Georgia Tech | Wallace H. Coulter Department of Biomedical Engineering
Georgia Tech College of Engineering and Emory School of Medicine | EMORY UNIVERSITY | Beth Israel Deaconess Medical Center | MIT

You Snooze, You Win:

The PhysioNet Computing in Cardiology Challenge 2018

Mohammad M Ghassemi[1], Benjamin E Moody[1], Li-wei Lehman[1], Christopher Song[1], Qiao Li, Haoqi Sun, Roger G Mark[1], M. Brandon Westover[2], Gari D Clifford[3,4]

[1] Institute for Medical Engineering & Science, Massachusetts Institute of Technology, USA
[2] Department of Neurology, Massachusetts General Hospital, USA
[3] Department of Biomedical Informatics, Emory University, Atlanta, GA USA
[4] Department of Biomedical Engineering, Georgia Institute of Technology, Atlanta, GA, USA

What Makes The Challenge Unique

PHYSIONET/COMPUTING IN CARDIOLOGY CHALLENGES

In cooperation with the annual Computing in Cardiology conference, PhysioNet hosts a series of **challenges**, inviting participants to tackle clinically interesting problems that are either unsolved or not well-solved.

1. The collection, and public release of, well-curated novel datasets in the domain of physiology

2. The open-source spirit (and formal requirement) of the challenge
   a. Competitors help improve the data labels
   b. … and create a large body of open source software

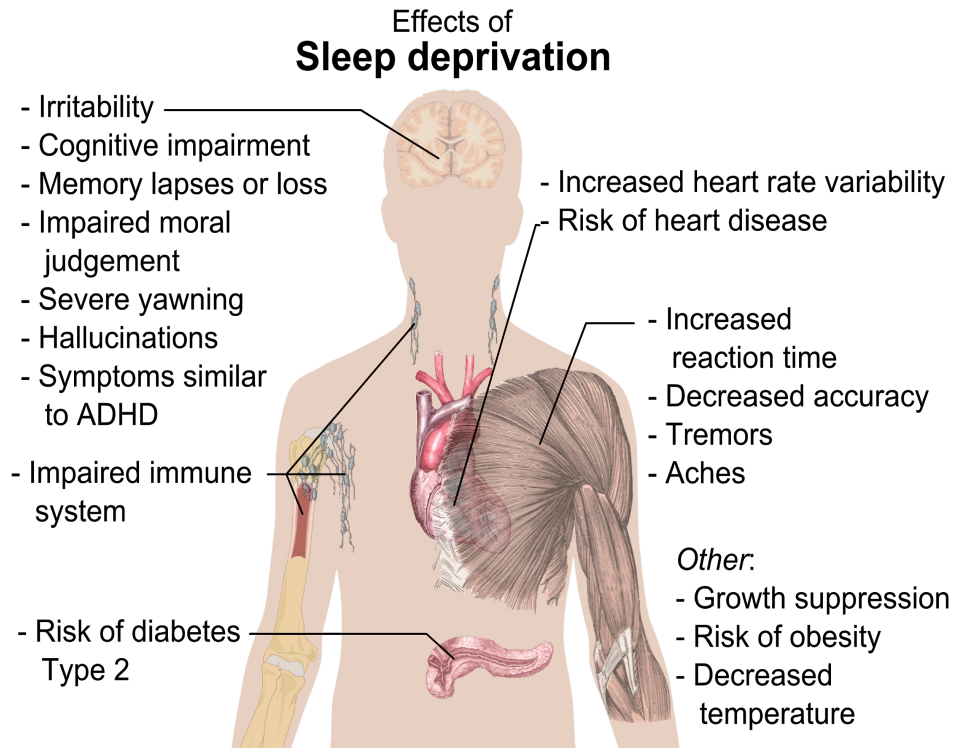
3. Competitors attend a public forum and verbally defend their work

4. Competitors follow up with peer reviewed articles

Introduction

- **The Challenge**
  - Develop automated techniques for the detection of non-apnea related sleep arousals.

- **Motivation**
  - Sleep quality is critical to health [1-4]
  - Arousals are brief intrusions of wakefulness that reduce quality.
  - To treat sleep disorders, they must first be diagnosed.



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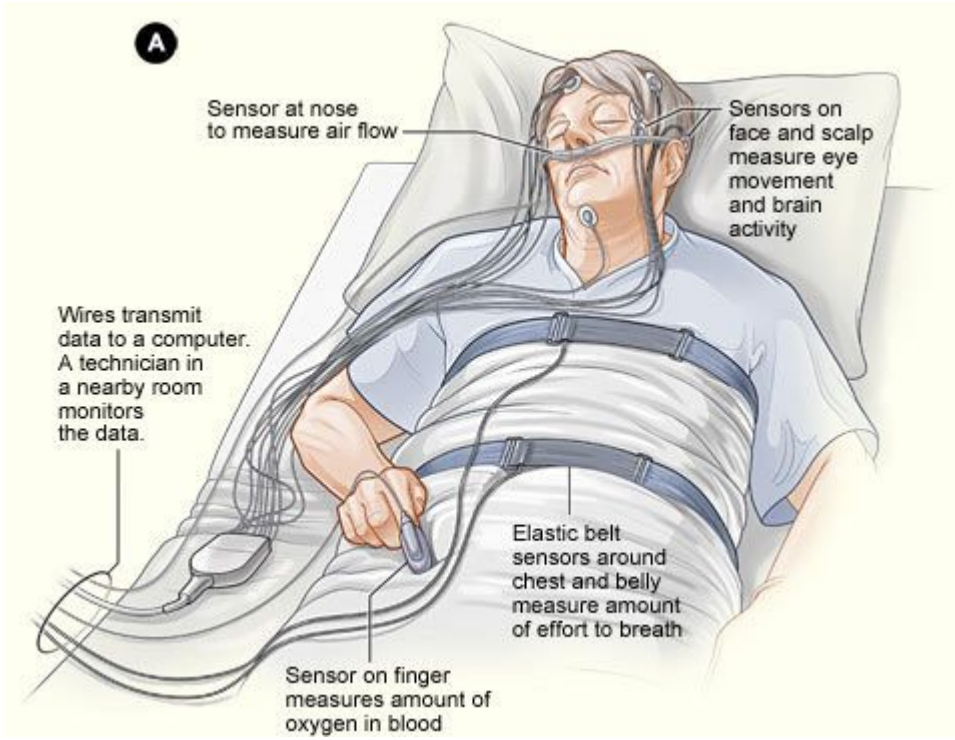
Data

