cardio4id

HEARTMETRICS EXPERTS

Integrating Physiological Monitoring in the Industry

André Lourenço

Jan 2022

Origins

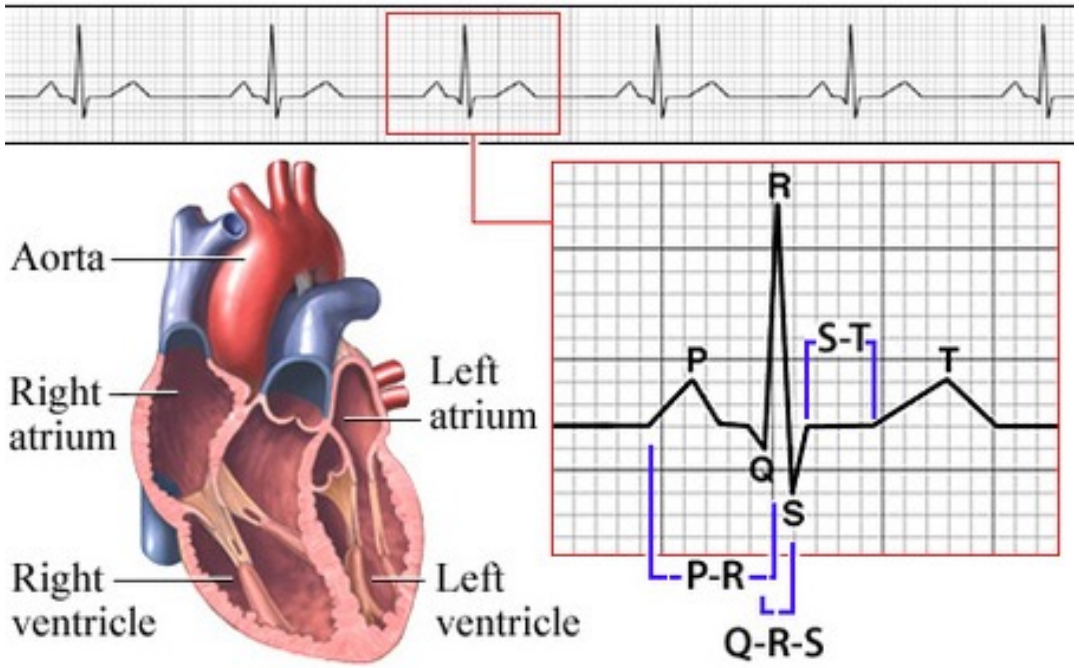
Applied Research at Instituto Superior Técnico, University of Lisbon

PATTERN RECOGNITION, ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING GROUP

Area of acquisition and automatic processing of biosignals.

HW, SW & algorithms with the goal of achieving automatic non-collaborative recognition of humans.

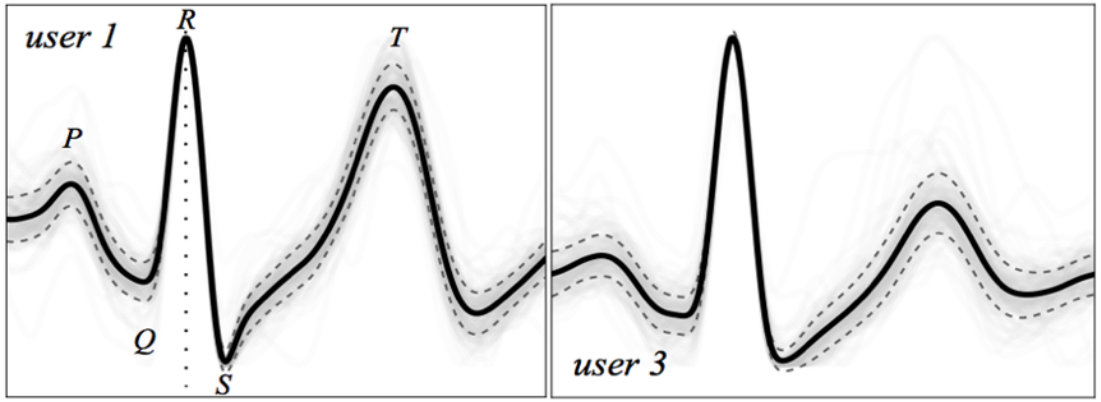
Main topic research: biometrics and ECG

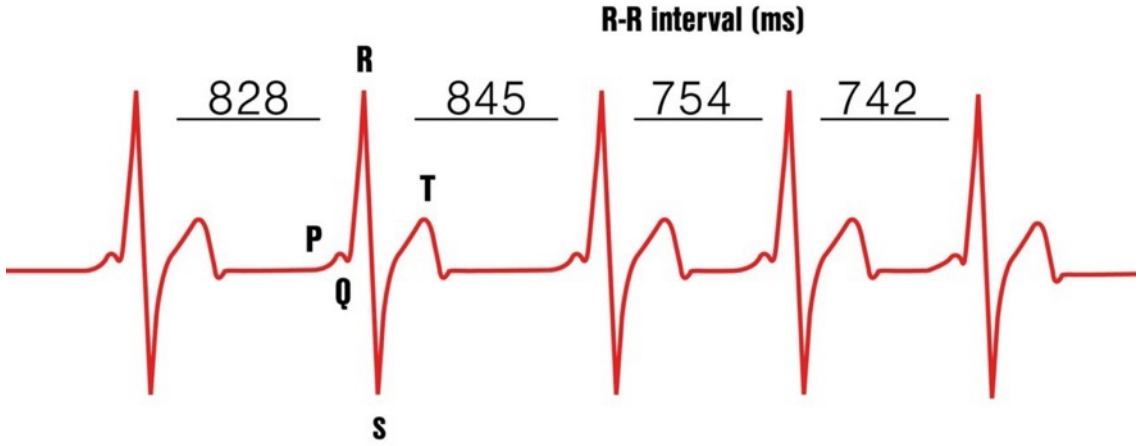


- The electrocardiogram (ECG) is an emerging biometric trait.
- Pioneer works from 2001 showed that the ECG contains sufficient discriminatory information to identify individuals.
- As measured from the body surface, the ECG signal is directly related to each individual's physiology, skin conductivity, genetic singularities, heart position and shape.

