INSTITUTE OF SCIENTIFIC INSTRUMENTS

Academy of Sciences of the Czech Republic, v. v. i.

False Alarms in ICU Monitors:

Detection of Life-threatening Arrhythmias

F. Plesinger, P. Klimes, J. Halamek, P. Jurak

What is an ICU?

ICU – Intensive Care Unit. When the <u>**life-threatenning arrhythmia**</u> occurs, the ICU monitor raises an alarm.

So what is the problem?

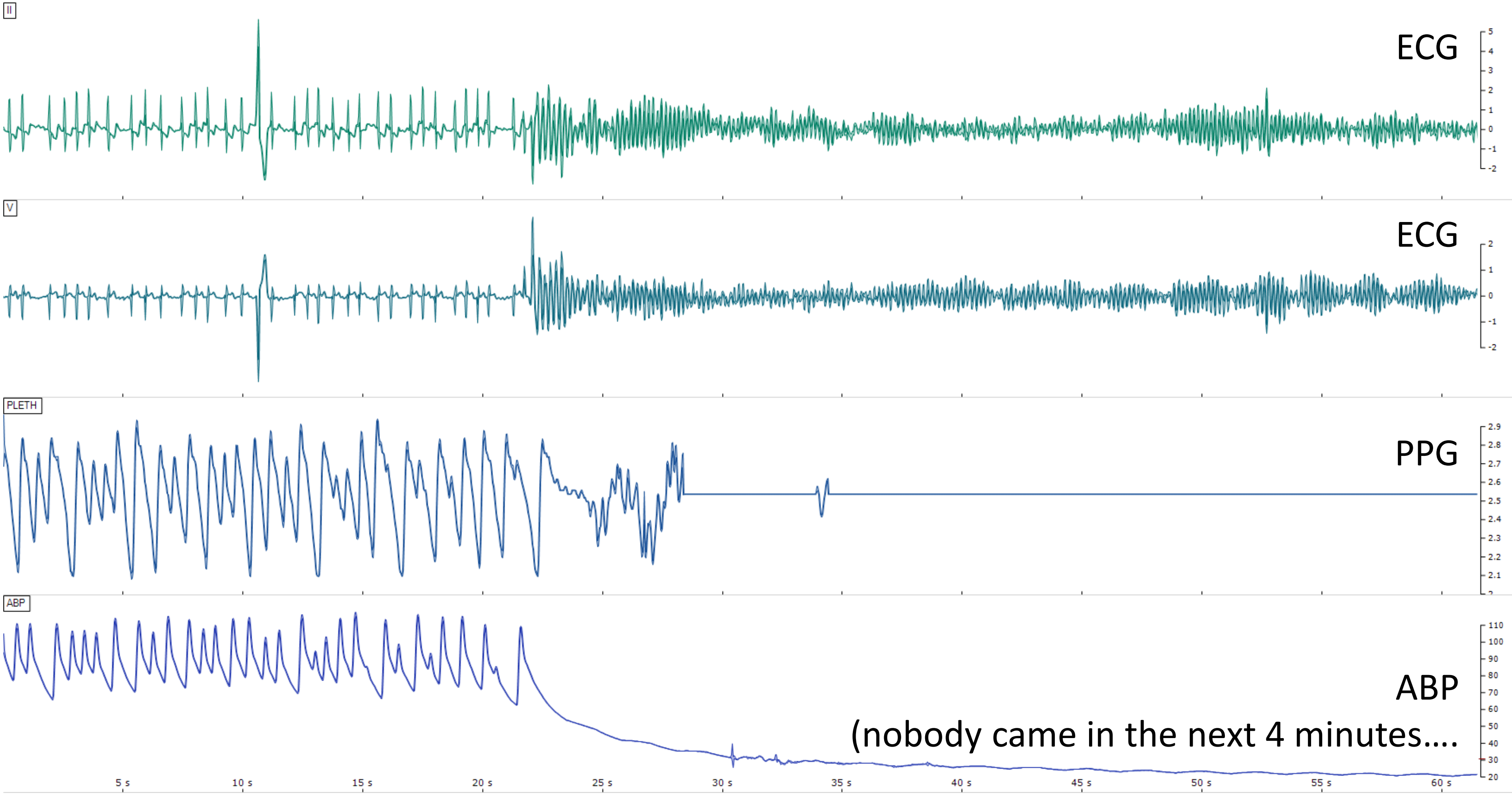
Up to 86% of ICU alarms are false =>

- Sleep deprivation of patients
- Psychically demanding for personell => less attention => „Crying wolf“ effect

Detection of Life-threatening Arrhythmias

Which may results in this…

(f545l.mat)



A solution to this problem was the task of Physionet Challenge 2015.

What is the PhysioNet /CinC Challenge?

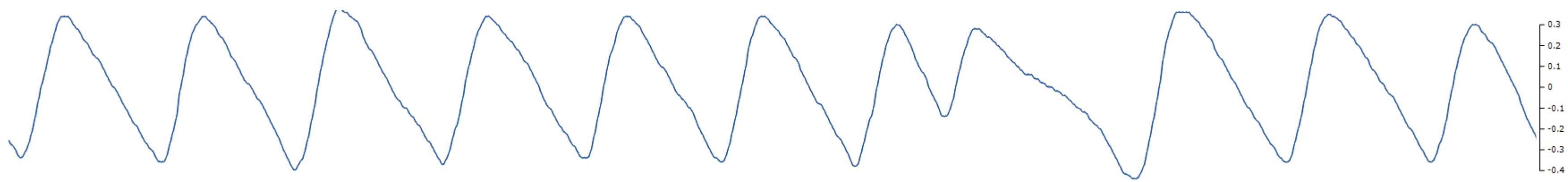
- Guys from **MIT** started this challenge in the year 2000. It is tightly connected to the conference Computing in Cardiology (CinC)
- Each year different topic aimed to processing of physiological signals
- Teams from all over the world (each year 20-110 teams). Most from academic field, some from private companies
- Ussual scenario is to develop algorithm and train it using public training set. Then the algorithm is sent to PhysioNet servers and tested on subset of hidden test set (max 10 trials for each team).
- https://physionet.org/

Which signals were available?

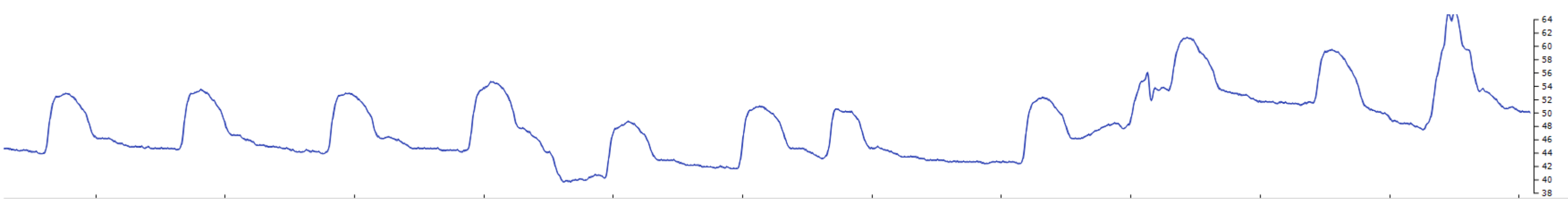
(All signals were downsampled to 250Hz, length 300 or 330 seconds)

2x ECG (Electrocardiogram)

PPG (Photoplethysmogram)



ABP (arterial blood pressure)



(respiratiory curve – not used)

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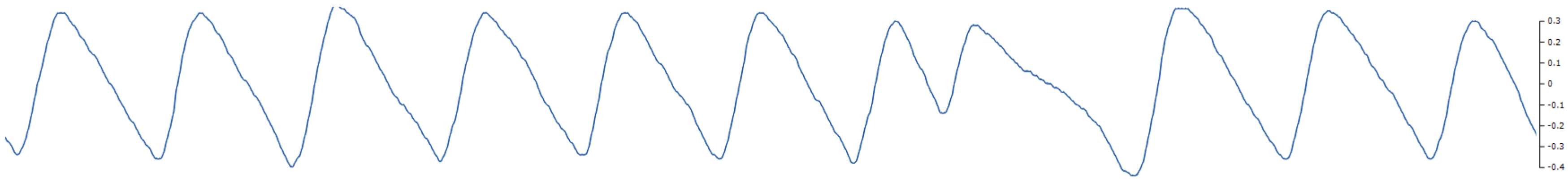

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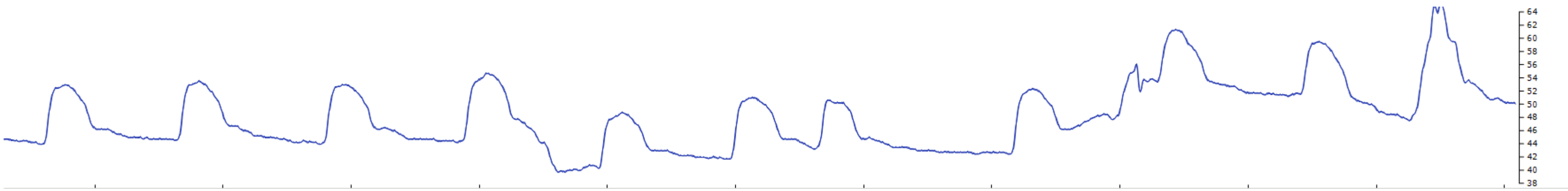