Data Source

- Overnight polysomnographic (PSG) recordings from *1,983* subjects collected during sleep studies at the Massachusetts General Hospital[1]
  - Massachusetts General Hospital's Sleep Lab
  - the Computational Clinical Neurophysiology Laboratory and
  - the Clinical Data Animation Center



[1] Following The American Academy of Sleep Medicine Guidelines

Data Source

- **PSG Signals** (200Hz)
  - Electroencephalography (EEG)[2]:
    F3-M2, F4-M1, C3-M2,
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  - Electrocardiography (EKG)[5]:
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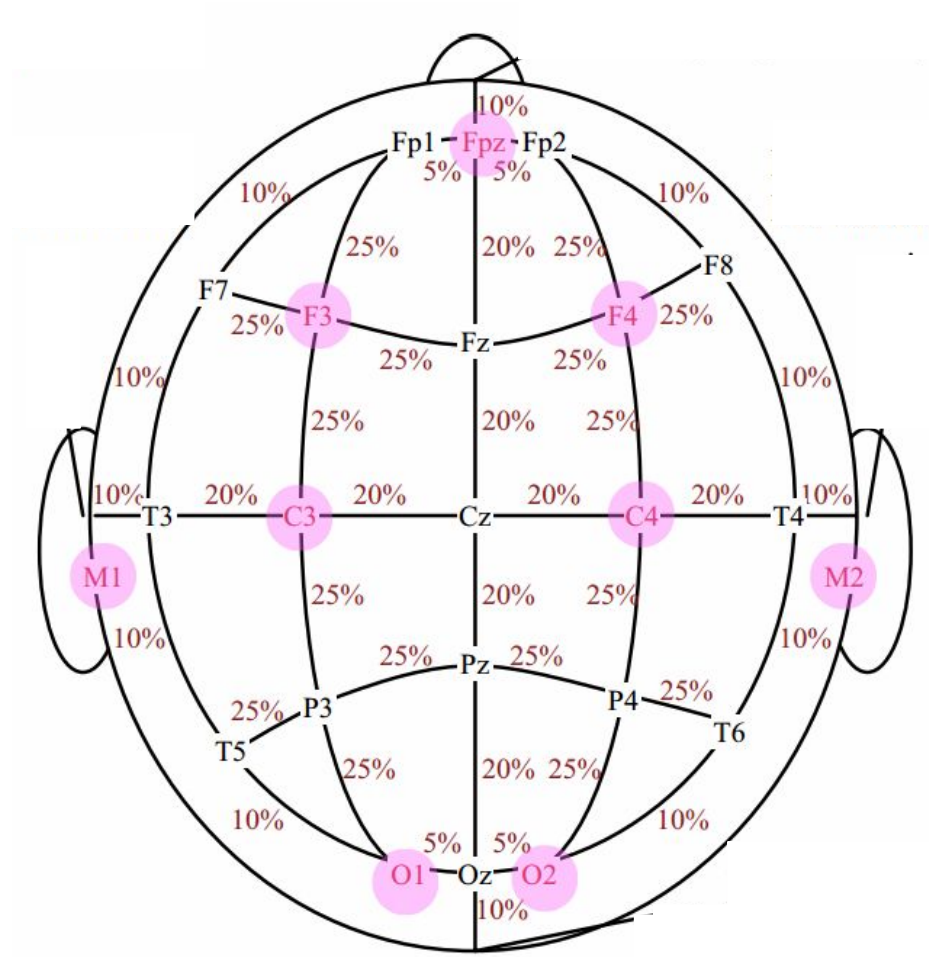

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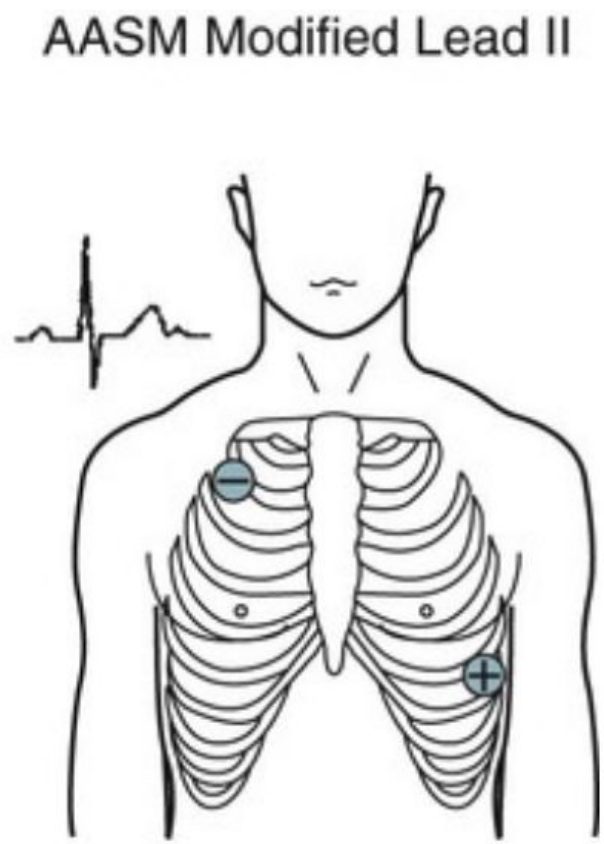

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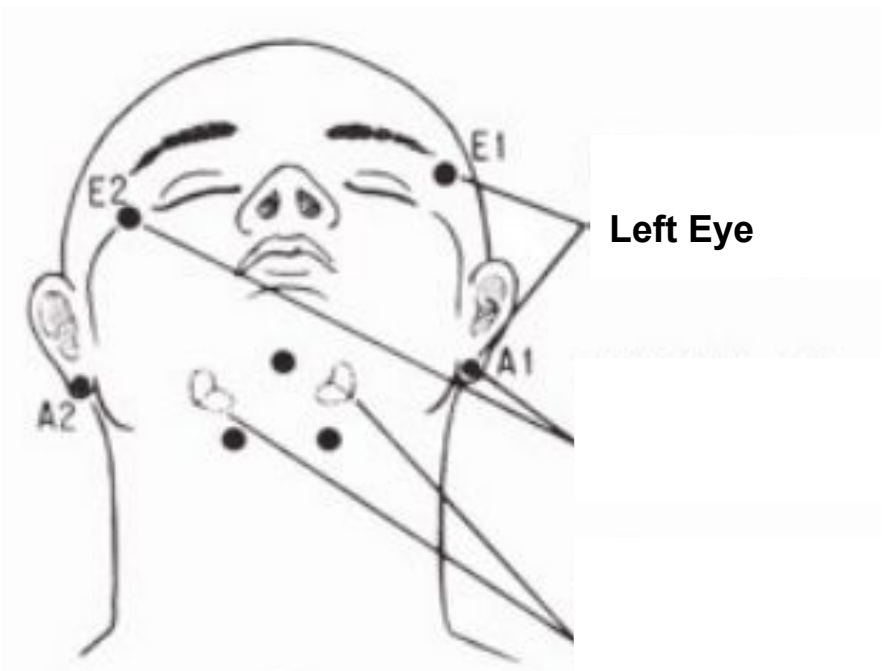