https://www.researchgate.net/publication/271386679_ECG_Biometrics_Principles_and_Applications

Your Heart is Unique

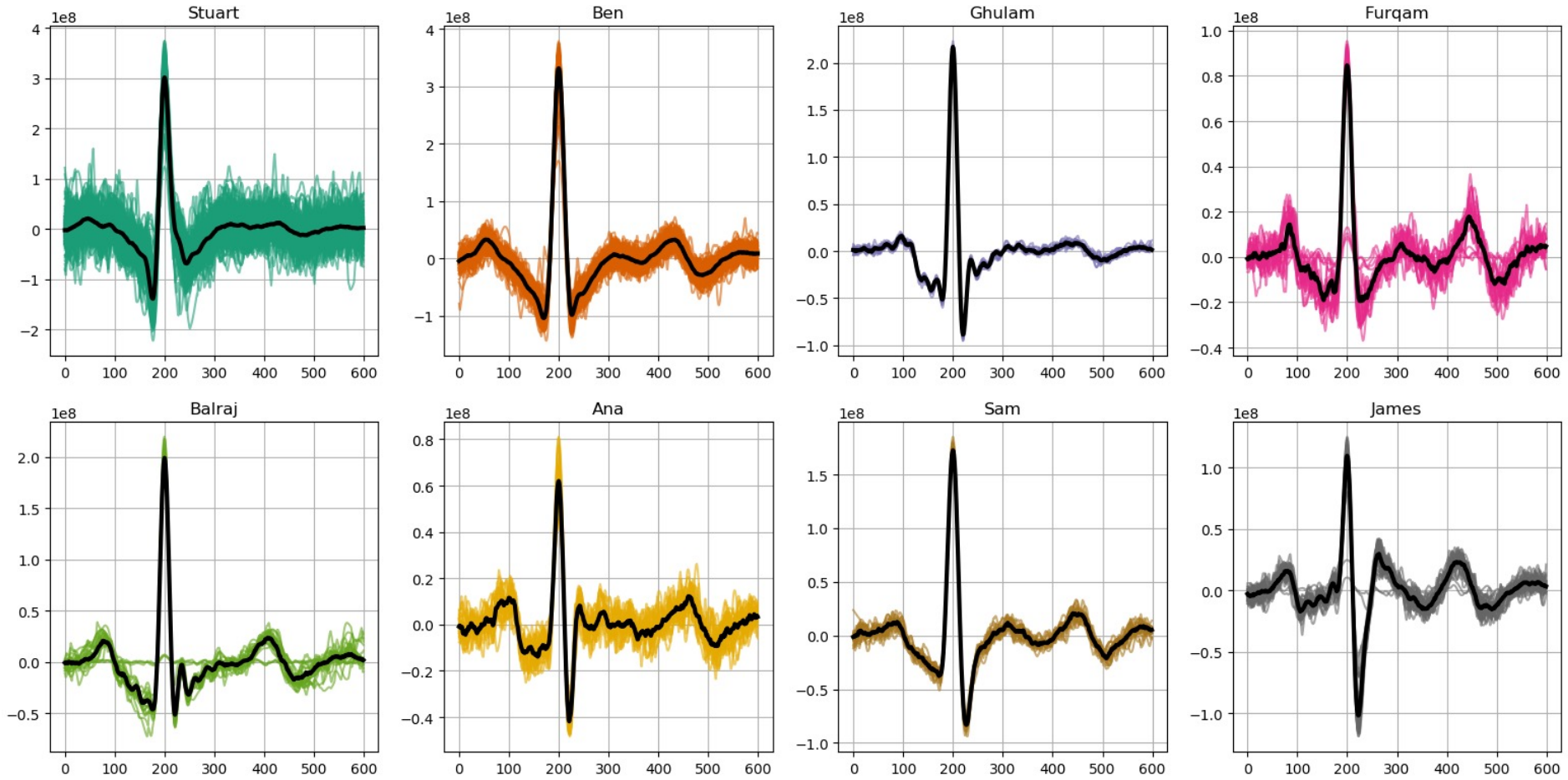




The ECG is the record of the electrical activity of the heart. The shape is different from individual to individual. (**see overlapping line**)

Heart Rate Variability, is the physiological phenomenon of the variation in the time interval between consecutive heartbeats.

Practical Examples



Sample of **9 individuals**, acquired on **Jan-2020** in **Dunton, England**, in a real-time acquisition demonstration (steering wheel), to researchers of **Vehicle Manufacturing Company.**

