



JEDAI project
CHIST-ERA PROJECTS SEMINAR

Antoine Frappé

Virtual – March 29th, 2022

**Event-Driven Artificial Intelligence
for biomedical sensors
ACAI 2018 Call**



Background

Cardiovascular diseases

- Leading cause of deaths worldwide (31% of all deaths)¹
- 66% of all CVD deaths happen outside the hospital²



1. World Health Organization, Health Statistics
2. The Burden of Heart Disease and Stroke. TN. 2006

Wearable Healthcare Monitoring



Feature extraction
from ICG and ECG

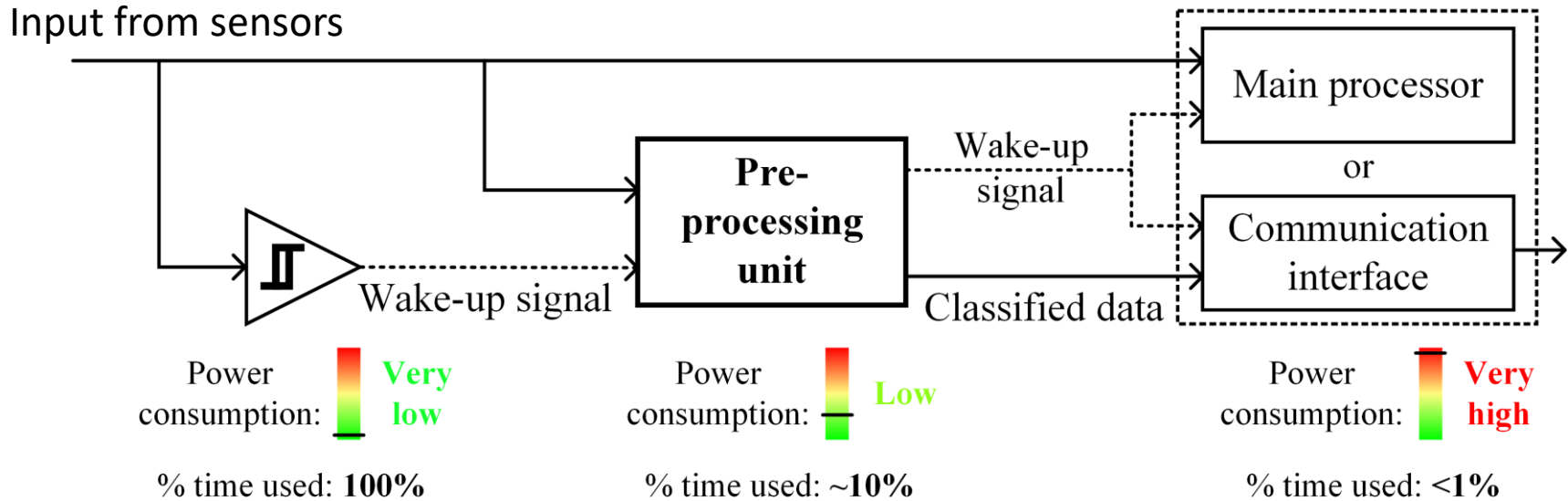


- Arrhythmia
- Sleep apnea
- Sleep stages analysis
- Stress

Requires ultra-low power
integrated intelligent hardware



Near-Sensor Processing (Edge AI)