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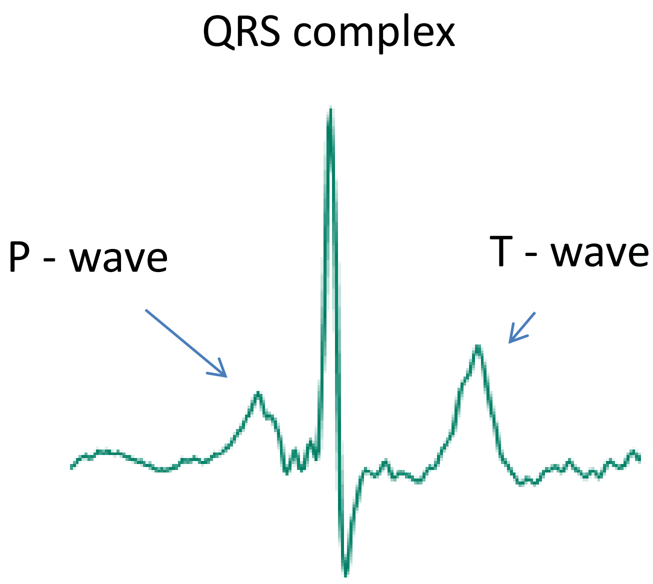
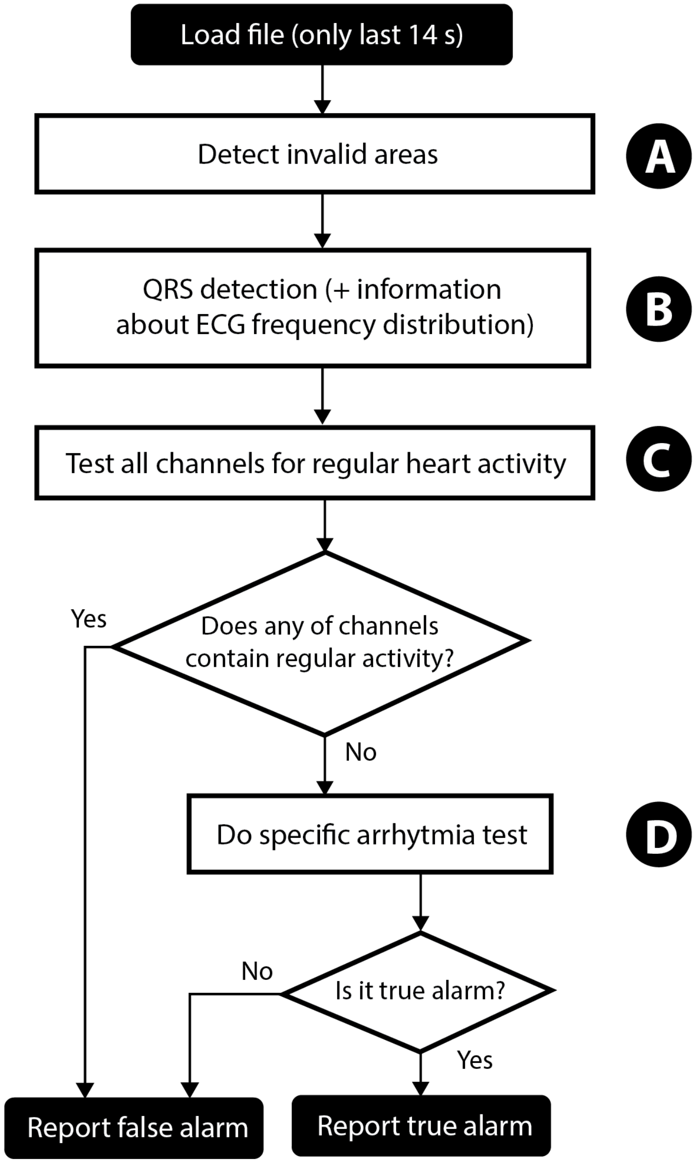
ECG detail



Detection of Life-threatening Arrhythmias



Basic flow diagram

<- Identify heavily damaged areas using FFT, descriptive statistics and histograms.

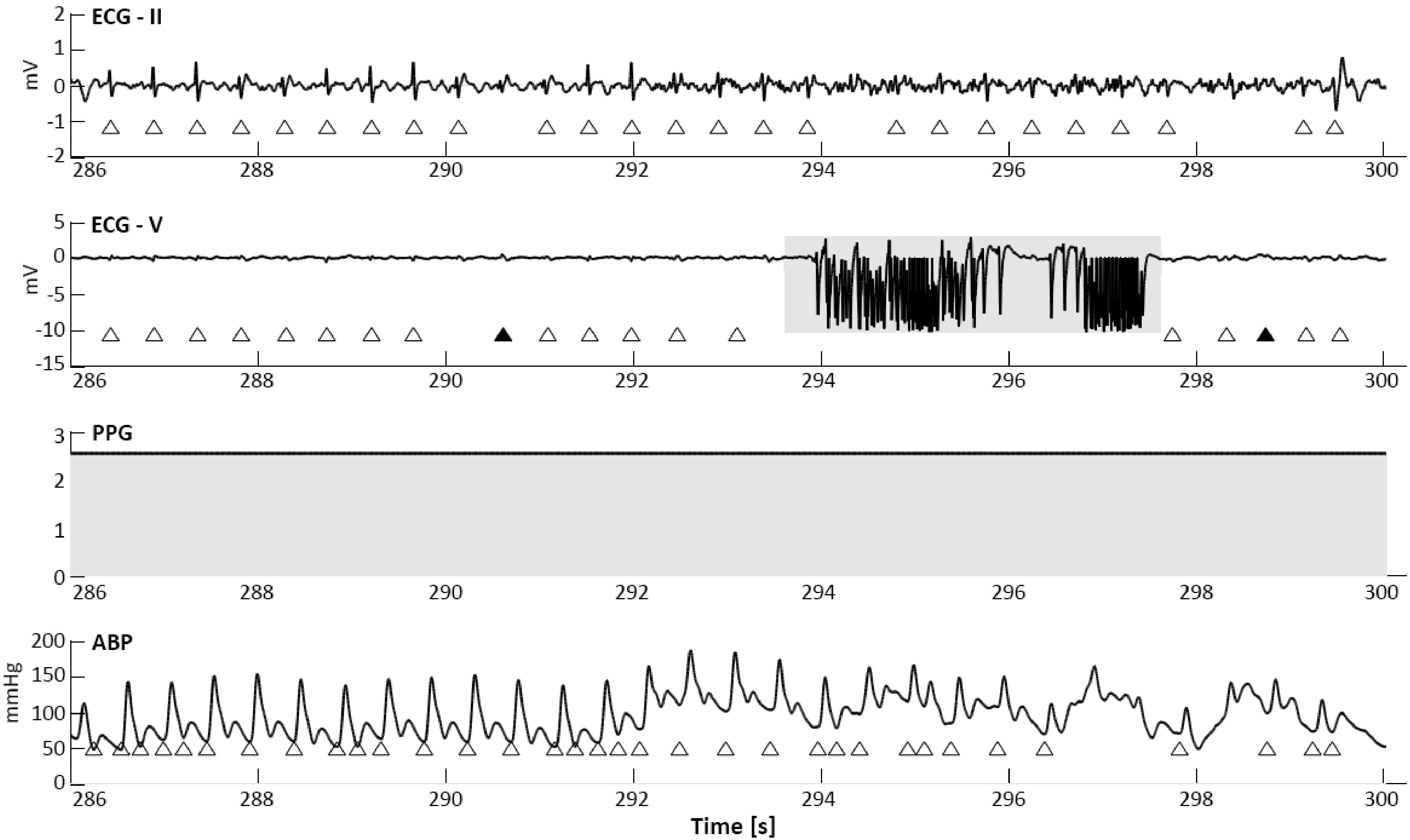
<- Different beat-detection alghorithms for ECG, ABP and PPG signals