Scientific Recognition

+70

International Conference Papers

8

Journal Papers

2

Best Paper Awards

1st

Best Demo Award

A. Lourenço, S. Bulo , C. Carreiras, A. L. N. Fred, "ECG Analysis Using Consensus Clustering", EUSIPCO, Lisbon, Portugal, September, 2014
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H. Silva, A. Lourenço, A. L. N. Fred, A. K. Jain, "Finger ECG Signal for User Authentication: Usability and Performance", IEEE BTAS, Washington DC, US, Sep, 2013
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C. Carreiras, A. Lourenço, H. Aidos, H. Silva, A. L. N. Fred, "Morphological ECG Analysis for Attention Detection", NTCA, Vilamoura, Portugal, September, 2013
C. Carreiras, A. Lourenço, H. Silva, A. L. N. Fred, "Comparative Study of Medical-grade and Off-the-person ECG System"s, IWoPE, Portugal, Sep, 2013
A. Lourenço, H. Silva, C. Carreiras, A. P. Alves, A. L. N. Fred, A web-based platform for biosignal visualization and annotation, Multimedia Tools and Applications,, February, 2013
A. P. Alves, H. Silva, A. Lourenço, A. L. N. Fred, SignalBIT: A web-based platform for real-time biosignal visualization and recording,ICSPMA, Reykjavik, Iceland, Vol., pp. 156 - 162, July, 201
H. Silva, A. P. Alves, A. Lourenço, A. L. N. Fred, I. Montalvão, L. Alegre, Towards the Detection of Deception in Interactive Multimedia Environments, HCI-KDD, Maribor, Slovenia, Vol., pp. 65 - 76, July, 2013
A. Lourenço, H. Silva, C. Carreiras, A. L. N. Fred, Outlier Detection in Non-intrusive ECG Biometric System, ICIAR, Póvoa do Varzim, Portugal, June, 2013
C. Carreiras, A. Lourenço, H. Silva, A. L. N. Fred, A Unifying Approach to ECG Biometric Recognition Using the Wavelet Transform ICIAR, Portugal, June, 2013
A. P. Alves, H. Silva, A. Lourenço, A. L. N. Fred, I. Montalvão, Uncovering lying detection using blood volume pulse and electrodermal activity, ConfTele, Castelo Branco, Portugal, Vol., pp. 265 - 268, May, 2013
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F. A. L. Canento, A. Lourenço, H. Silva, A. L. N. Fred, On Real Time ECG Algorithms for Biometric Applications, Biosignals, Barcelona, Spain, Feb, 2013
A. H. Holzinger, C. Stocker, M. B. Bruschi, A. Auinger, H. Silva, H. Gamboa, A. L. N. Fred, On Applying Approximate Entropy to ECG Signals for Knowledge Discovery on the Example of Big Sensor Data, AMT, Macau, China, Vol., pp. 646 - 657, De, 2012
M. Cânovas, H. Silva, A. Lourenço, F. A. L. Canento, A. L. N. Fred, Mobile framework for biosignal acquisition and remote processing, Portuguese Conf. on Pattern Recognition - RecPad, Coimbra, Portugal, October 2012
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L. Canento, A. L. N. Fred, H. Silva, H. Gamboa, A. Lourenço, Multimodal Biosignal Sensor Data Handling for Emotion Recognition, IEEE Sensors, Limerick, Ireland, Vol., pp. 647 - 651, October, 2011
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A. Lourenço, H. Silva, A. L. N. Fred, Unveiling the Biometric Potential of Finger-Based ECG Signals, , Vol. 2011, No. 5, pp. -, January, 2011,
A. L. N. Fred, H. Silva, A. Lourenço, Palm based ECG biometrics, Portuguese Conf. on Pattern Recognition - RecPad,Porto, Portugal, Vol., pp. -, October, 2011
H. Silva, A. L. N. Fred, A. Lourenço, Check Your Biosignals Here: Experiments on Affective Computing and Behavioral Biometrics, RecPad, Porto, Portugal, Vol., pp. -, October, 2011
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A. Lourenço, H. Silva, D. P. Santos, A. L. N. Fred, Towards a Finger Based ECG Biometric System, Biosignals, Rome, Italy, Vol., pp. -, January, 2011
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H. Silva, H. Gamboa, A. L. N. Fred, Applicability of Lead V2 ECG Measurements in Biometrics,

A company was born…

Headquarters
CEIIA – Automotive Engineering Cluster
Av. Dom Afonso Henriques, 1825
4450-017 Matosinhos
Portugal

R&D&I + Administration
ISEL – Engineering Faculty
Av. Cons. Emidio Navarro, 1
1959-007 Lisbon
Portugal

Foundation: 21/3/2014
Personnel: 7 Full Time
Interns: 3

COMPANY REGISTERED IN PORTUGAL NR. PT513077634

ist spin-off https://tt.tecnico.ulisboa.pt/en/innovators/comunidade-ist-spin-off/

CONTEXT-BASED PHYSIOLOGIC COMPUTING

BIOMETRICS
DROWSINESS
WELLBEING
HUMAN-FACTORS
ENGINEERING

cardio id
HEARTMETRICS EXPERTS

CONTEXT-BASED PHYSIOLOGIC COMPUTING

AUTOMOTIVE

ADAS SYSTEMS EDGE PROCESSING

R&D&I

SENSING ELECTRONICS BASED ON VITAL-SIGNS

HEALTH & WELLBEING

PERVASIVE DEVICES FOR CONTINUOUS VITAL-SIGNS MONITORING

BIOMETRICS, DROWSINESS, WELLBEING, HEALTH
ECG AND PPG: HEART-RATE-VARIABILITY, MORPHOLOGY, RHYTHM
VIDEO AND OTHER SENSORS (INERTIAL INFORMATION, LOCATION)

Industrial Property

Family of Patents based on WO2013109154A1 | Device and Method for Biometric Recognition Based on Electrocardiographic Signals