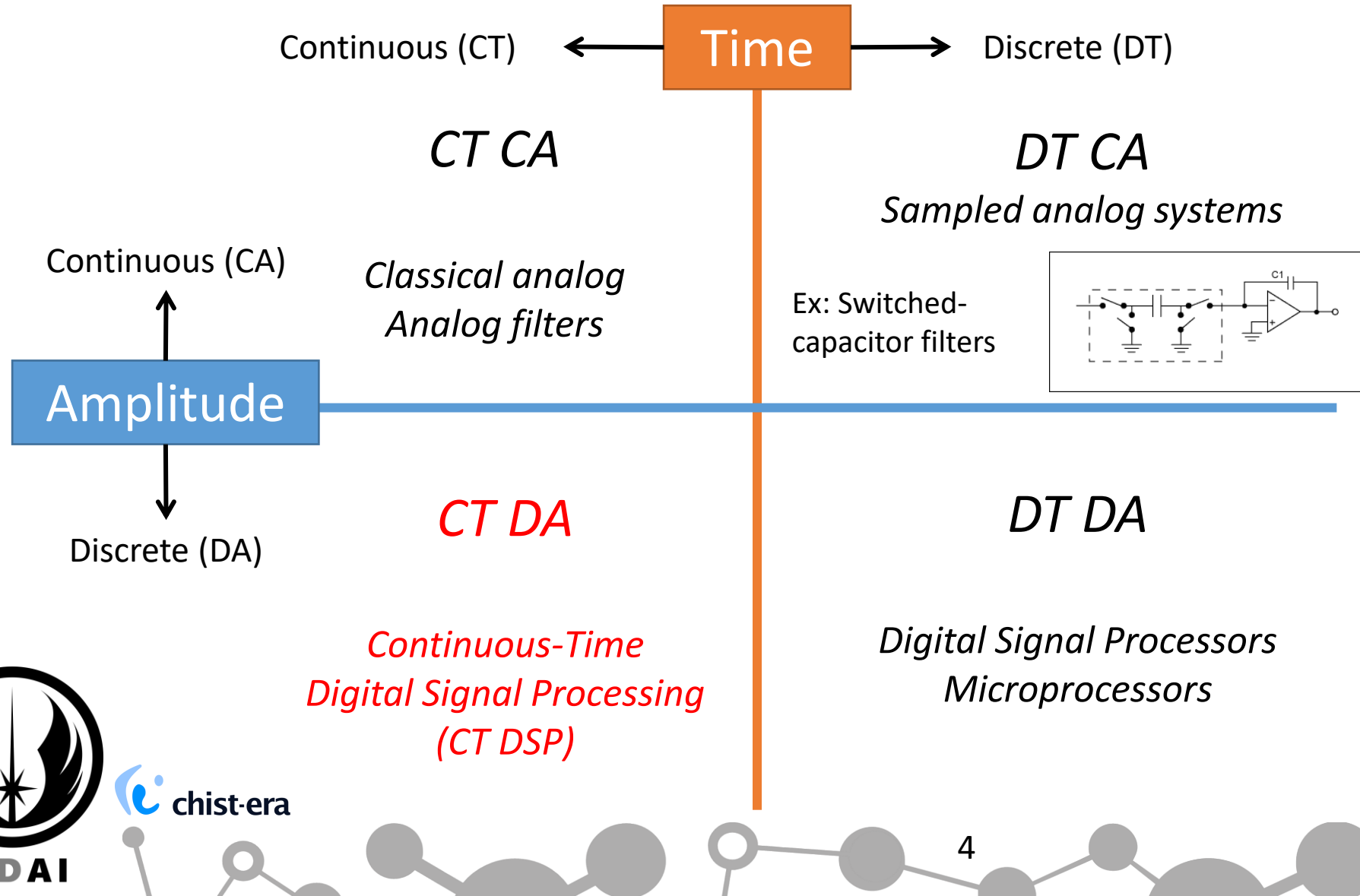


Process **relevant** data **as close as the sensor** as possible

- Aggregation of a **lower amount of data**
- Need of energy-hungry processing during a **lower amount of time**



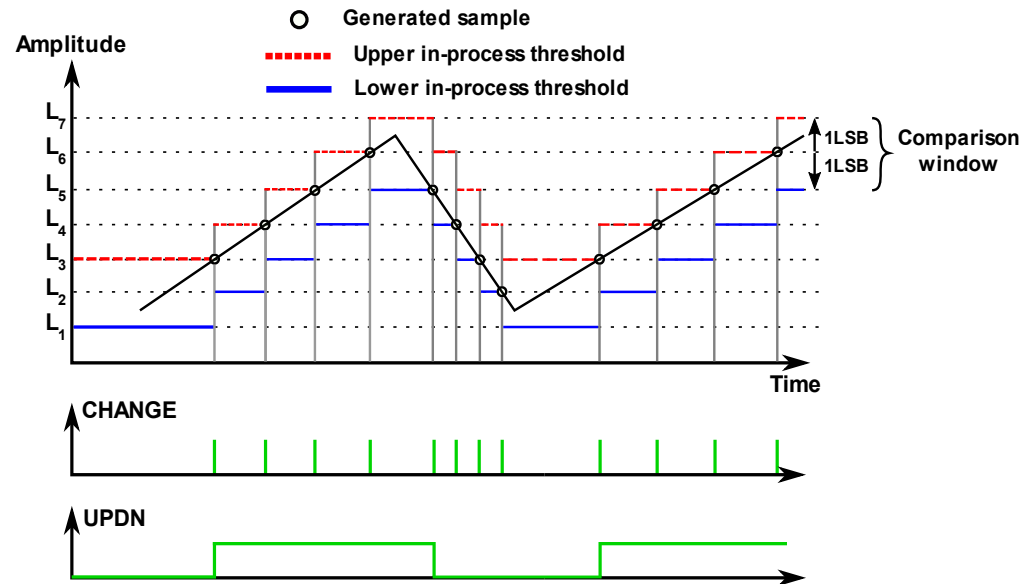
Continuous-Time Digital Signal Processing (CTDSP)