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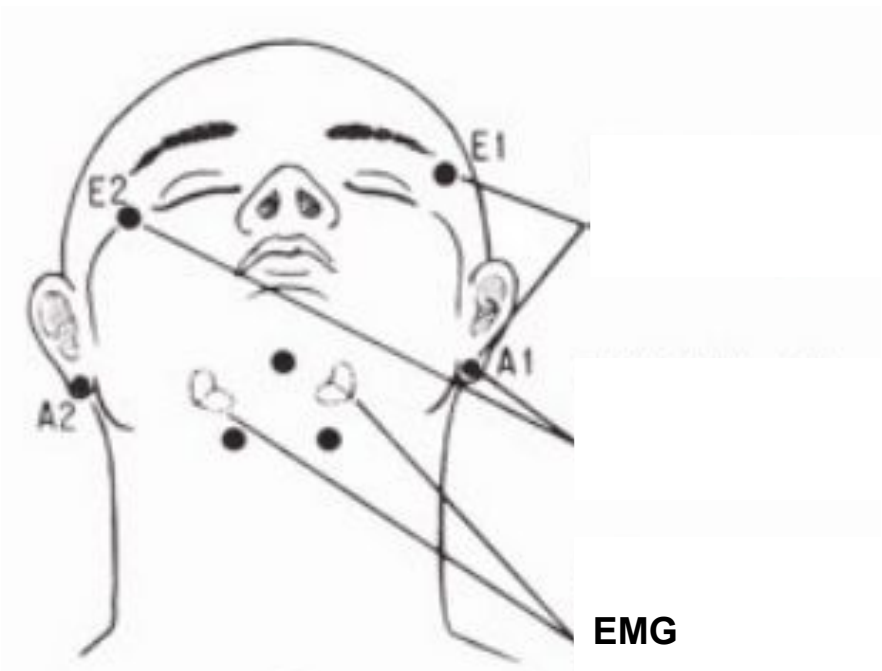

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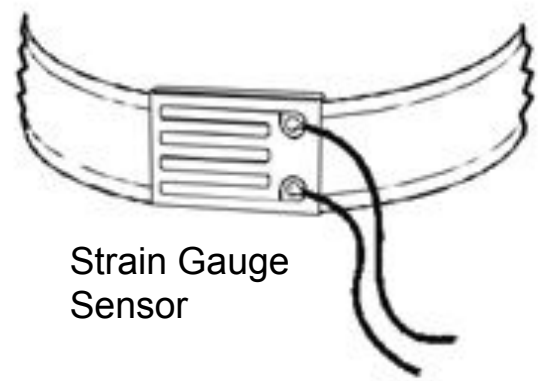

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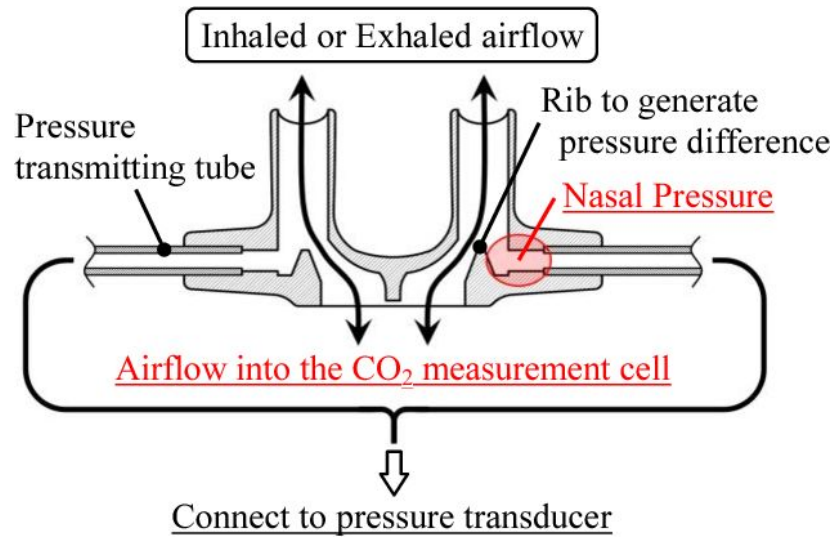

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Clinical Annotations

- Seven scorers annotated[1,2] data in non-overlapping, 30-second epochs.

- Arousals:
  - spontaneous, respiratory effort related arousals (RERA),
    bruxisms , hypoventilations, hypopneas, apneas (central, obstructive and mixed),
    vocalizations, snores, periodic leg movements,
    Cheyne-Stokes breathing or partial airway obstructions.

- Sleep Stages
  - wake (W), rapid eye movement (REM), non-REM stage 1 (N1),
    non-REM stage 2 (N2), and non-REM stage 3 (N3)

[1] One scorer per PSG record

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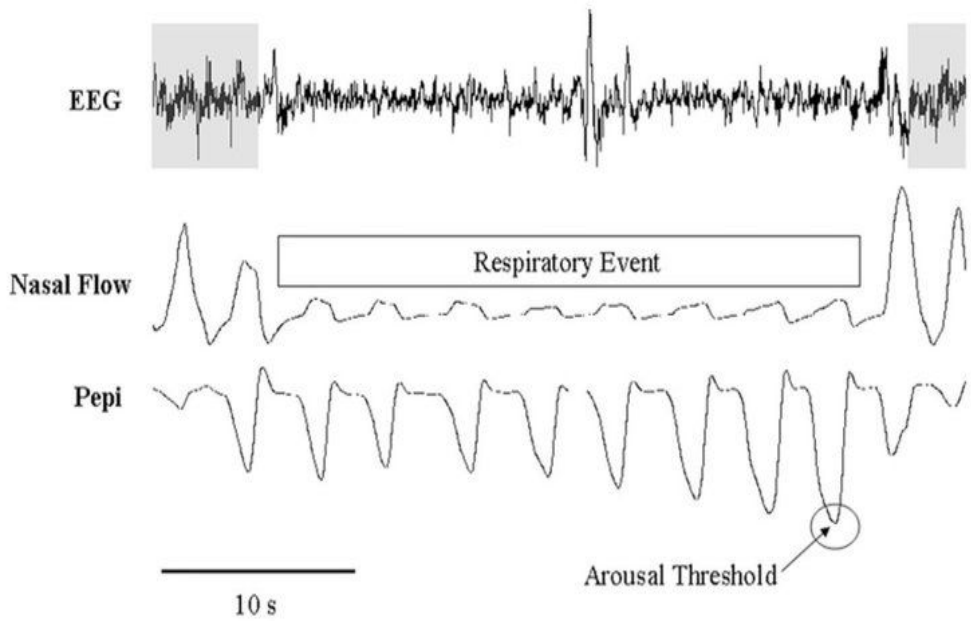
Challenge Details

Challenge Objective

- Objective:
  - Use PSG signals to correctly classify target arousal regions.