GRANTED IN PORTUGAL, USA,

CANADA, JAPAN AND SOUTH

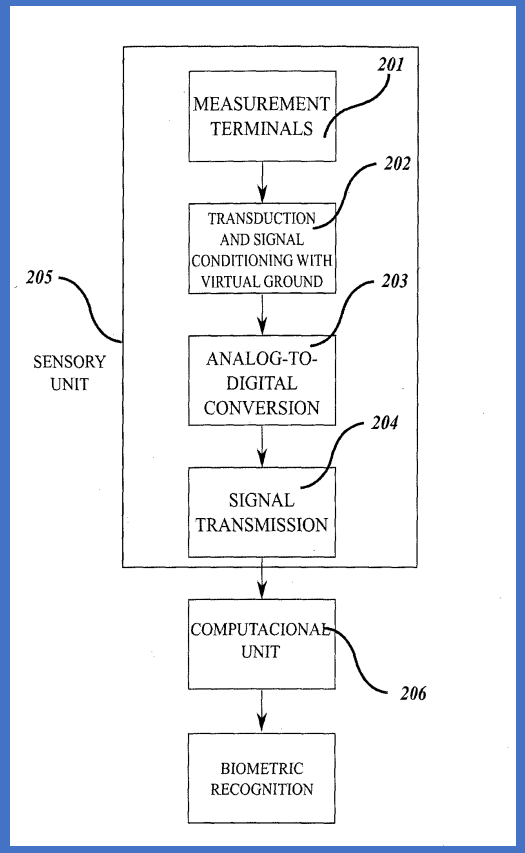
KOREA

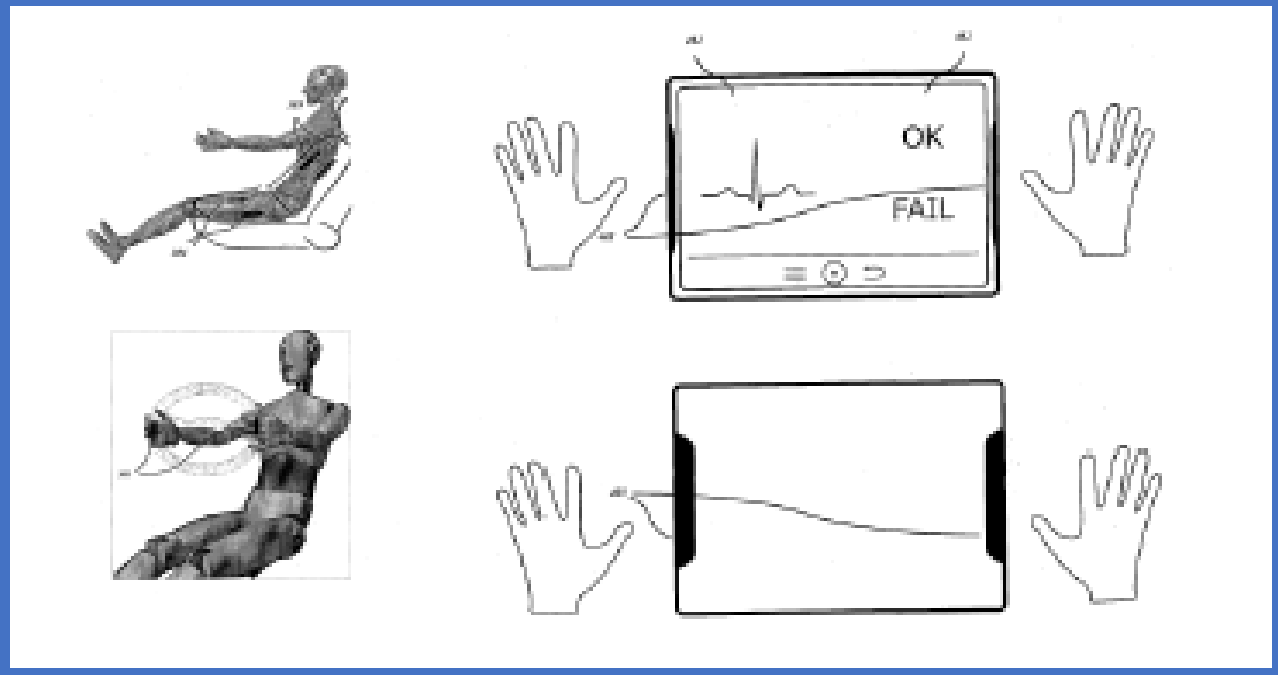
PENDING IN FEW EU COUNTRIES

PRIORITY DATE 19/1/2012

Classifications

- A61B5/04012 Analysis of electro-cardiograms, electro-encephalograms, electro-myograms
- A61B5/0402 Electrocardiography, i.e. ECG
- A61B5/117 Identification of persons
- A61B5/6893 Cars
- A61B5/6895 Sport equipment
- A61B5/6898 Portable consumer electronic devices, e.g. music players, telephones, tablet computers
- A61B5/7225 Details of analog processing, e.g. isolation amplifier, gain or sensitivity adjustment, filtering, baseline or drift compensation
- G06F21/32 User authentication using biometric data, e.g. fingerprints, iris scans or voiceprints
- G06K9/0053 Feature extraction by analysing the shape of a waveform, e.g. extracting parameters relating to peaks
- G06K9/00885 Biometric patterns not provided for under G06K9/00006, G06K9/00154, G06K9/00335, G06K9/00362, G06K9/00597; Biometric specific functions not specific to the kind of biometric
- G07C9/37
- F04C2270/041 Controlled or regulated
- G06K2009/00939 Biometric patterns based on physiological signals, e.g. heartbeat, blood flow