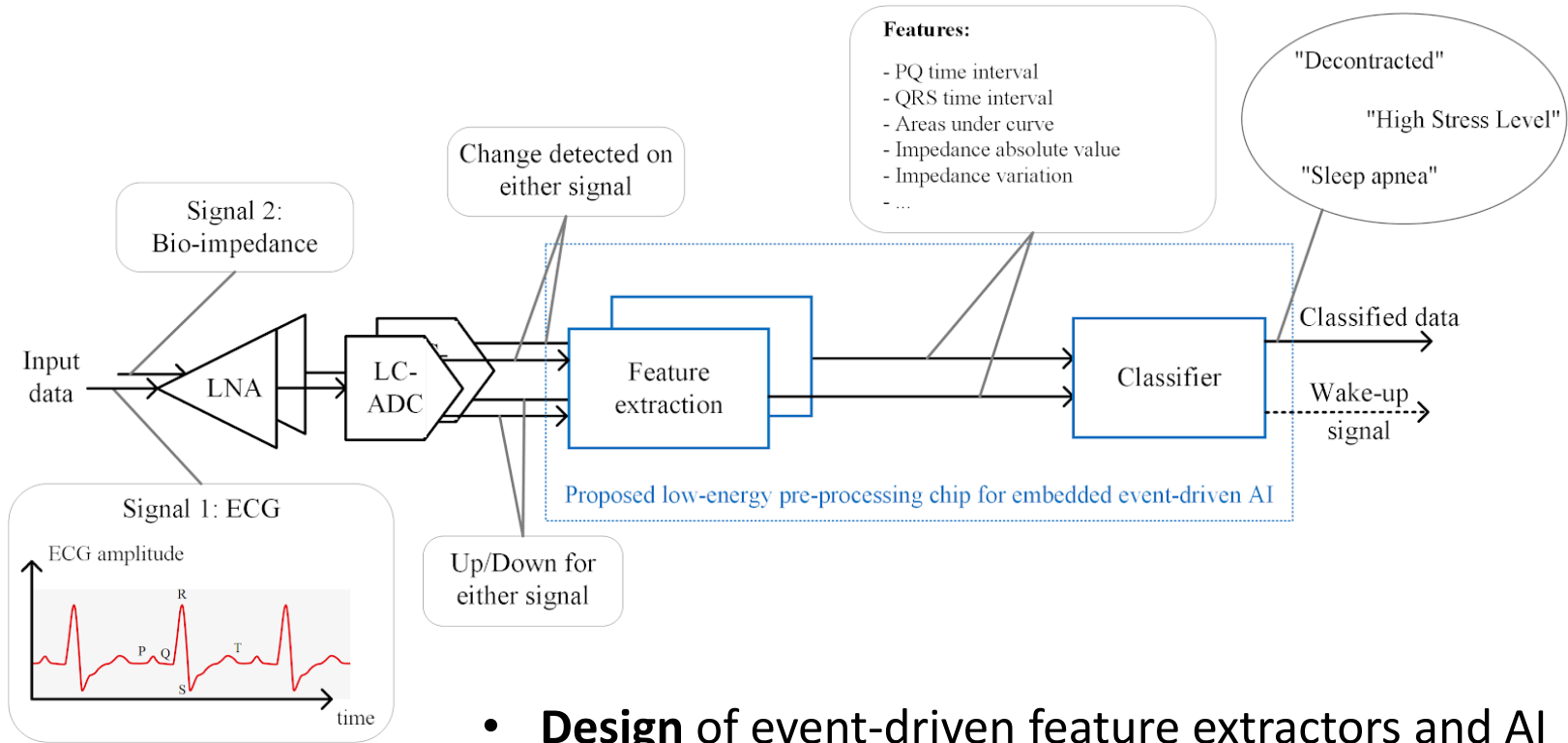
CTDSP opportunities

- + Event-driven system** No clock generation and distribution
Event-driven power consumption
- + CMOS Digital System** Configurability / Programmability
Scalability
High integration level
- + Quantization only** No sampling $\rightarrow$ no aliasing
smaller in-band quantization error