- Target arousals:
  - 2 seconds before a RERA arousal begins, up to 10 seconds after
  - 2 seconds before a non-RERA, non-apnea arousal begins, up to 2 seconds after

- Nontarget arousals:
  - 10 seconds before or after a subject awoke, had an apnea arousal, or a hypopnea arousal



Challenge Data

- Data was split into public training and hidden testing sets[1].
  - Training: 994 PSGs
    994 annotations
    Testing: 989 PSGs
    989 annotations

- Subject characteristics were similar across the training and testing sets.

Clinical Feature	Total	Training	Test
Sample size	1,983	994	989
Age	55 (14.4)	55 (14.3)	55 (14.4)
Gender (% male)	65	67	63
BMI	33 (7.6)	33 (7.8)	33 (7.5)
AHI	19 (14.4)	19 (14.6)	18.9 (14.4)
ESS	8.6 (5.3)	8.5 (5.3)	8.7 (5.3)
Recording time (h)	7.7 (0.7)	7.7 (0.7)	7.7 (0.7)
Time in bed (h)	7.5 (0.7)	7.5 (0.7)	7.5 (0.7)
Sleep time (h)	6.2 (1.2)	6.2 (1.1)	6.1 (1.2)
Drug Use (%)			
Hypertension	40.9	41.0	40.6
Sleep aids	28.3	29.0	27.8
Antidepressant	26.1	25.7	26.5
Neuroactive	19.1	20.8	17.5
Benzodiazepine	16.1	16.9	15.4
Diabetic	11.7	11.9	11.5
Opiate	7.4	8.1	6.7
Antihistamine	4.8	4.8	4.8
Stimulant	4.7	3.9	5.5
Neuroleptic	4.2	4.5	3.8
Herbal	4.2	4.3	4.0
Reason for visit (%)			
Diagnostic	41.8	41.16	42.47
Split night CPAP	38.35	37.95	39.03
All night CPAP	19.85	20.88	18.5

BMI: Body Mass Index; AHI: Apnea-Hypopnea Index;
ESS: Epworth Sleepiness Scale;
CPAP: Continuous Positive Airway Pressure

[1] Data was partitioned to ensure a uniform distribution of AHIs in both sets (Kolmogorov-Smirnov test p-value 0.97). There were no subjects in common between the training and test sets.

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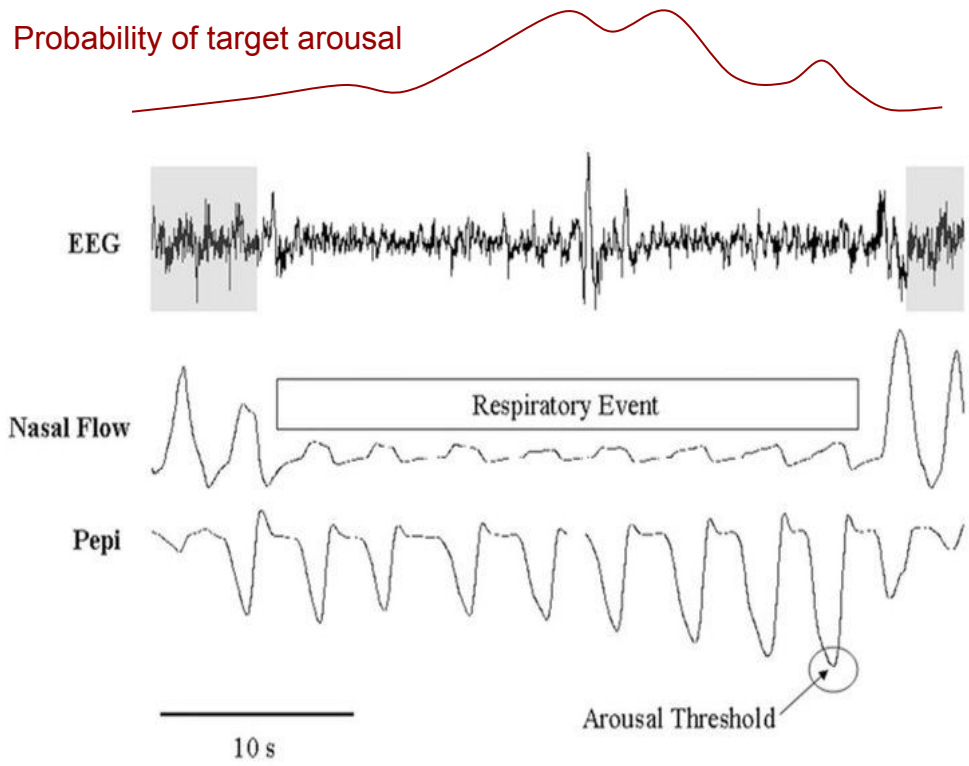
Clinical Feature	Total	Training	Test
Time spent in sleep stage (%)			
Wake	29.3	28.0	31.0
NREM 1	19.5	19.6	19.0
NREM 2	51.3	51.0	51.7
NREM 3	13.8	14.0	13.8
REM	15.3	15.5	15.2
Number of target arousals			
Bruxism	–	30	–
Cheyne-Stokes breathing	–	3	–
Hypoventilation	–	4	–
Noise	–	1	–
Partial airway obstruction	–	11	–
PLM	–	36	–
RERA	–	43,822	–
Snoring	–	28	–
Spontaneous	–	70	–
Number of non-target arousals			
Hypopnea	–	56,936	–
Central apnea	–	22,763	–
Mixed apnea	–	2,641	–
Obstructive apnea	–	32,547	–

PLM: Periodic leg movement
RERA: Respiratory effort-related arousals

[1] Data was partitioned to ensure a uniform distribution of AHIs in both sets (Kolmogorov-Smirnov test p-value 0.97). There were no subjects in common between the training and test sets.