<- Regular heart activity test reveals some of false alarms

<- Specific arrhytmia tests prove or deny alarm

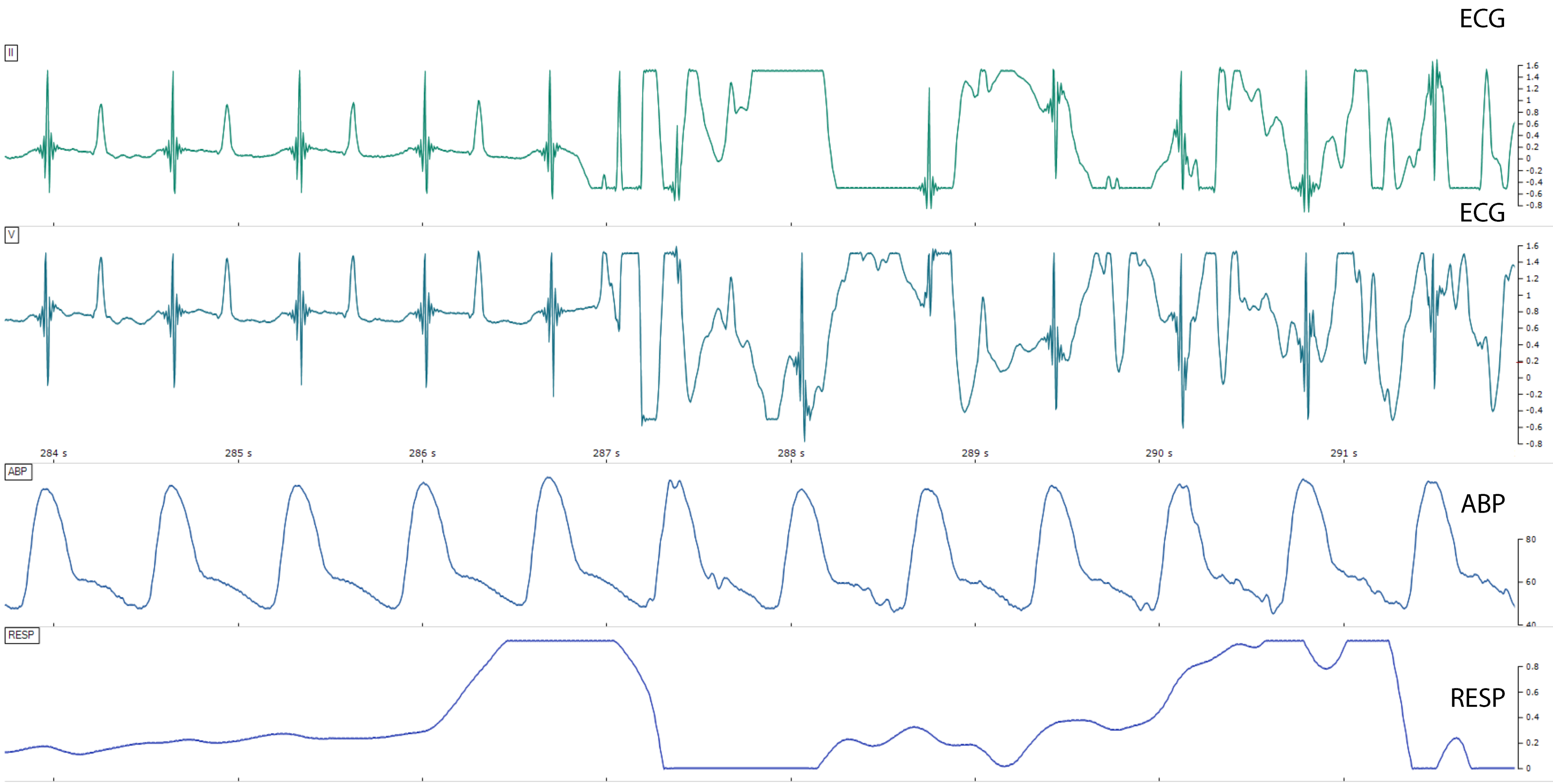
Detection of Life-threatening Arrhythmias

Signal validity (example 1 – statistical properties of 0.8 s window)



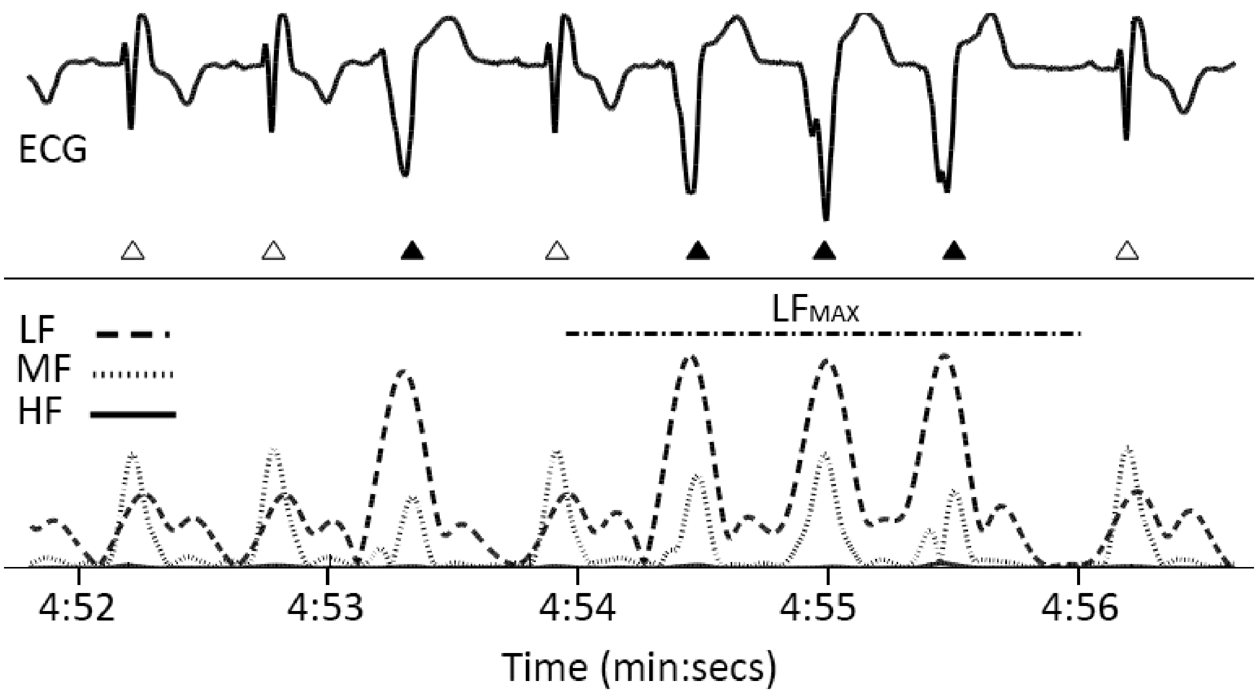
Detection of Life-threatening Arrhythmias

Signal validity (example 2 – saturation, PCM)



QRS detection from ECG

- Based on amplitude envelopes (frequency ranges: 1-8Hz, 5-25Hz, 50-70Hz)
- Automatically supresses noise and pacemaker stimuli (*R*=*MF*-*HF* x *k*).
- Distinguish QRS type by LF/MF ratio (white triangles vs. black triangles)
- Output: QRS list with „**Group**“ and **max. low-frequency dominant time** (LF max)



QRS detection from ECG … may be very challenging task

- Based on amplitude envelopes (frequency ranges: 1-8Hz, 5-25Hz, 50-70Hz)
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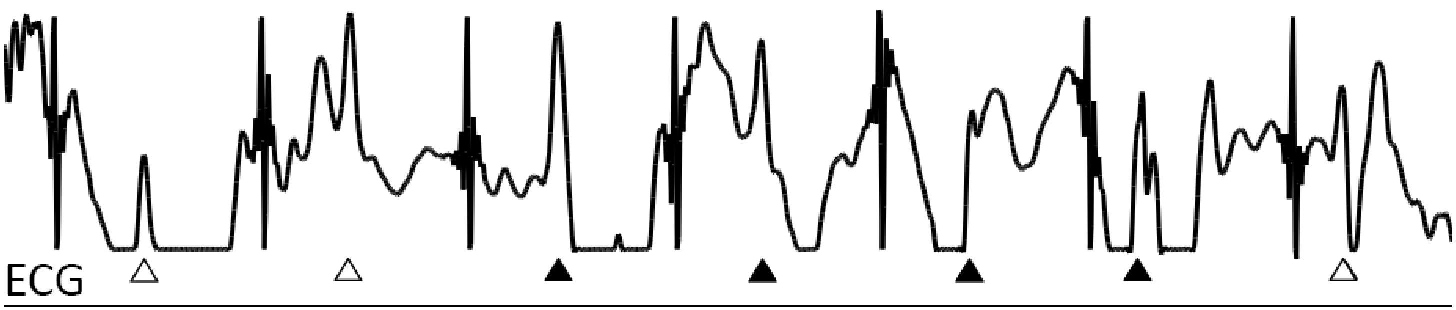
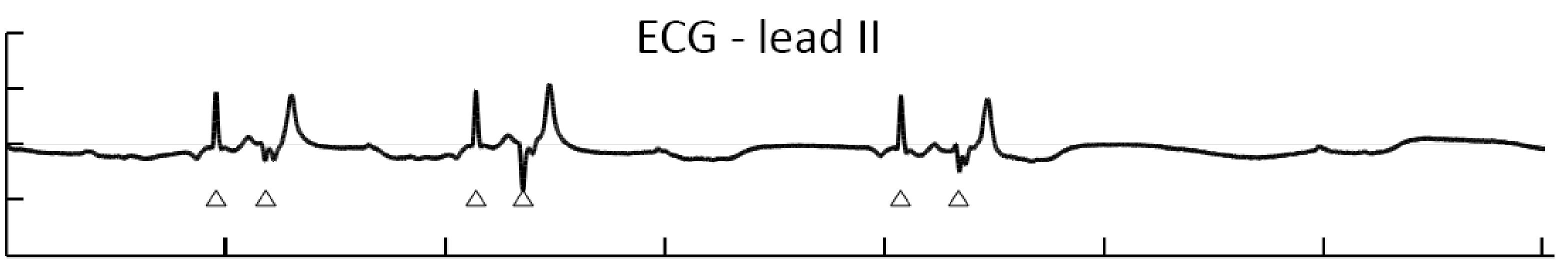
Example A