Level-crossing ADC
sampling scheme



JEDAI project objectives



- **Design** of event-driven feature extractors and AI integrated circuits in advanced CMOS technology.
- **Validation** of the AI chips with external front-end
- **Demonstration** of innovative local fusion of ECG and bioimpedance analog signals for selected applications.

Complementary partners



Dublin, IE

Expertise in signal processing for ECG
Develop event-driven architectures
for signal processing, fusion and
machine learning

Tallinn, EE

**TAL
TECH**

Expertise in impedance cardiography
Develop test circuits and system-level
validation

Lille, FR



Coordination

Expertise in integrated circuit design
Develop event-driven architectures for Edge AI



 **chist-era**

Main scientific results

1. Cardiac Arrhythmia Classification using ECG signals
2. Impedance cardiography (ICG)-based systems

Main scientific results

1. Cardiac Arrhythmia Classification using ECG signals

- Proposition of a non-uniformly sampled process and evaluation of level-crossing ADC [ISCAS21] [TBioCAS21]

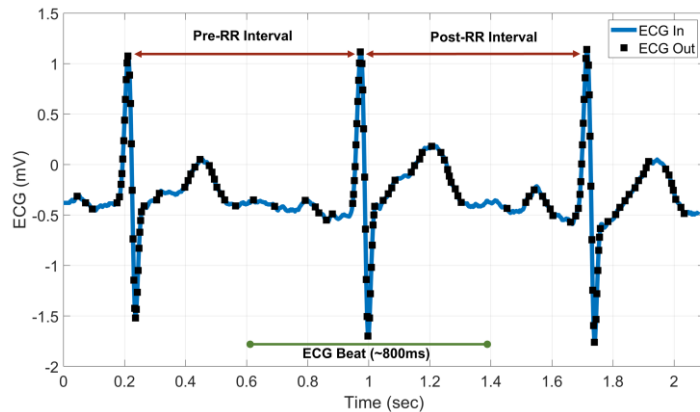
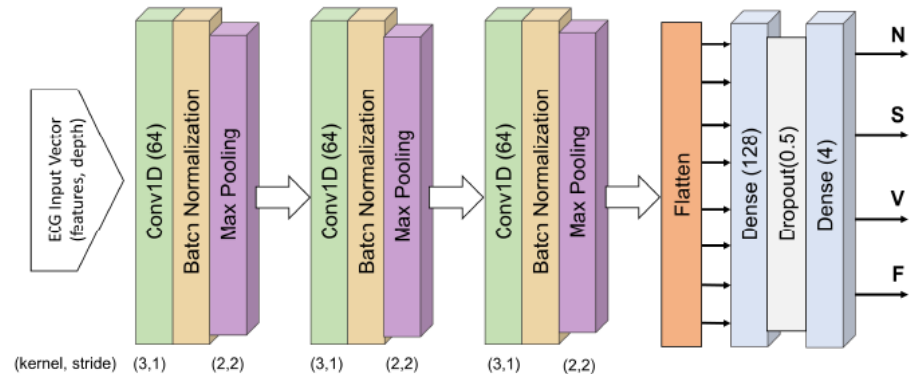


TABLE IV: Complexity Analysis of Event-Driven and Uniformly Sampled 1D-CNN Models

Type	Input Vector	Parameters	FLOPS
Event-Driven	120x2	132,676	2397144
Uniform	238x1	255,748	4883224



Creation of a publicly-available event-driven ECG database



Main scientific results

1. Cardiac Arrhythmia Classification using ECG signals

- Proposition of energy-efficient classification models using configurable early exits (patent on-going) and Shuffled Multi-Scale Group Convolution (SMSGC)