201
MEASUREMENT TERMINALS
202
TRANSDUCTION AND SIGNAL CONDITIONING WITH VIRTUAL GROUND
205
SENSORY UNIT
203
ANALOG-TO-DIGITAL CONVERSION
204
SIGNAL TRANSMISSION
COMPUTACIONAL UNIT
206
BIOMETRIC RECOGNITION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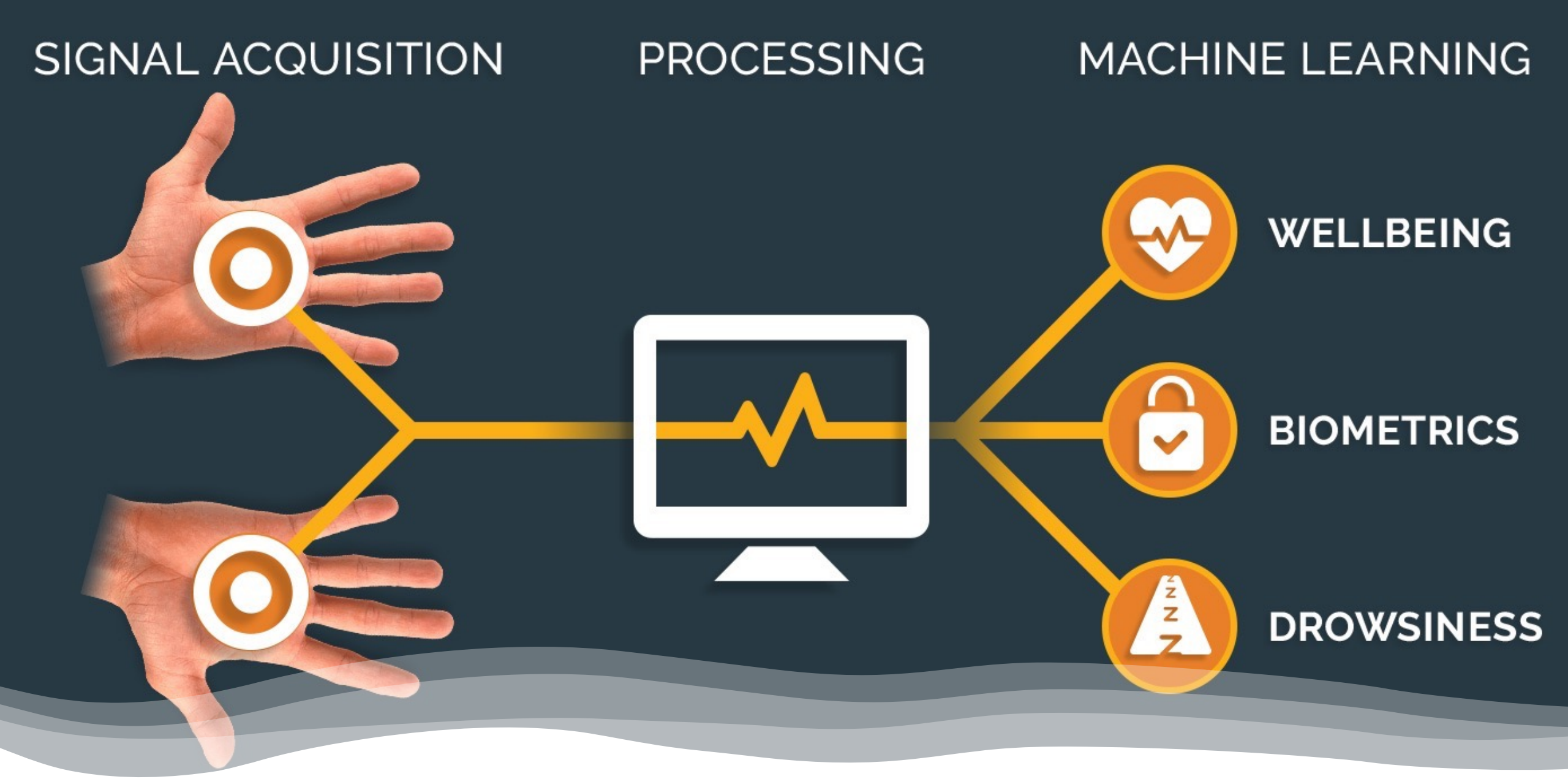
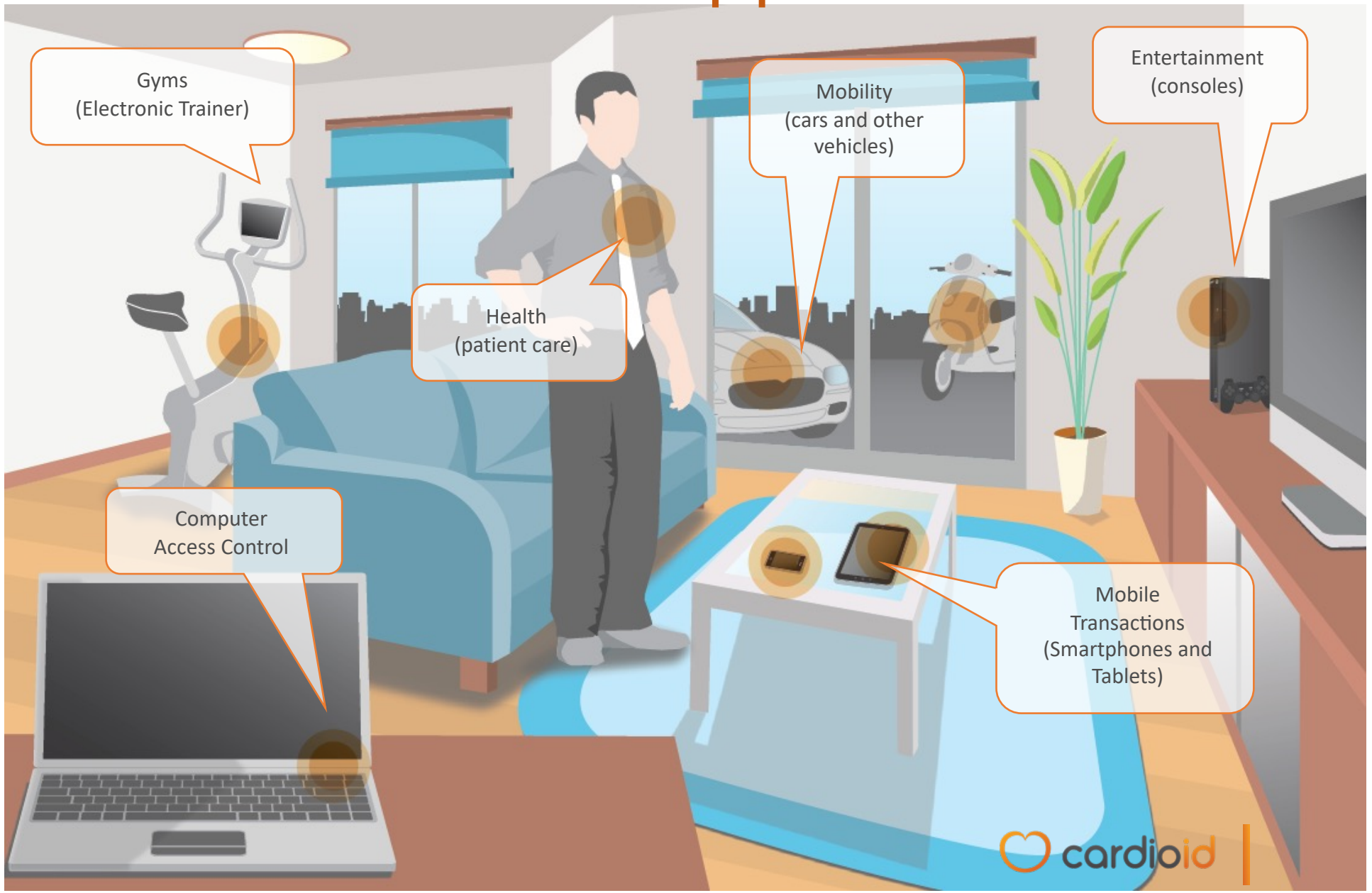
FAIL