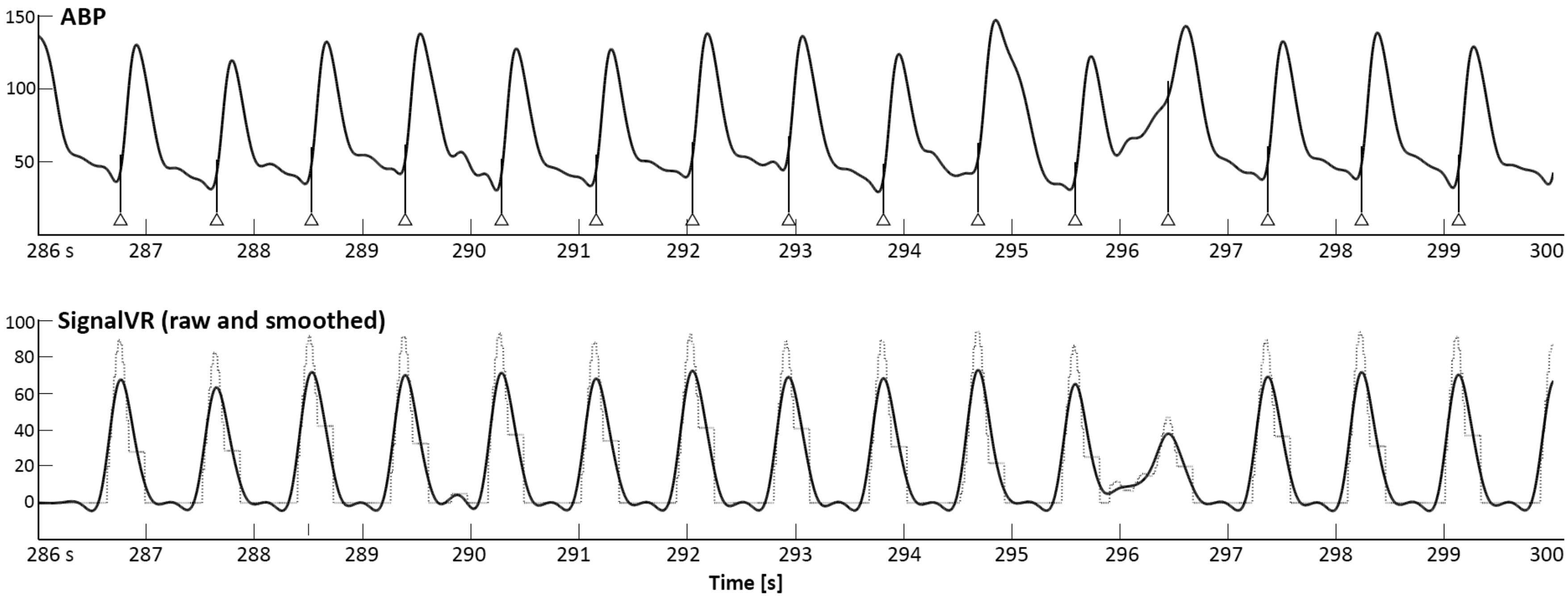


Example B



Beat detection from ABP signal

Based on signal variation range in a 150 ms window and comparison of the left and right half of the window.



Beat detection from ABP signal

Based on signal variation range in a 150 ms window and comparison of the left and right half of the window.

Beat detection from PPG signal

Based on slope recognition on the left and right of local minima.

Regular activity test

Independently for each channel:

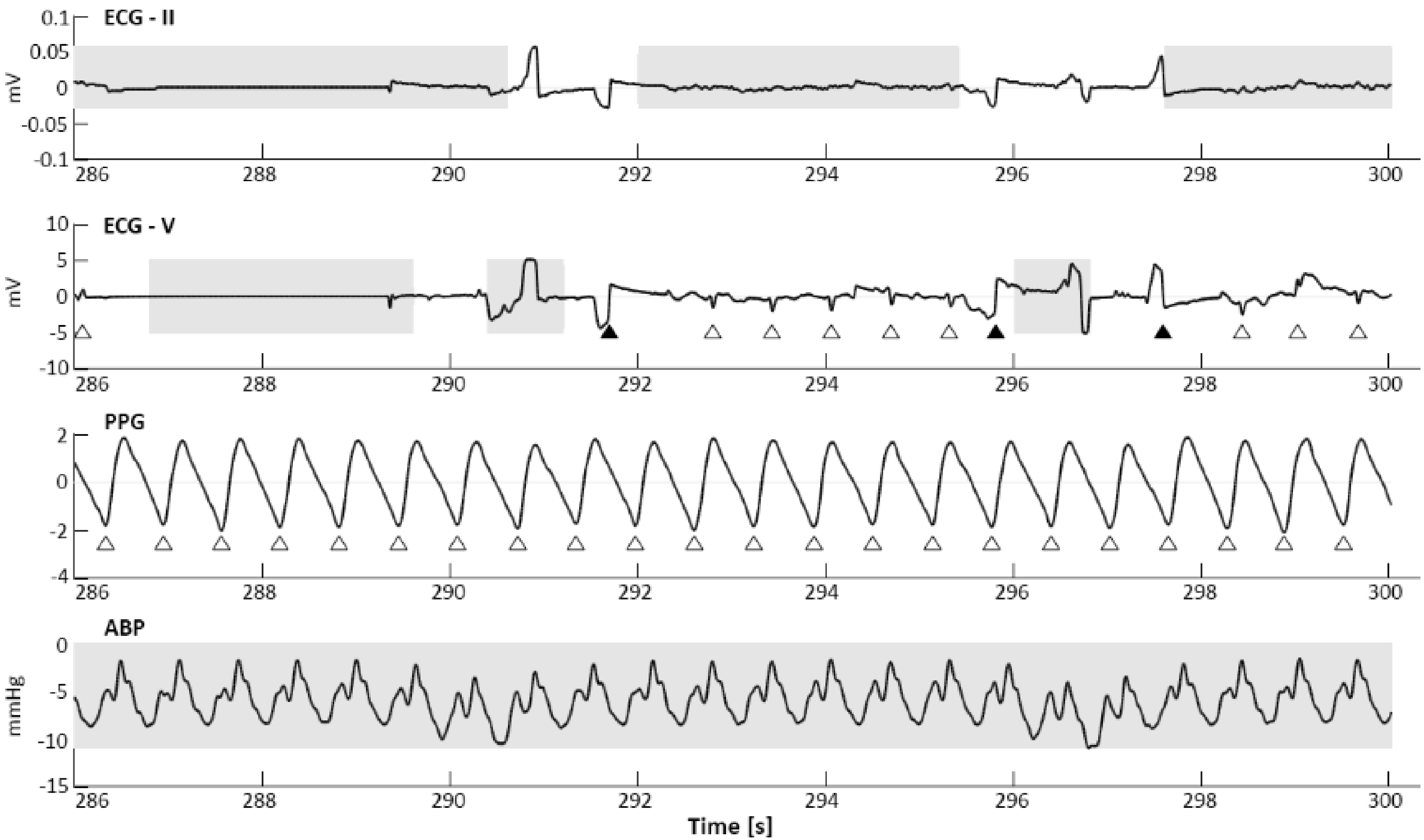
- Beat temporal distribution (count, standard deviation and time coverage)
- Mean heart rate
- Presence of low-frequency dominance
- Presence of invalid data

Regular activity test filtres out 35% of false alarms (training set)