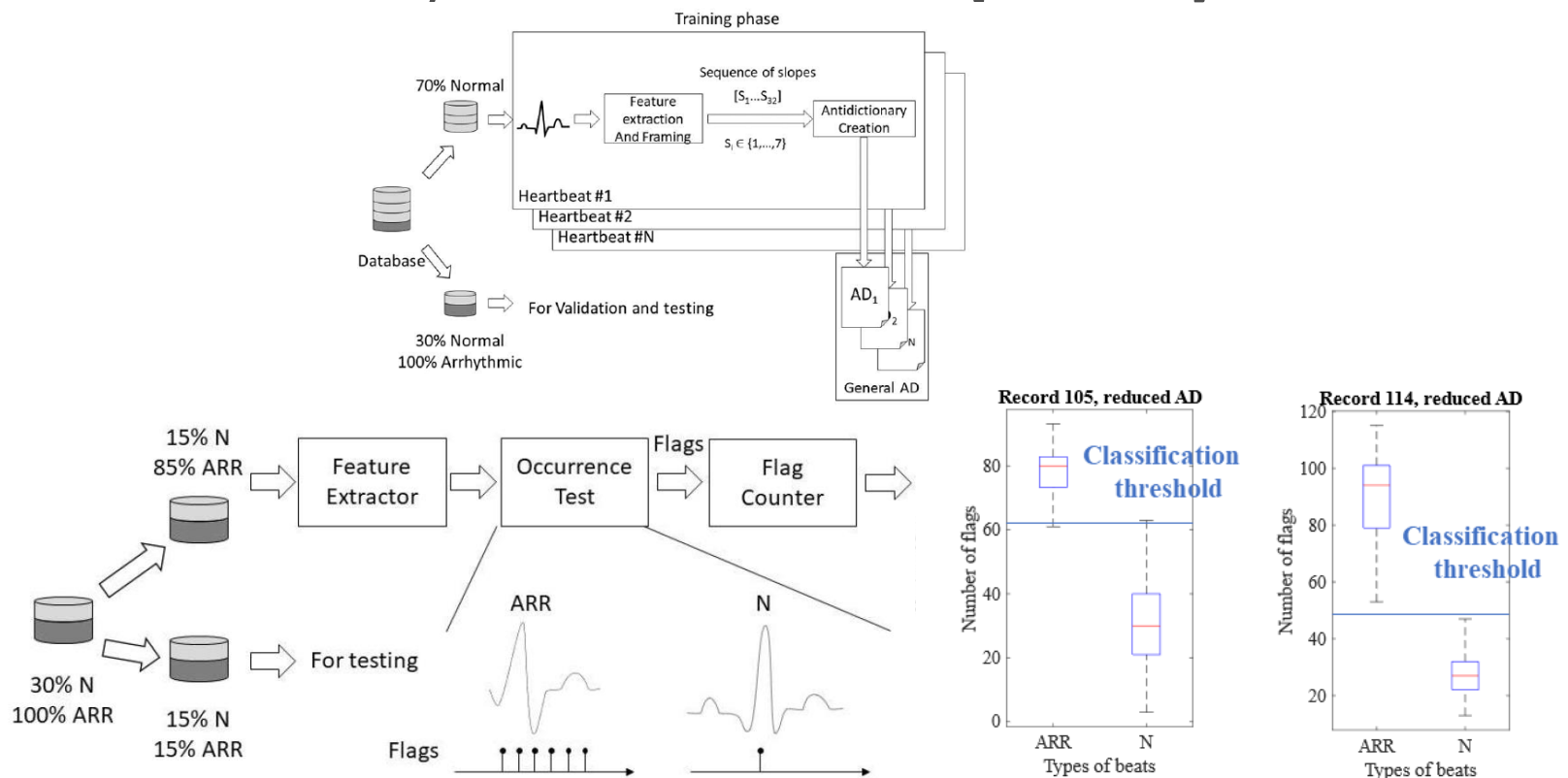
Model	MACs	Params	Acc	F1
[TBioCAS 22] 1D-CNN (3 Conv Layers + 2MLP)	1,236,417	132,289	97.44%	89.29%
SMSGC	42,613	15,674	97.54%	89.37%
Complexity reduction	-96.5%	-88.5%	Similar classification results	