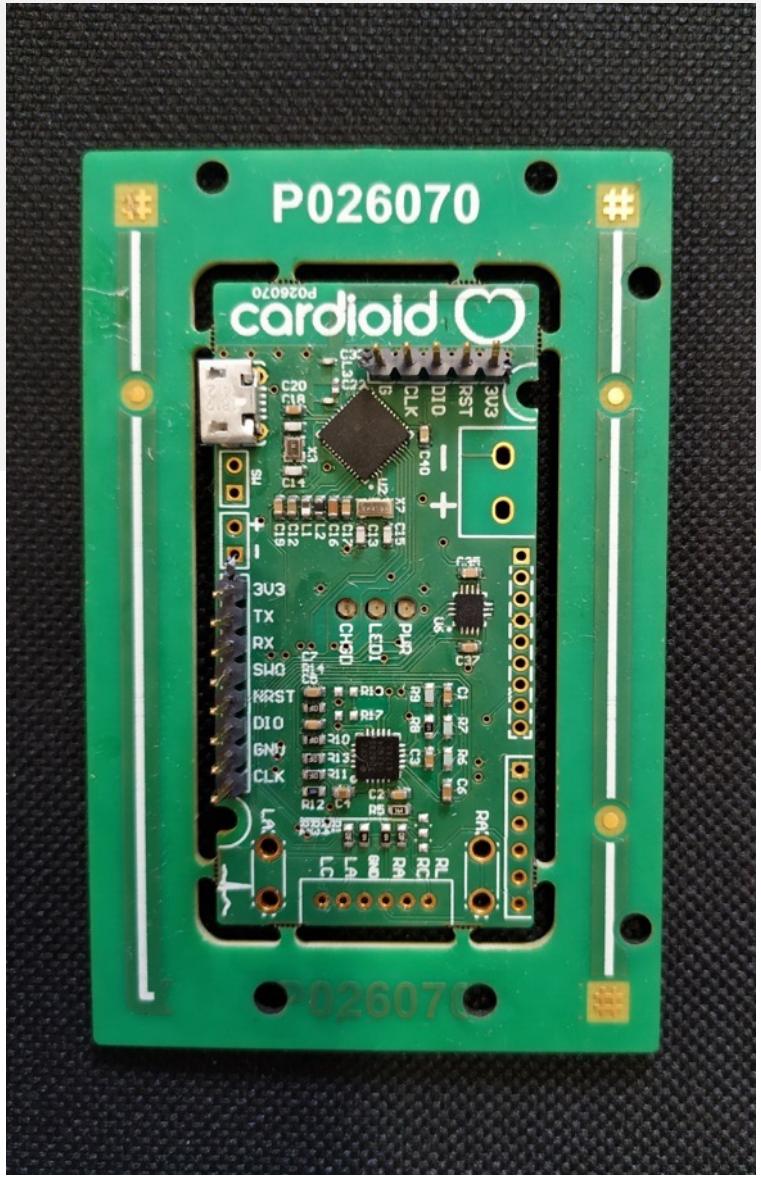

SIGNAL ACQUISITION
PROCESSING
MACHINE LEARNING
WELLBEING
BIOMETRICS
DROWSINESS

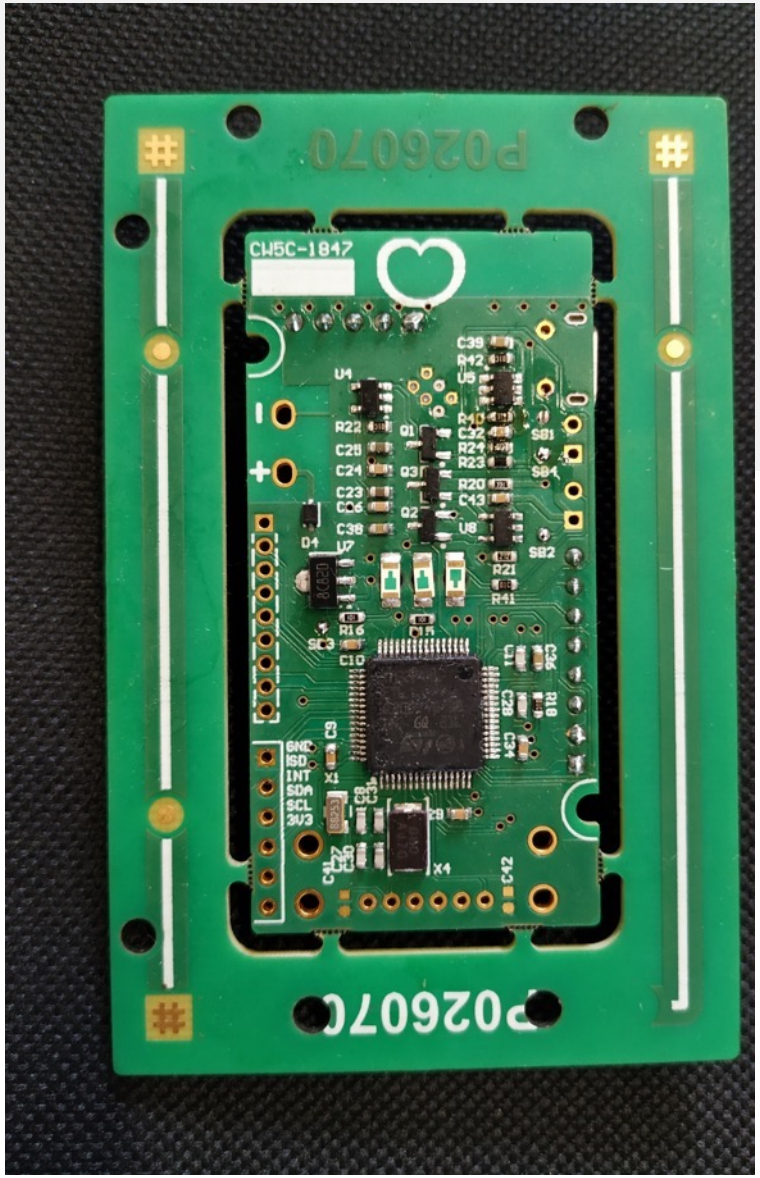
A World of Opportunities



CardioID Embedded Systems

- Features
- Single-lead ECG analog front-end
- MCU with several communication interfaces (BLE, UART, I2C, SPI)
- Power supply: 12-24 V; 5V USB plug; 3.7 V single cell Li-Po battery
- Low-power consumption
- ECG-based biometrics
- Wellness: several cardiac arrhythmias; fatigue; sleepiness; drowsiness
- FMS for fatigue-related driver performance