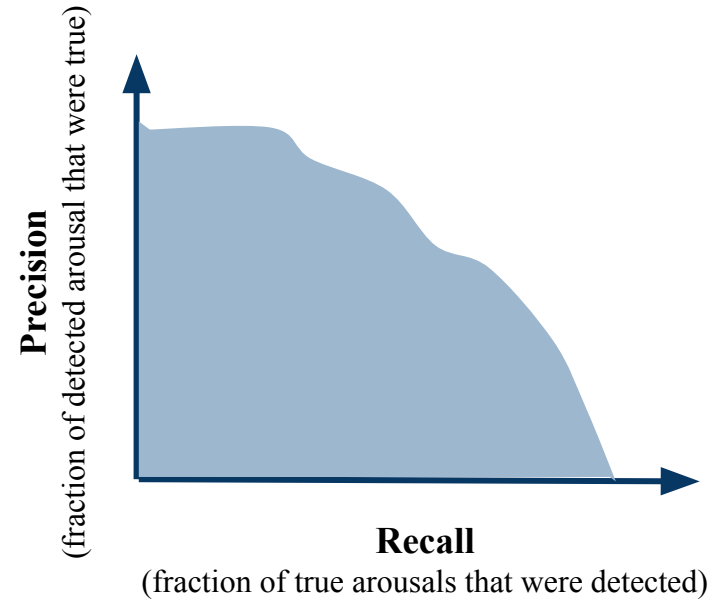
Challenge Process

- Challengers were given:
  - Training PSGs and annotations
  - Testing PSGs
- Challengers submitted:
  - Testing annotations: a vector providing the probability of target arousal, at the sample level.
  - A complete, working implementation of their algorithm that could be run in the Challenge sandbox



Challenge Scoring

- Algorithms were graded for their binary classification performance on target arousal and non-arousal regions, as measured by the area under the precision-recall curve (AUPRC).



- *N* indicates the set of non-scored samples, *A* indicate the set of target arousal samples, and P_j indicates the set of samples for which the predicted arousal probability was at least *j/1000*

$$AUPRC = \sum_{j,\ |P_j \cap \overline{N}| \neq 0} p_j (r_j - r_{j+1})$$

Recall:

$$r_j = \frac{|A \cap P_j \cap \overline{N}|}{|A \cap \overline{N}|}$$

Precision:

$$p_j = \frac{|A \cap P_j \cap \overline{N}|}{|P_j \cap \overline{N}|}$$

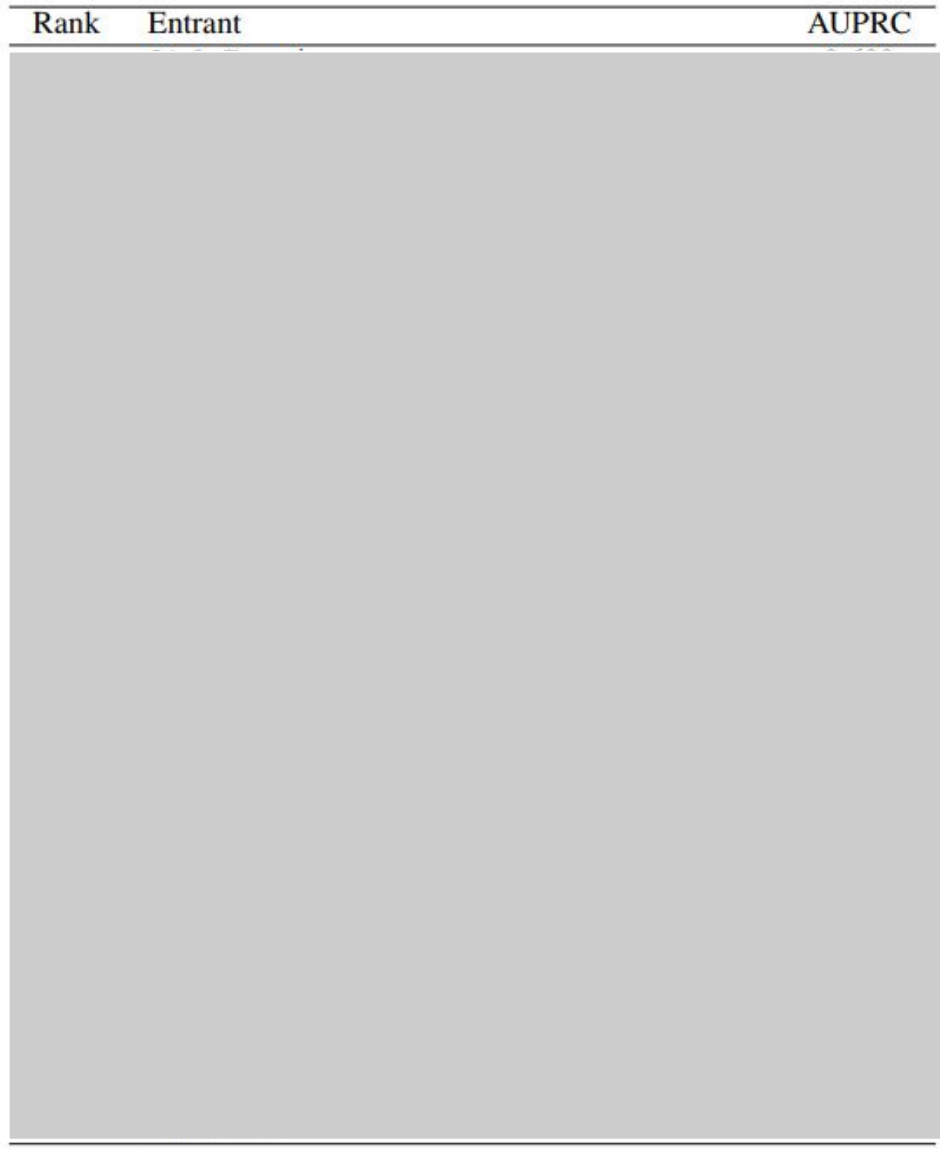
Challenge Results

And the winners are ...

Announced at the Closing Ceremony
This Afternoon!

