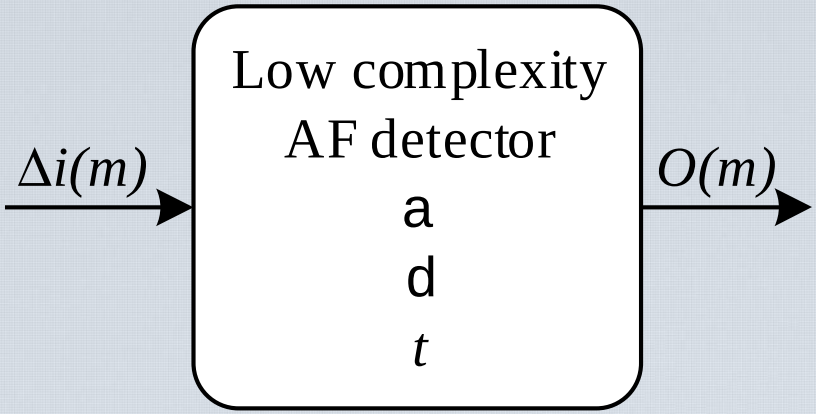
Methodology: Thresholding



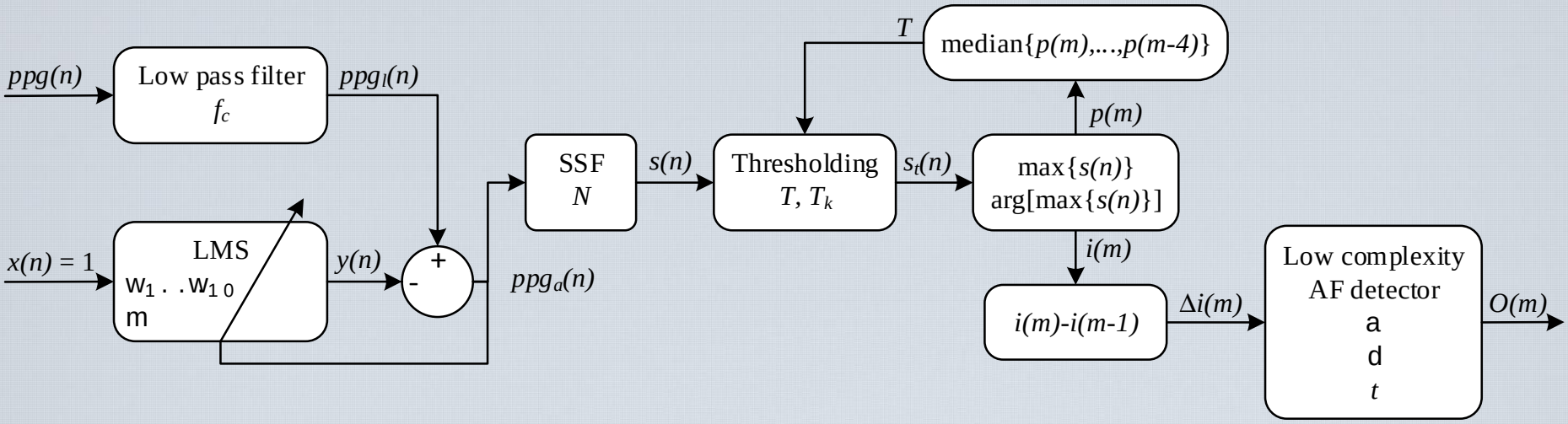
Thresholding and peak-to-peak



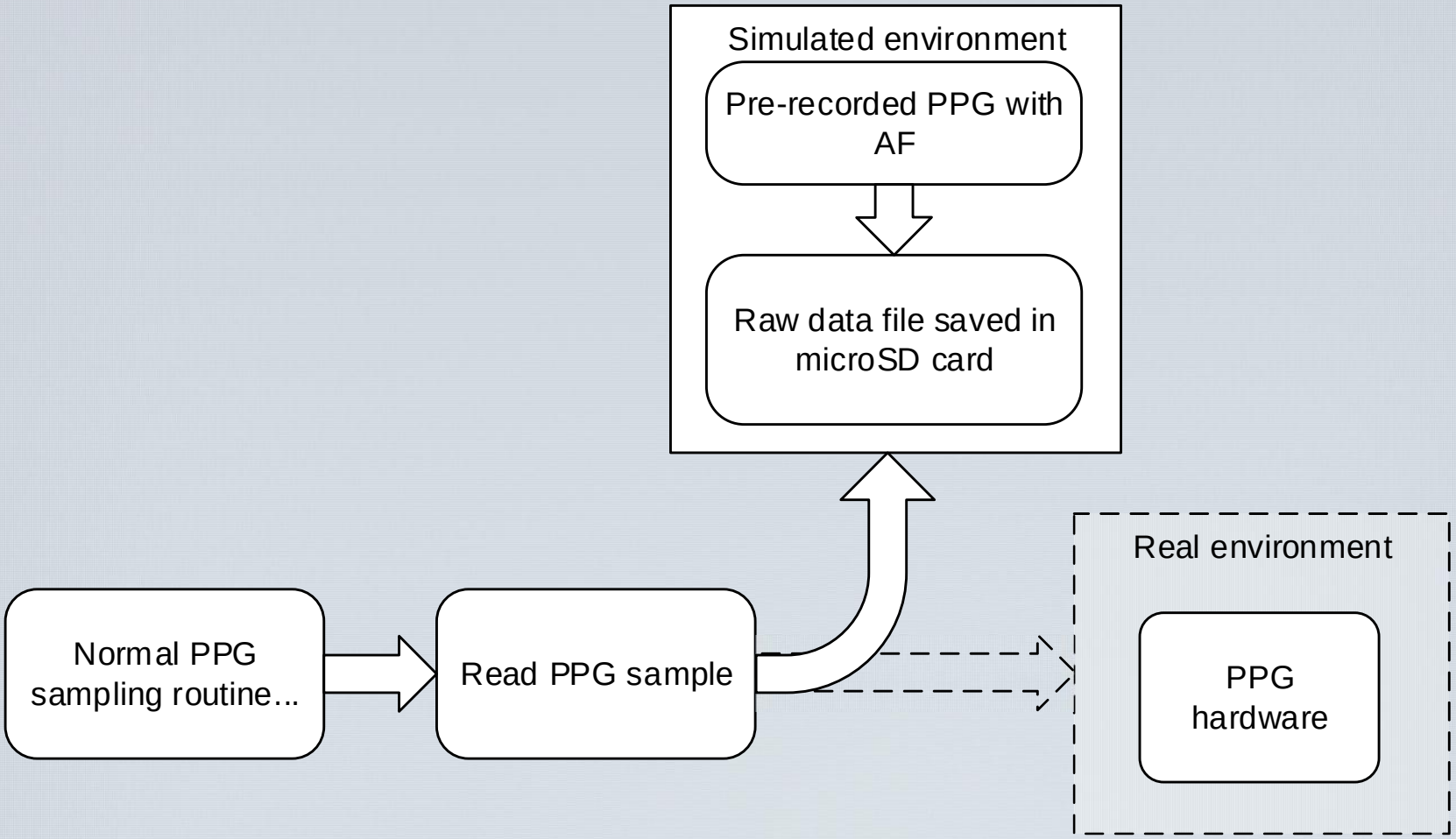
Methodology: AF detector



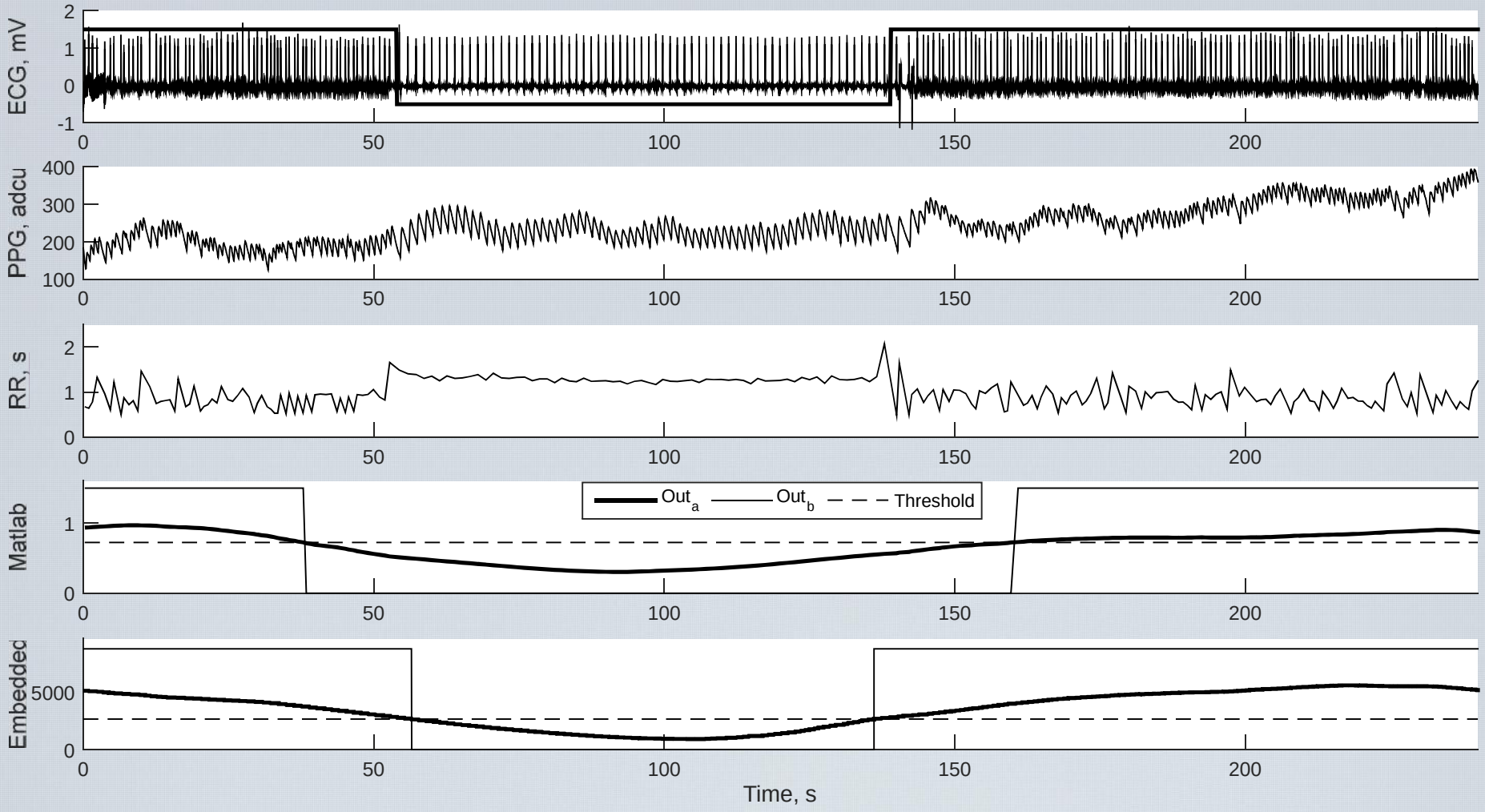
Methodology: overall



Testing: hardware-in-the-loop



Results


ECG, mV
PPG, adcu
RR, s
Matlab
Embedded
Out_a
Out_b
Threshold
Time, s

Conclusion

The proposed system has a potential to be applied for an unobtrusive real-time AF detection using solely the photoplethysmogram.

Future directions

- Introduce signal quality metrics
- Introduce morphology-based features
- Determine the optimal placement of the device

Acknowledgment

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- CARRE – CARdio REnal disease
- http://www.carre-project.eu