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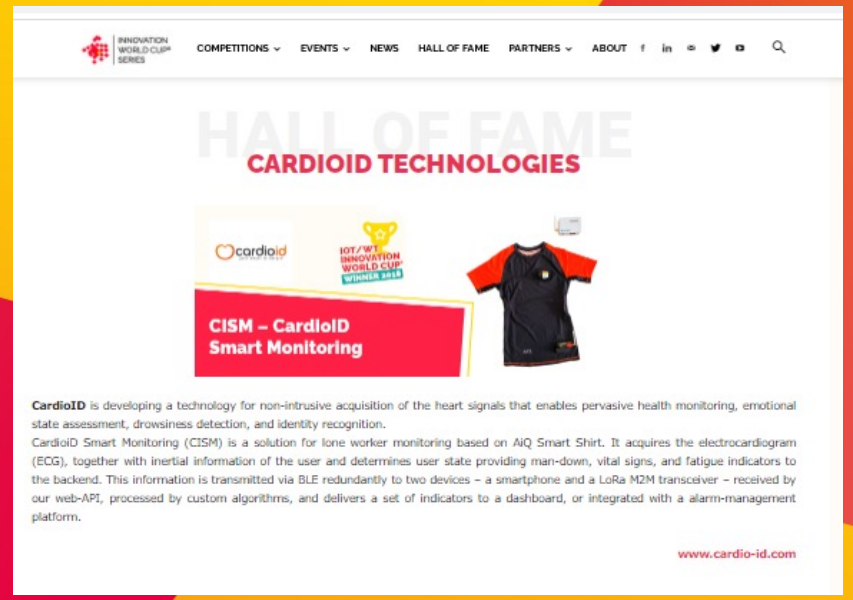
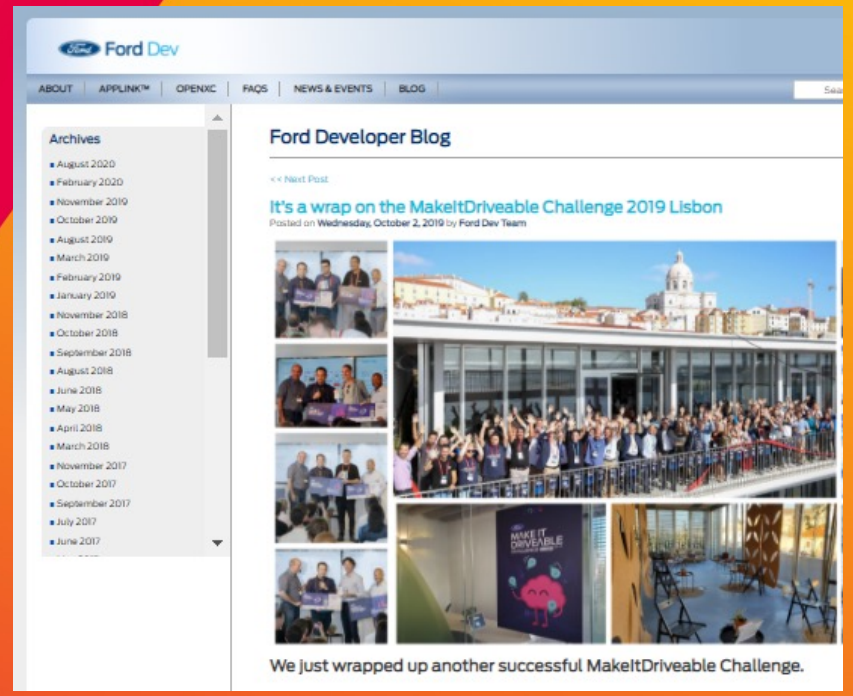
Awards

cardio id





News

cardio id

Top 5 Driver Monitoring Startups Impacting the Automotive Industry

startus INSIGHTS

February 2019

Sighthound | EDGE3 | Sober Steering | cardio id HEARTMETRICS EXPERTS | Optalert

This Heat Map illustrates the geographical distribution of 5 out of 200 driver monitoring startups disrupting the automotive industry.

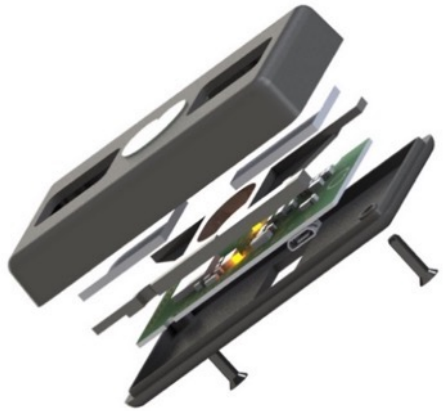
https://www.startus-insights.com/innovators-guide/top-5-out-of-200-driver-monitoring-startups-in-automotive/