Challenge Submissions

- Total Entries:
  - 624 entries
  - 34 unique entrants
- Total Qualified Entries:
  - 29 entries
  - 19 unique entrants
- Software Licenses of Qualified Entrants:
  - 8/19: MIT X11 License
  - 10/19: GNU GPL (version 3)
  - 1/19: GNU GPL (version 2)



Reproducibility

- 7/19 submissions produced results that differed measurably ($r < 0.99$) from the results obtained by the authors
- 2/19 submissions produced different results when run multiple times under identical conditions
- One submission produced *exactly* the output that the authors expected

Authors	r	ΔAUPRC	ND
Li & Guan *(unofficial)*	0.98871	−0.01	
Howe-Patterson & Pourbabaee	1.00000		
Kristjansson et al.	0.99647		
He et al.	1.00000		
Varga et al.	0.98253	+0.01	
Patane et al.	0.98867	−0.01	*
Warrick & Homsi	1.00000		
Miller et al.	1.00000		
Szalma et al.	1.00000		
Bhattacharjee et al.	0.99779		
Li et al.	0.18428	−0.22	
Parvaneh et al.	1.00000		
Plesinger et al.	1.00000		
Zabihi et al.	1.00000		
Schellenberger et al.	0.96586		*
Bilal et al.	0.78022	+0.02	
Jia et al.	1.00000		
Wang et al. *(unofficial)*	0.99999		
Shen	NaN		

Prizes

- $3,500 total to top three official open-source entries
- Presented at closing ceremony - you have to be there to collect them! No mailing!!

Finally - the big thank yous!

- Mathworks for the $3,500 prize money and free licenses during the competition!
- Mohammad Ghassemi
- Brandon Westover & the MGH Team ...

Physiological Measurement

Arousal Detection

Focus issue for the PhysioNet/Computing in Cardiology Challenge 2018

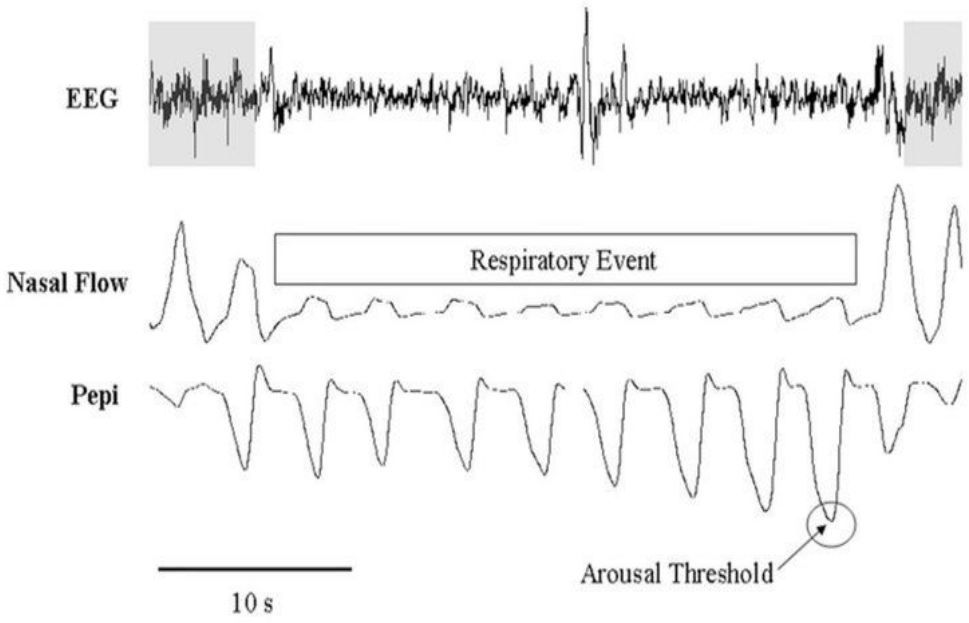
Guest editors: Mohammad Ghassemi, Benjamin Moody, Li-wei Lehman, Qiao Li, Gari D. Clifford

Closing date for submission: **1 Feb 2018**
Estimated online publication: **05-09 2019**

Open to all related submissions - no page limit

Please speak to the guest editors or journal editorial staff for more details

More details available at:
http://iopscience.org/pmea



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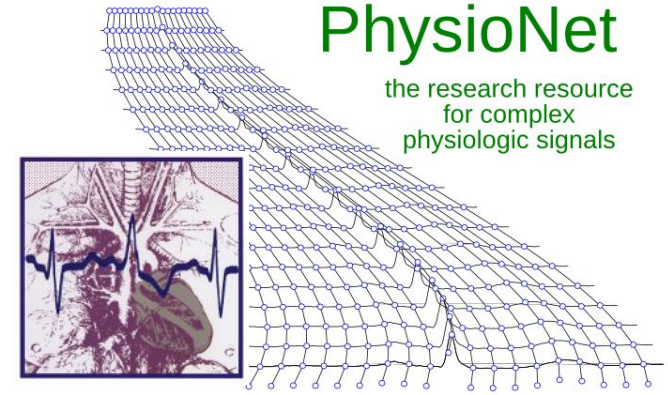
Discussion



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26th September 2018

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3. Competitors attend a public forum and verbally defend their work

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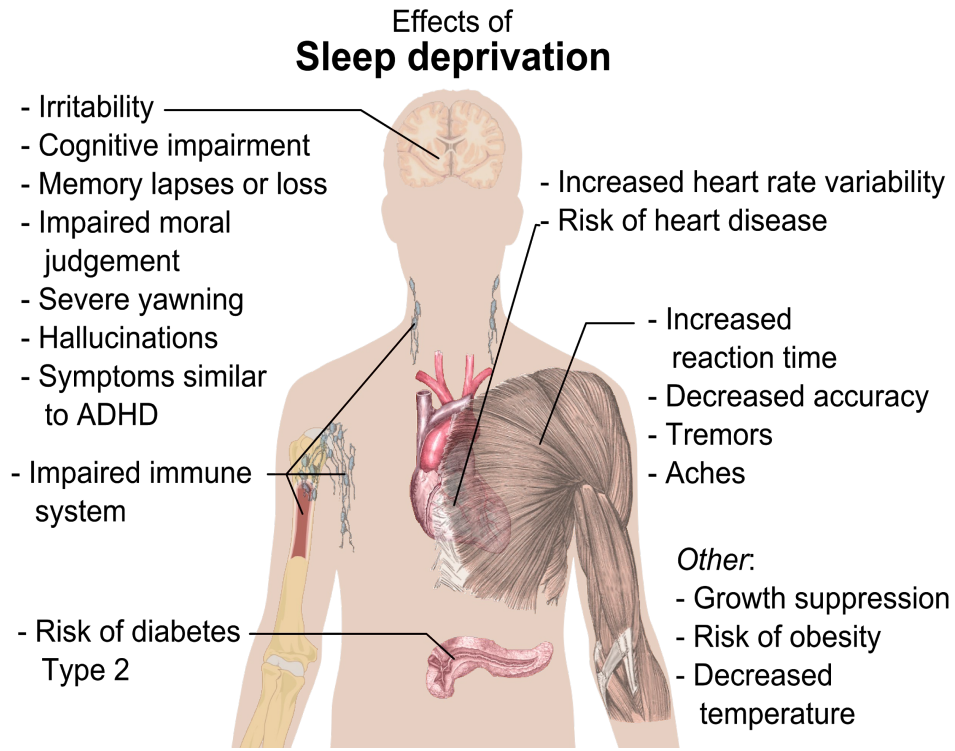