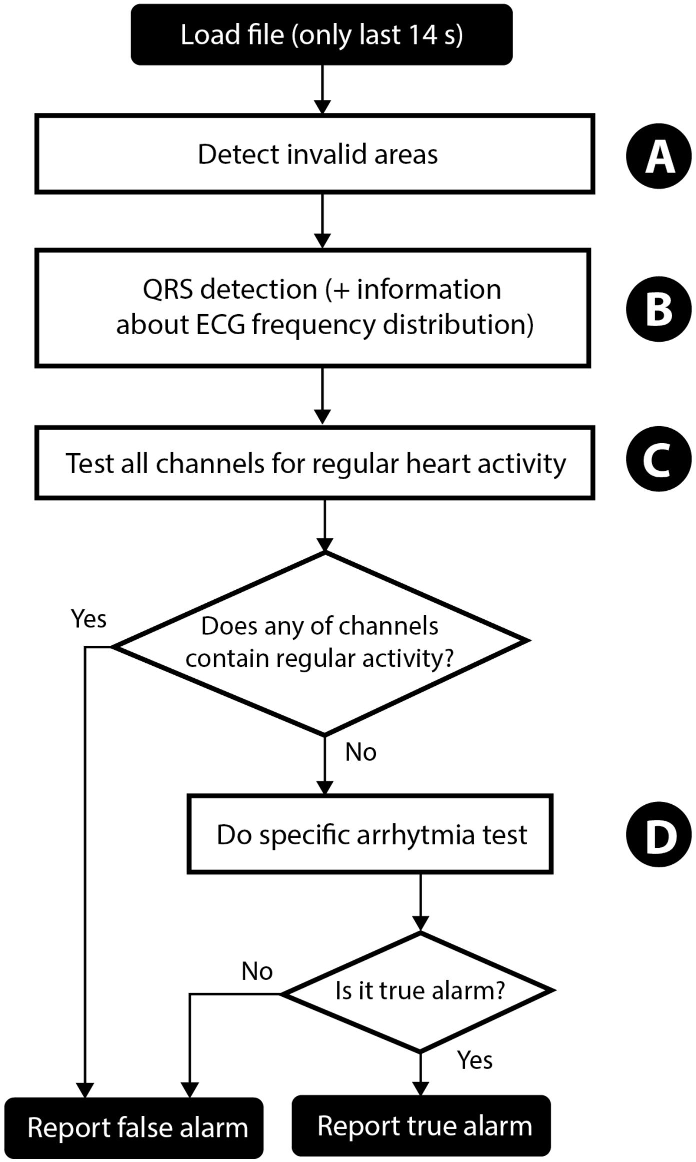
Detection of Life-threatening Arrhythmias

Regular activity test (Independent across channels)

- QRS temporal distribution (count, standard deviation and time coverage)
- Mean heart rate; Presence of low-frequency dominance; only valid data



Detection of Life-threatening Arrhythmias



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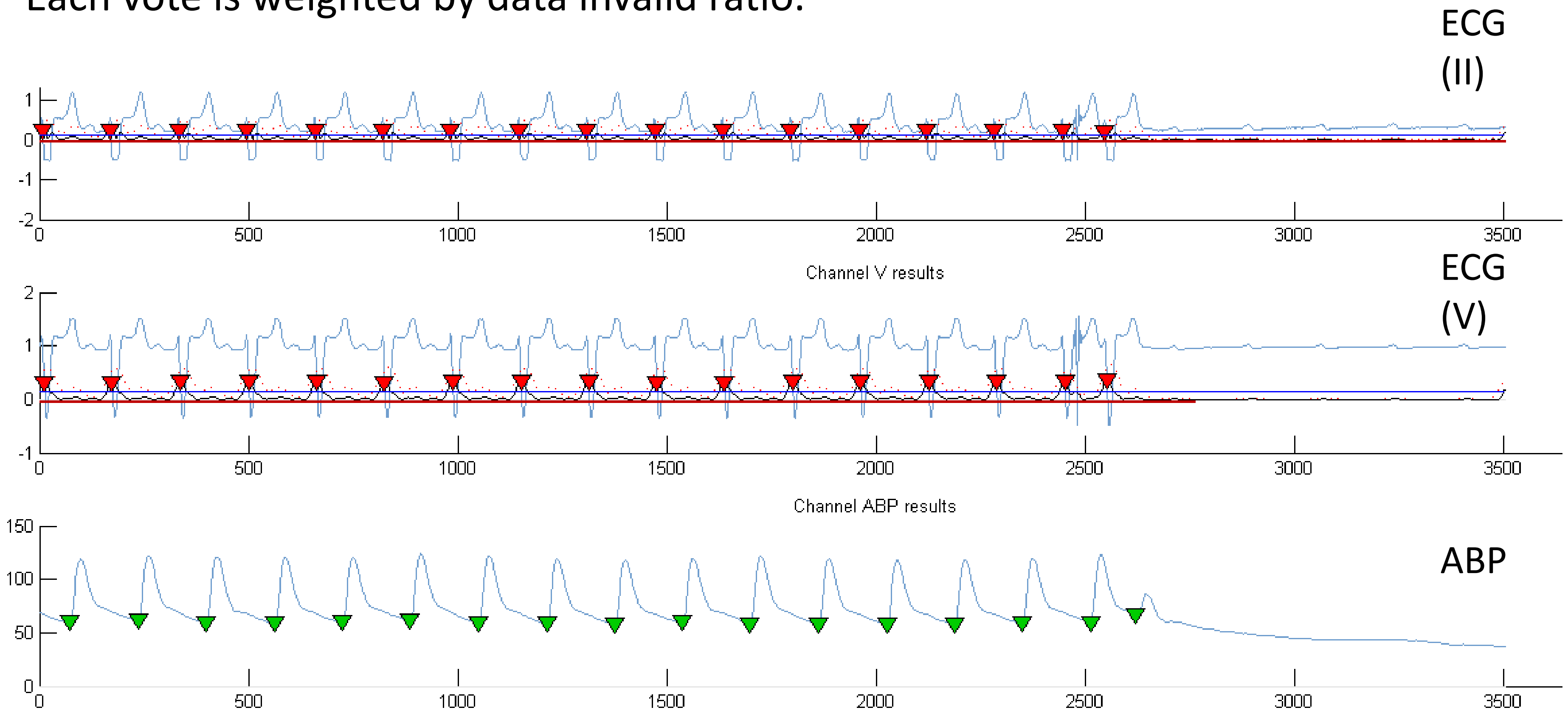
Asystole test (semi-democratic elections)

Count QRSs in moving 3 secs window, then all channels vote for alarm presence. Each vote is weighted by data invalid ratio.



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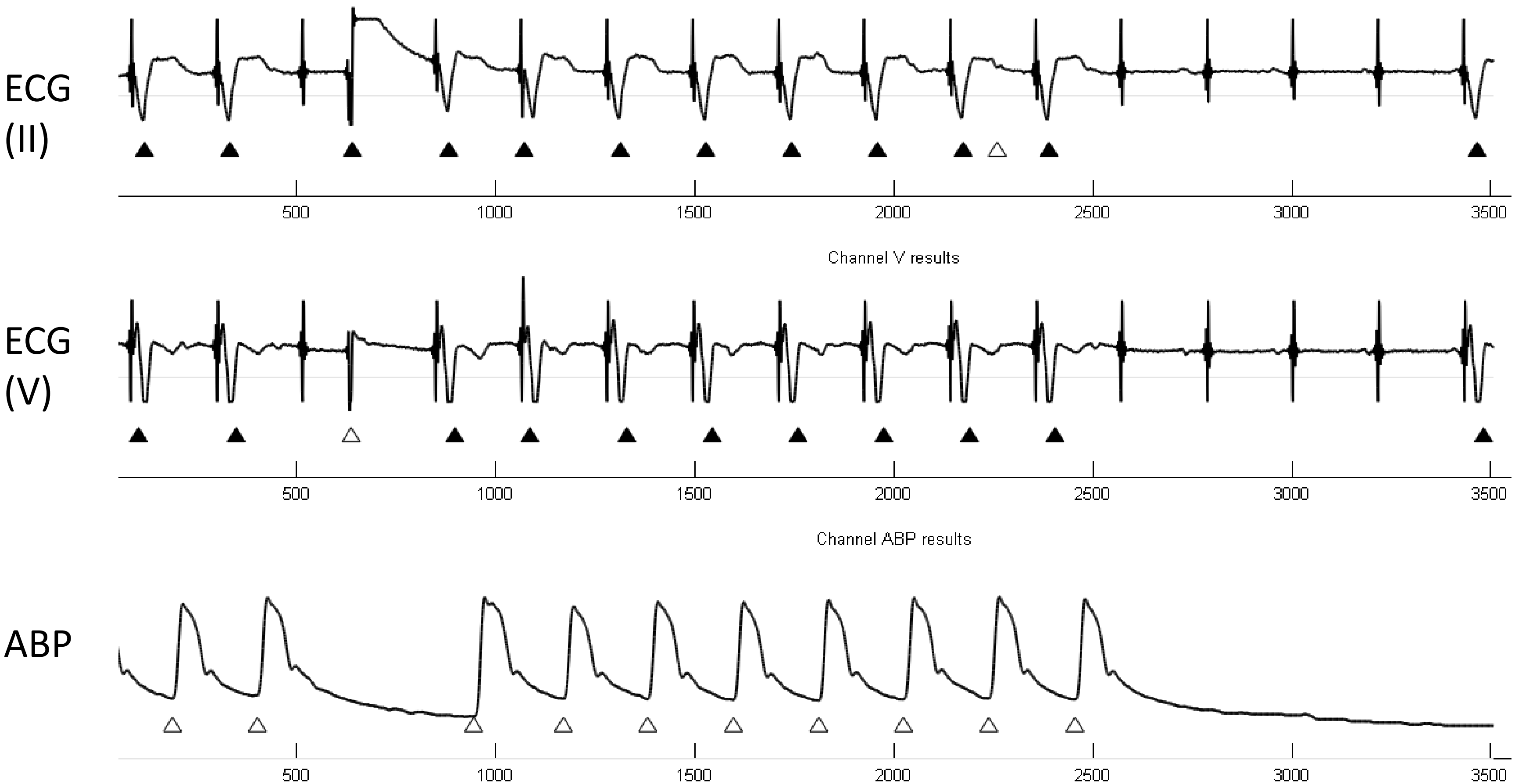