Main scientific results

1. Cardiac Arrhythmia Classification using ECG signals

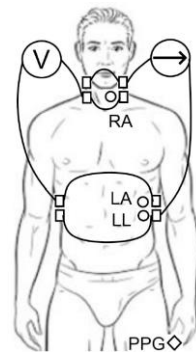
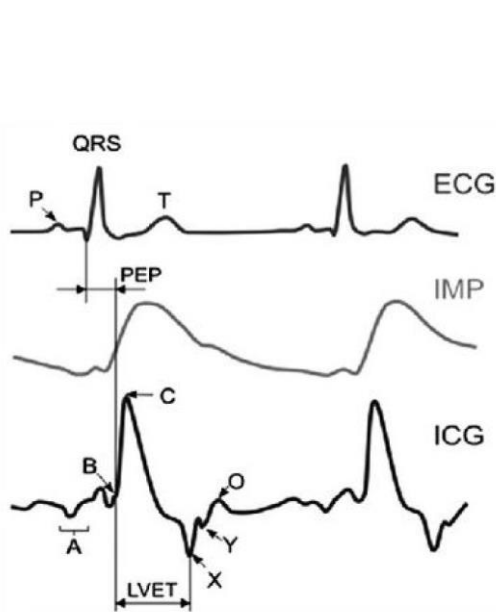
- Proposition of slope-based feature extraction [BioCAS21] and antidictionary-based classification [ISCAS22].



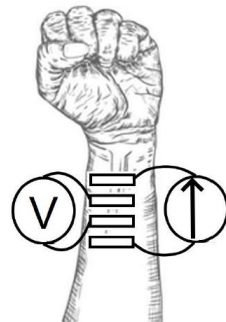
Main scientific results

2. Impedance cardiography (ICG)-based systems

- Creation of an ICG database and study of the electrode locations with a focus on wrist-based systems [EMBC21]