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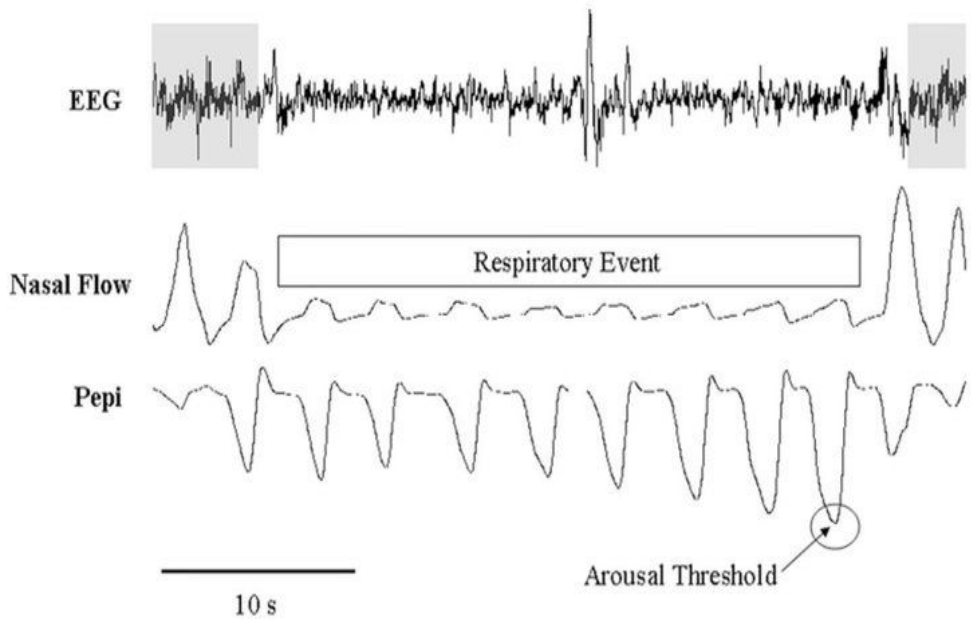

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The Winners

COMPUTING IN CARDIOLOGY

PhysioNet

Challenge 2018:
You Snooze, You Win

Computing in Cardiology and PhysioNet,
in recognition of outstanding achievement, present to

Runnan He, Kuanquan Wang,
Yang Liu, Na Zhao, Yongfeng Yuan,
Qince Li, and Henggui Zhang

Third Place

this certificate of merit for participation
with distinction in the 19th annual
Computing in Cardiology/PhysioNet Challenge

Maastricht, The Netherlands September 26, 2018

3.

2.

COMPUTING IN CARDIOLOGY

PhysioNet

Challenge 2018:
You Snooze, You Win

Computing in Cardiology and PhysioNet,
in recognition of outstanding achievement, present to

Guðni Fannar Kristjansson, Heiðar Már Þráinsson,
Hanna Ragnarsdóttir, Bragi Marinósson,
Eysteinn Gunnlaugsson, Eysteinn Finnsson,
Sigurður Ægir Jónsson, Halla Helgadóttir,
and Jón Skírnir Ágústsson

Second Place

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Computing in Cardiology/PhysioNet Challenge

Maastricht, The Netherlands September 26, 2018

3. He, Wang, Liu, Zhao, Yuan, Li, & Zhang

1.

COMPUTING IN CARDIOLOGY

PhysioNet

Challenge 2018: You Snooze, You Win

Computing in Cardiology and PhysioNet,
in recognition of outstanding achievement, present to

Matthew Howe-Patterson,
Bahareh Pourbabaee,
and Frederic Bernard

2.

First Place

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Maastricht, The Netherlands September 26, 2018

3.