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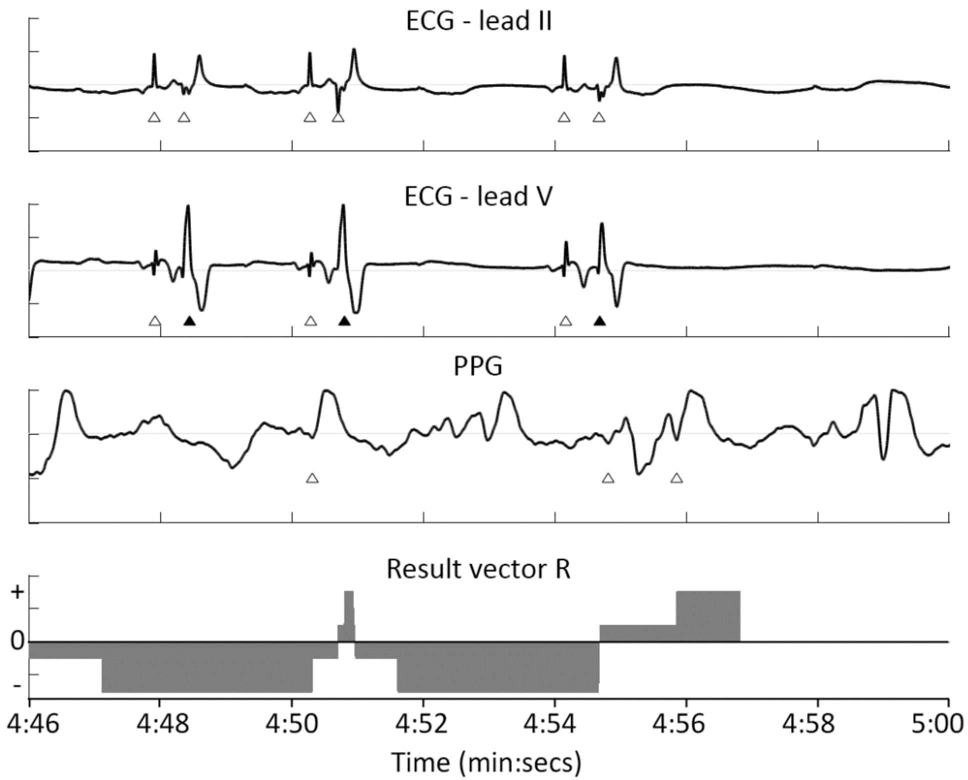


Asystole results

Training set

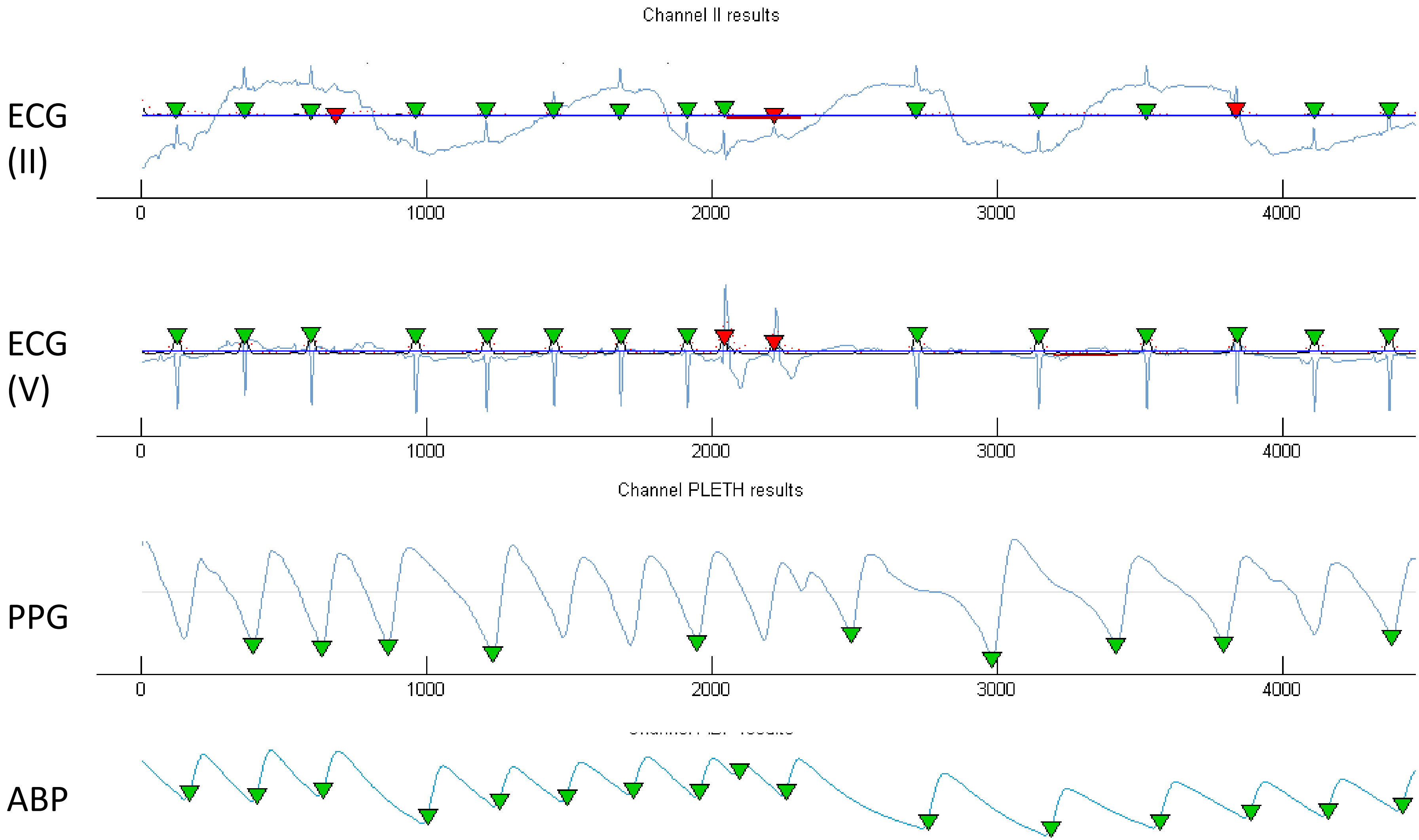
Sensitivity	Specificity
96%	**92%**

Test set

Sensitivity	Specificity
100%	**97%**

Detection of Life-threatening Arrhythmias

Bradycardia – heart is working too slowly

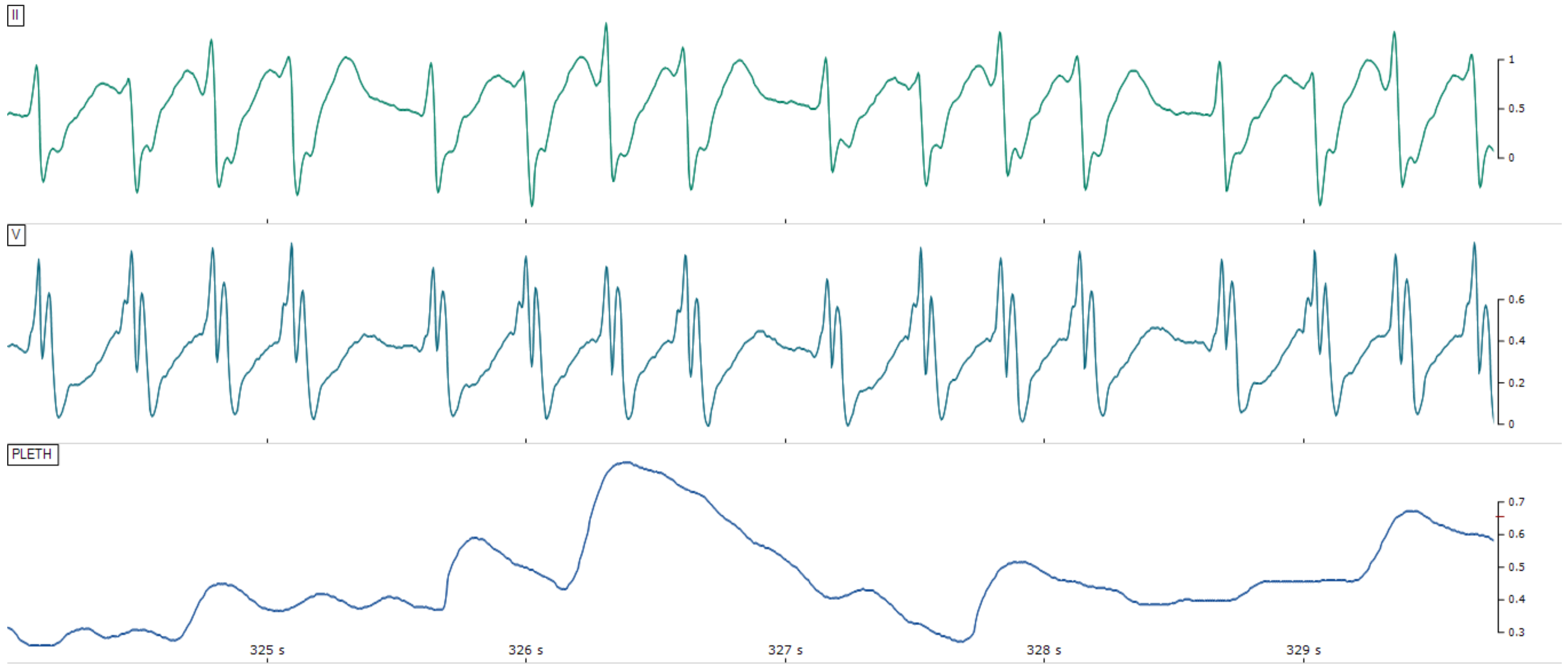


Tachycardia – heart is working too quickly

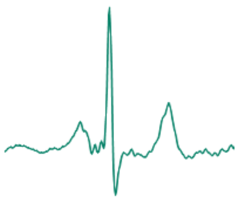
ECG (II)

ECG (V)

PPG



Compare ECG above with the „nice“ ECG:



Bradycardia and Tachycardia tests

Choose the most reliable channel (using descriptive statistics) and compare heart rate to limits (**HR < 46** BPM for bradycardia, **HR > 135** for tachycardia).