(a) TEPC-1



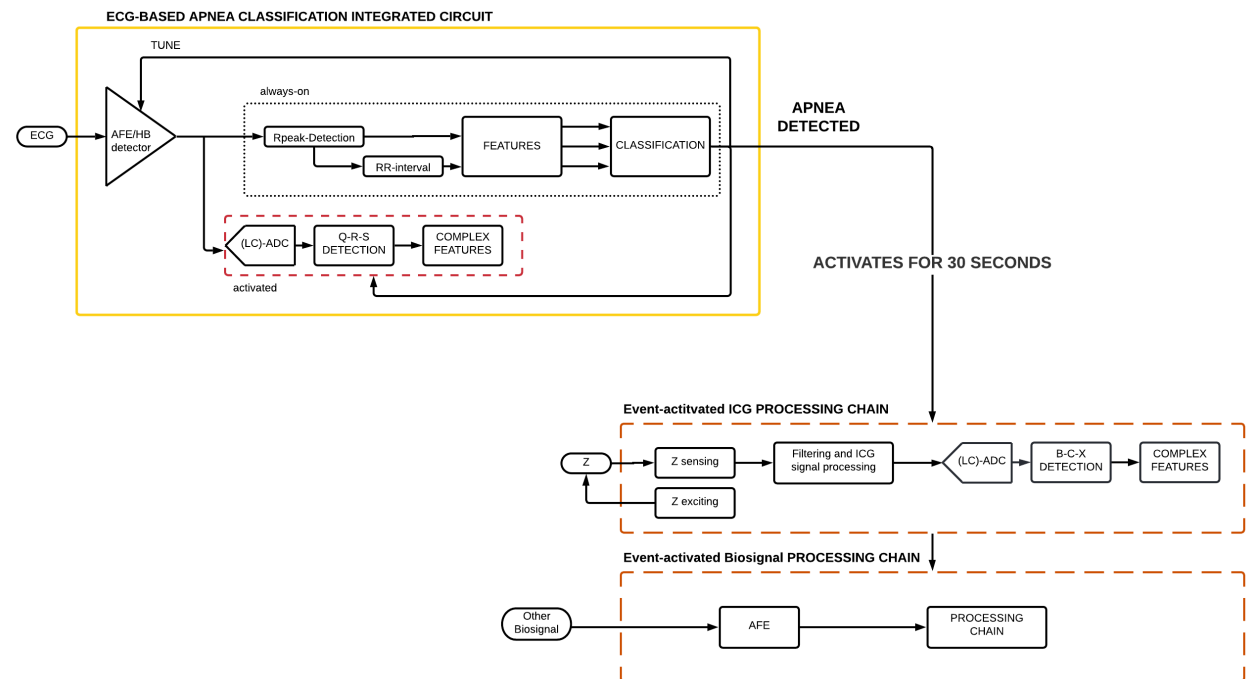
(a) AEPC1

No	Conf	Quality	C-C errors	C-X errors	B-C errors	Total periods
1	TEPC-1	3	0	0	0	16
2	TEPC-2	1	9	9	8	16
3	TEPC-3	1	2	6	3	9
4	TEPC-4	2	0	0	0	15
5	TEPC-5	1	3	9	1	13
6	TEPC-6	0	11	16	16	27
7	TEPC-7	2	2	12	6	12
8	AEPC-5	2	0	8	2	17
9	AEPC-1	3	0	4	0	17
10	AEPC-2	2	2	7	0	18
11	AEPC-3	2	2	9	0	18
12	AEPC-4	2	0	6	0	17

Main scientific results

2. Impedance cardiography (ICG)-based systems

- ICG feature point extraction and evaluation of possible architectures to extract hemodynamic parameters [SOCC21] [I2MTC22] + patent ongoing
- Proposition of an architecture for low-power sleep apnea detection



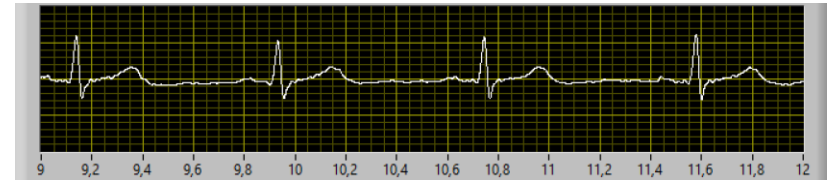
Main scientific results

2. Impedance cardiography (ICG)-based systems

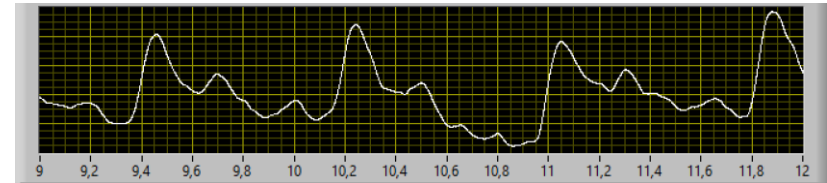
- Embedded evaluation and test platform for joint ICG ECG (PPG) measurements



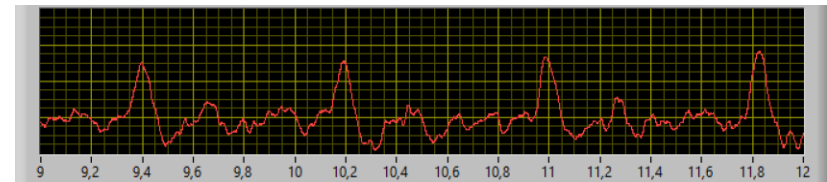
ECG



ICG



ICG
(1st derivative)



Collaboration between partners

- ❑ Kick-off meeting in Lille, France in Nov 2019
- ❑ Second physical meeting held in Tallinn, Estonia in Feb 2022
- ❑ Regular online meetings (every other week) with all the partners
- ❑ Student exchanges:
 - A. Gautier (Ph.D. student at IEMN Lille) has spent 1.5 months at Taltech



Valorization / Exploitation

- ❑ 2021: 6 publications (including 5 multi-partners) in major IEEE conferences (ISCAS, BioCAS, EMBC, SOCC, I2MTC) and major journals (IEEE Transactions on Biomedical Circuits and Systems)
- ❑ Presentation in seminars and workshops, for example during the STMicroelectronics-IEMN annual workshop
- ❑ Creation of a publicly-available open-source event-driven ECG dataset (derived from MIT-BIH arrhythmia database)
 - [GitHub - jedaiproject/Open-Source-Event-Driven-ECG-Dataset](https://github.com/jedaiproject/Open-Source-Event-Driven-ECG-Dataset)
- ❑ www.jedai.eu
- ❑ 2 patents on-going





Thank you for your attention !



Antoine Frappé

antoine.frappe@iemn.fr