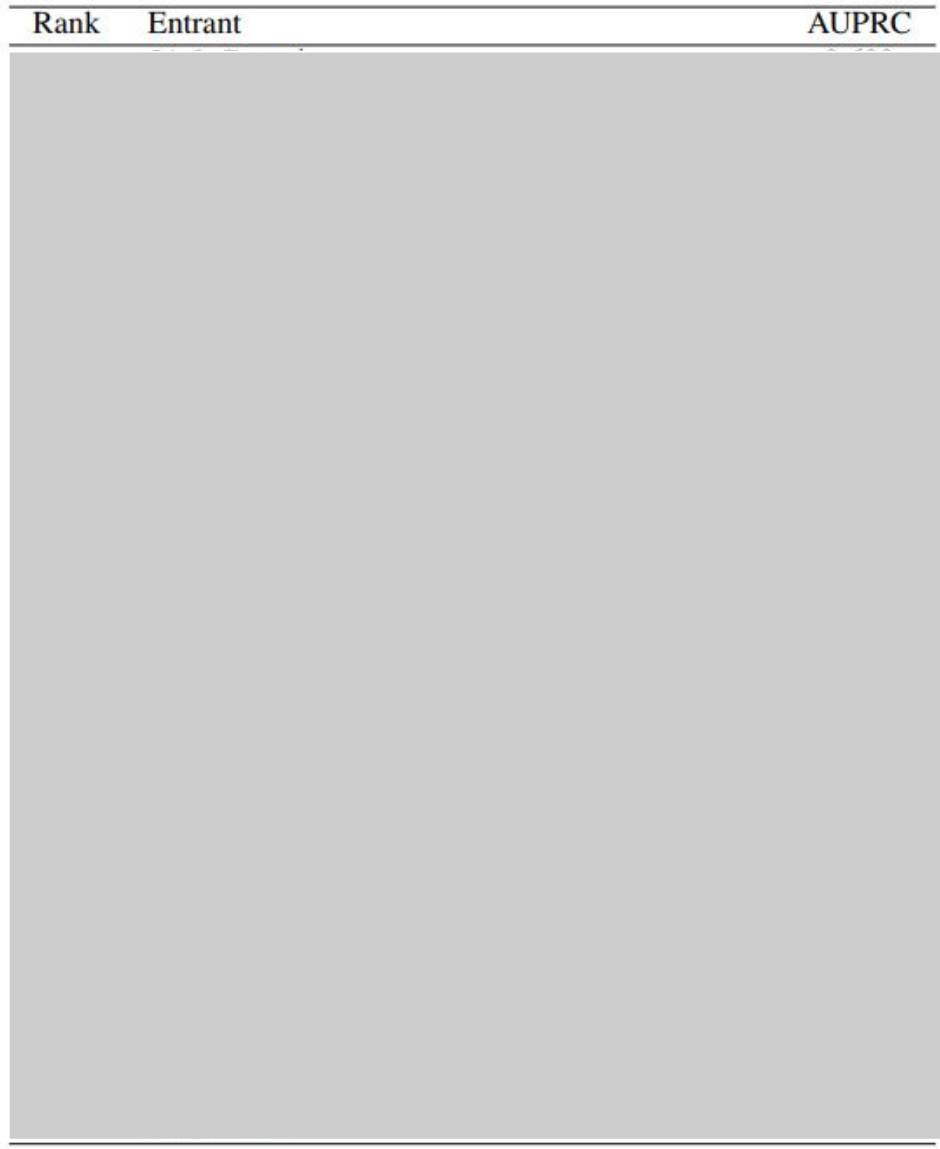
1. Howe-Patterson, Pourbabee & Bernard

2. Kristjánsson, Þráinsson, Ragnarsdóttir, Marinósson, Gunnlaugsson, Finnsson, Jónsson, Helgadóttir, & Ágústsson

3. He, Wang, Liu, Zhao, Yuan, Li, & Zhang

Challenge Submissions

- Total Entries:
  - 624 entries
  - 34 unique entrants
- Total Qualified Entries:
  - 29 entries
  - 19 unique entrants
- Software Licenses of Qualified Entrants:
  - 8/19: MIT X11 License
  - 10/19: GNU GPL (version 3)
  - 1/19: GNU GPL (version 2)



Challenge Submissions

- The excellent performance of the current runner-up (AUPRC = 0.57) indicates that automated arousal detection is realizable.

- However, the large variance in performances across entrants (mean 0.28, and ranging from 0.07 to 0.60) indicates that arousal detection is a challenging problem.

- Many entries used neural networks as a component of their arousal detection algorithms.
  - The eight highest-scoring entries all used either Tensorflow or Pytorch.
  - So did the five lowest-scoring entries.

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Rank	Entrant	AUPRC
–	Miller, Ward, & Bambos	0.369
–	Szalma, Bánhalmi, & Bilicki	0.338
–	Bhattacharjee, Das, Choudhury, & Banerjee	0.321
–	Li, Cao, Zhong, & Pan	0.315
–	Parvaneh, Rubin, Samadani, Prakash, & Katuwal	0.222
–	Plešinger, Nejedly, Viscor, Andrla, Halámek, & Jurák	0.212
–	Zabihi, Rad, Särkkä, Kiranyaz, Katsaggelos, & Gabbouj	0.191
–	Schellenberger, Shi, Mai, Wiedemann, Steigleder, Eskofier, Weigel, & Kölpin	0.159
–	Bilal, Khan, Khan, Qureshi, Saleem, & Kamboh	0.136
–	Subramanian, Chlon, Chamadia, & Chakravarty	0.120
–	Jia, Yu, Yan, Zhao, Xu, Hu, Wang, & You	0.114
–	Nesaragi, Sharma, & Patidar	0.095
–	*Wang, Wang, & Li* †	0.077
–	Shen	0.072
–	Majumder, Wang, Mohamud, Verma, & Tavakolian	0.072

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Rank	Entrant	AUPRC
–	He, Wang, Liu, Zhao, Yuan, Li, & Zhang	0.453
–	Varga, Görög, & Hajas	0.445
–	Patane, Ghiasi, Scilingo, & Kwiatkowska	0.426
–	Warrick & Homsi	0.421
–	Miller, Ward, & Bambos	0.369
–	Szalma, Bánhalmi, & Bilicki	0.338
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Rank	Entrant	AUPRC
–	*Li & Guan* †	0.609
–	Howe-Patterson & Pourbabaee	0.573
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Prizes

- $3,500 total to top three official open-source entries
- Presented at closing ceremony - you have to be there to collect them! No mailing!!

Finally - the big thank yous!

- Mathworks for the $3,500 prize money and free licenses during the competition!
- Mohammad Ghassemi & Benjamin Moody
- Brandon Westover & the MGH Team ...

Physiological Measurement

Arousal Detection

Focus issue for the PhysioNet/Computing in Cardiology Challenge 2018

Guest editors: Mohammad Ghassemi, Benjamin Moody, Li-wei Lehman, Qiao Li, Gari D. Clifford

Closing date for submission: **1 Feb 2018**
Estimated online publication: **05-09 2019**

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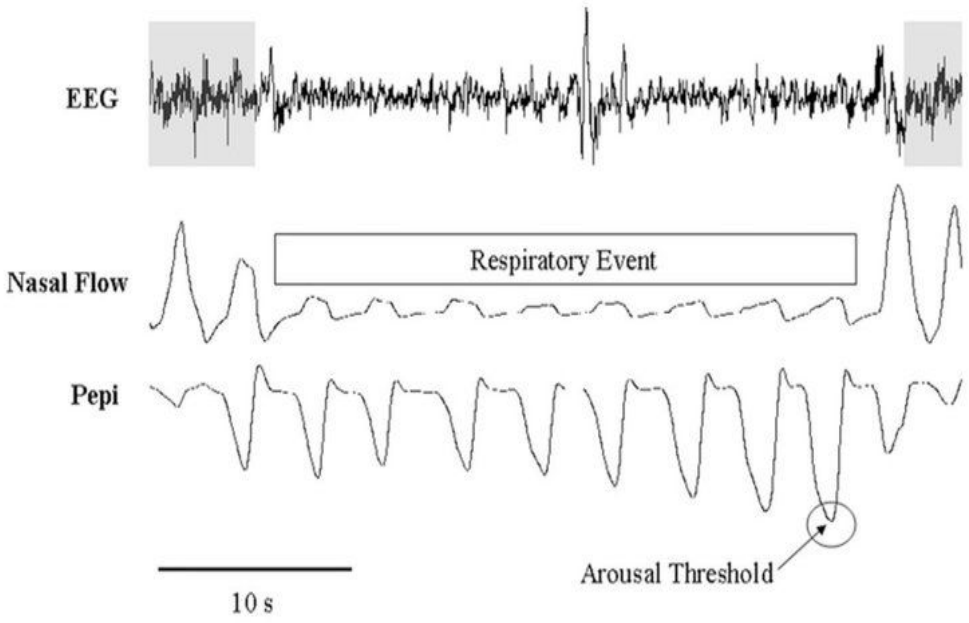

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