Bradycardia results

Training set

Sensitivity	Specificity
98%	**74% (-> 89%)**

Test set

Sensitivity	Specificity
100% (->95%)	**72% (->76%)**

Tachycardia results

Training set

Sensitivity	Specificity
99%	**89%**

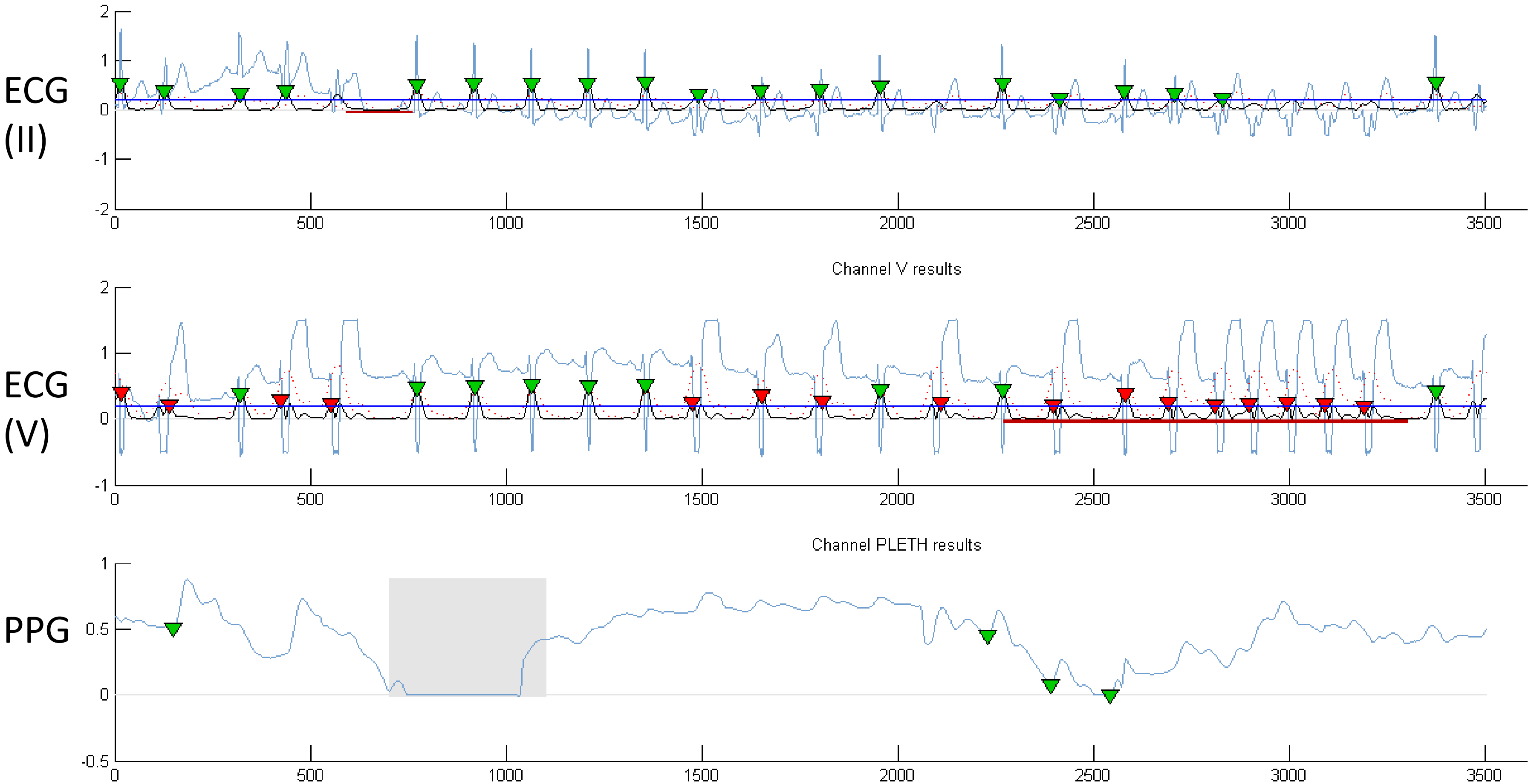
Test set

Sensitivity	Specificity
97%	**100%**

Detection of Life-threatening Arrhythmias

Ventricle Tachycardia

Searchs sequence of 3 consecutive LF beats at heart rate > 95 BPM using „**Group**“ information from ECG detection. Uses variation range of ABP signal.



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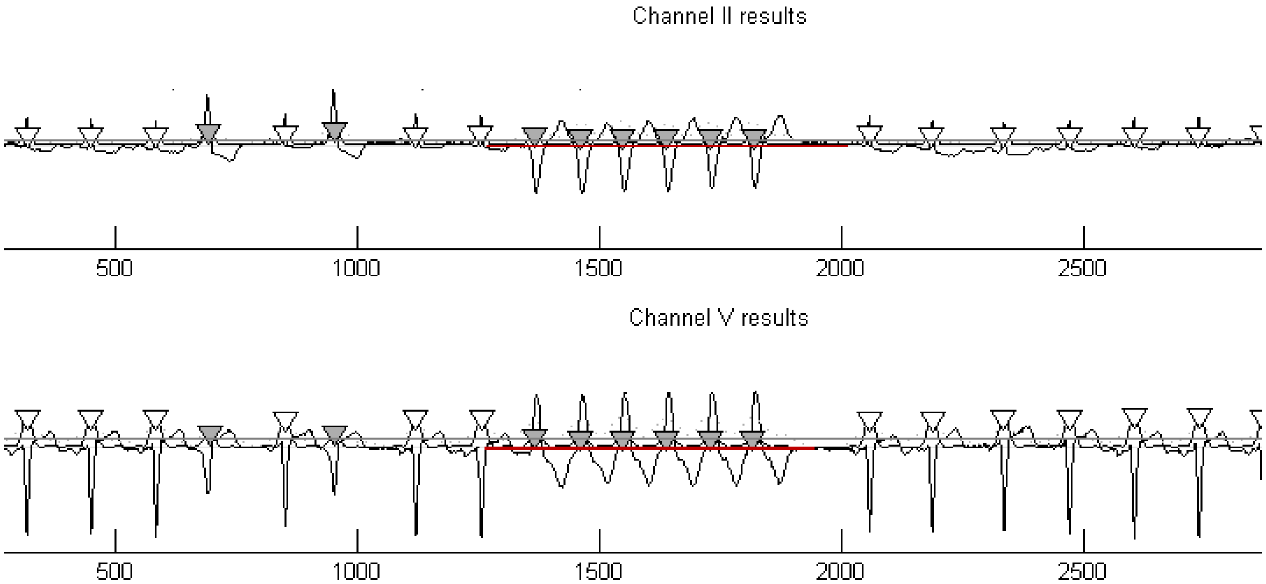


Vent. tachycardia results

Training set

Sensitivity	Specificity
83%	**82%**

Test set

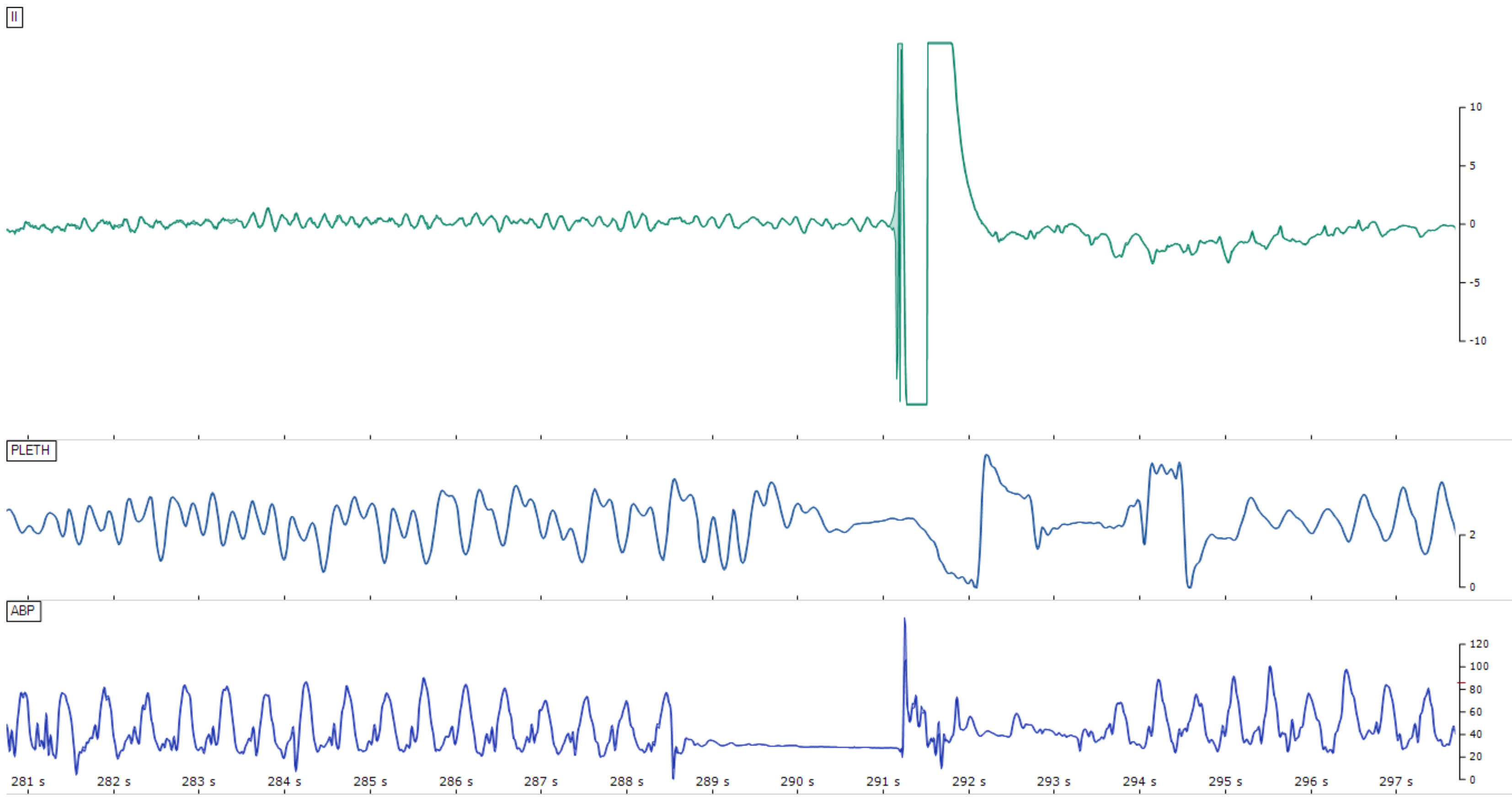
Sensitivity	Specificity
85%	**84%**

Ventricle Fibrilation/ Flutter test

ECG (II)

PPG

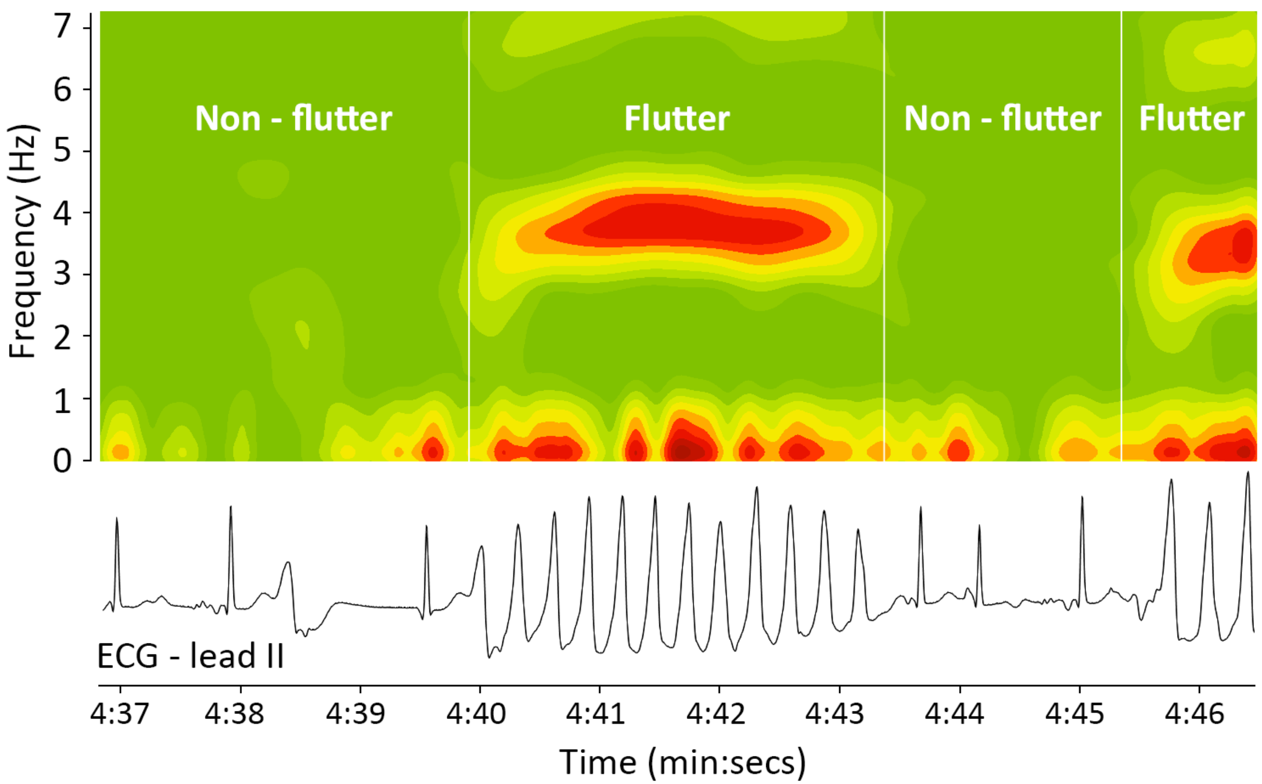
ABP



Detection of Life-threatening Arrhythmias

Ventricle Fibrilation/ Flutter test

Finds out maximal frequencies in ECG spectra. ABP channel can raise an alarm.



Flutter/ Fib. results

Training set

Sensitivity	Specificity
83% (->100%)	**100%**

Test set

Sensitivity	Specificity
67%	**100% (->98%)**

Detection of Life-threatening Arrhythmias

Overall results – score **81.39** (real-time) and **84.96** (retrospective)

Training set results (750 records)

	Sens.	Spec.
Asystole	96%	92%
Bradycardia	98%	74%
Tachycardia	99%	89%
V. Tachycardia	83%	82%
Flutter/ Fib.	83%	100%
Average	96%	89%
Gross	93%	86%

Test set results (500 records)

	Sens.	Spec.
Asystole	100%	97%
Bradycardia	100%	72%
Tachycardia	97%	100%
V. Tachycardia	85%	84%
Flutter/ Fib.	67%	100%
Real-time	92%	88%
Retrospective	95%	88%

Physionet/CinC Challenge results - comparison with other competitors

Entrant	Event 1 (Real-time)			Event 2 (Retrospective)		
	TPR (%)	TNR (%)	Score	TPR (%)	TNR (%)	Score
Plešinger *et al* (2015)	92	88	**81.39**	95	88	84.96
Kalidas and Tamil (2015)	**94**	82	79.44	94	86	81.85
Krasteva *et al* (2015b)[a]	93	83	79.41[a]	93	84	79.56[a]
Couto *et al* (2015)	89	**91**	79.02	88	**92**	78.28
Fallet *et al* (2015)	**94**	77	76.11	**99**	80	**85.04**
Hoog Antink and Leonhardt (2015)	93	77	75.55	90	82	75.18
Eerikäinen *et al* (2015)	90	82	75.54	89	85	75.52
Ansari *et al* (2015)	89	84	74.48	89	87	76.57
Liu *et al* (2015)	89	79	71.68	93	78	75.91

+ 34 others

Thank you for your attention

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Acknowledgements

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More information regarding this work:

Easy, popular article (MathWorks website article):
Developing Detection Algorithms to Reduce False Alarms in Intensive Care Units
https://www.mathworks.com/company/newsletters/articles/developing-detection-algorithms-to-reduce-false-alarms-in-intensive-care-units.html

Brief scientific paper (CinC conference paper):
False alarms in intensive care unit monitors: detection of life-threatening arrhythmias using elementary algebra, descriptive statistics and fuzzy logic
http://www.cinc.org/archives/2015/pdf/0281.pdf

Detailed scientific paper (Full paper in the Physiological Measurement journal):
Taming of the monitors: reducing false alarms in intensive care units
http://iopscience.iop.org/article/10.1088/0967-3334/37/8/E5/pdf