CardioWheel

cardio4id

cardiowheel

Steering Wheel Cover



Embedded System

- **ECG-based biometrics**

security and user personalization

- **Fatigue detection**

fleet management for fatigue-related
driver performance

- **Wellbeing**

detection of abnormal changes on the heart signal

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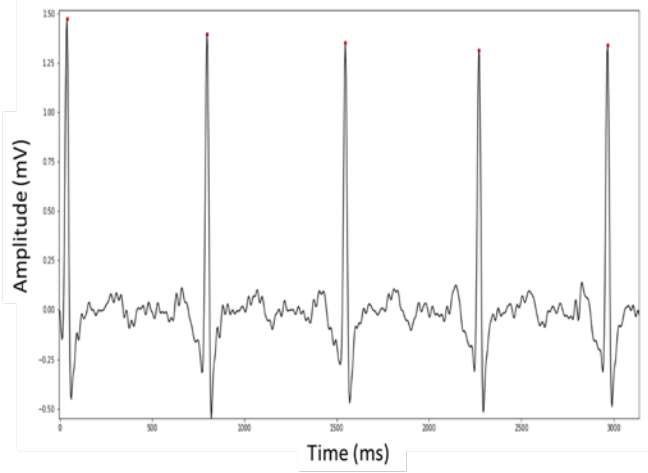
cardiowheel

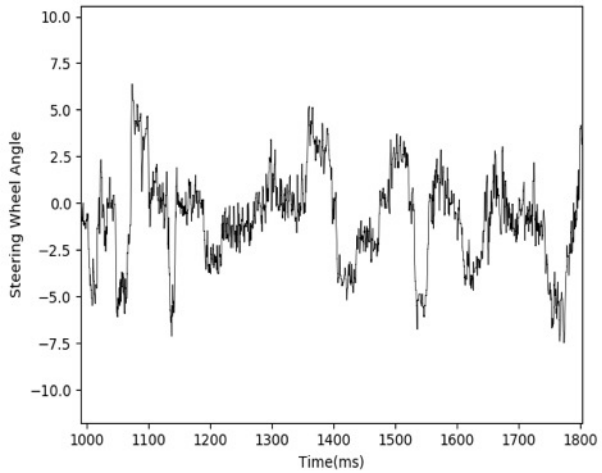
- Features:
  - ECG based-biometrics
  - Driver Physiological monitoring - Heart-rate variability (HRV)
  - Drowsiness indication based on Karolinska Sleepiness Scale (KSS) + Inertial Monitoring + Personalized Models
- Communication Interfaces
  - BLE

Driver drowsiness detection methods

ECG signal



SWA



Mobileye Events

Driver Behavior

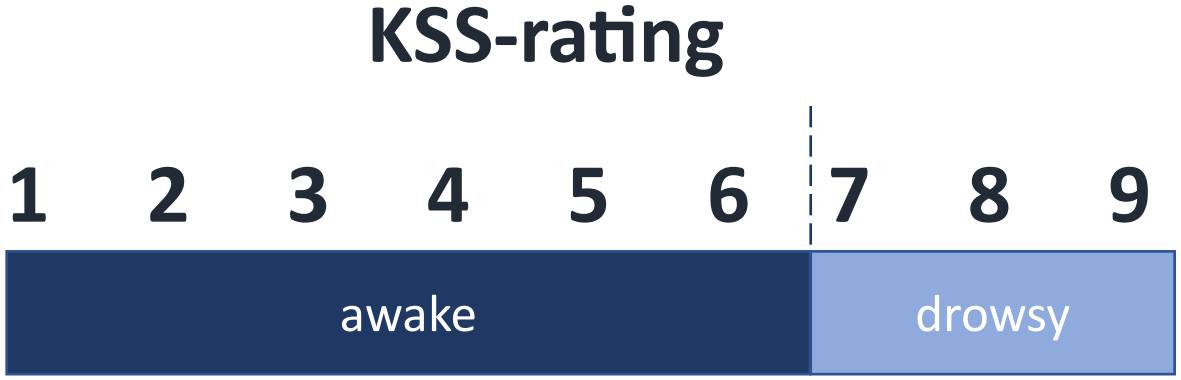
cardiowheel

MOBILEYE®

GEOTAB
management by measurement

Labels (Level of drowsiness)

Karolinska Sleepiness Scale	
1	Extremely alert
2	Very alert
3	Alert
4	Fairly alert
5	Neither alert nor sleepy
6	Some signs of sleepiness
7	Sleepy, but no effort to keep alert
8	Sleepy, some effort to keep alert
9	Very sleepy, great effort to keep alert, fighting sleep



This rating is given by the driver, using his perception of his level of drowsiness

Research Work

- Evolution, Current Challenges, and Future Possibilities in ECG Biometrics, IEEE Access'2018: https://ieeexplore.ieee.org/abstract/document/8392675
- Towards a Continuous Biometric System Based on ECG Signals Acquired on the Steering Wheel, *Sensors 2017*: https://www.mdpi.com/1424-8220/17/10/2228
- Driver drowsiness detection: a comparison between intrusive and non-intrusive signal acquisition methods, EUVIP'2018 (collaboration with VTI): https://ieeexplore.ieee.org/abstract/document/8611704
- Semi-Supervised Consensus Clustering for ECG Pathology Classification, *ECML/PKDD 2015:* https://link.springer.com/chapter/10.1007/978-3-319-23461-8_10

Dashboard – 360º Driving Overview

- Real-time alerts
- Driver identity recognition
- Hands on/off wheel

- Analytics & Reports
- Driver behavior
- Route/shift optimization based on driver health status

Collaborative Projects

Collaborative Projects

http://soul-fi.ipn.pt/
SOUL FI is a FIWARE accelerator aimed at selecting, funds and accelerate SMEs and web Entrepreneurs who developed innovative web-based solutions for smarter urban life of Europe's citizens.

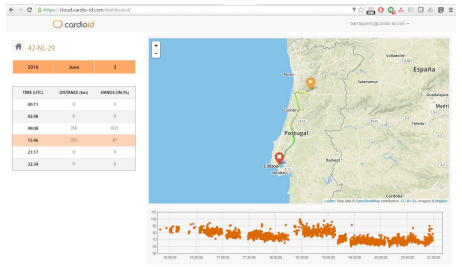
Project : CardioWheel Prototype

https://www.impact-accelerator.com/connected-car/
The program focused on the cars of the future, driverless transportation, connected cars, and innovative experiments in the auto industry.

Project : CardioWheel Prototype Validation

Implementation of CardioWheel Driver Change and Drowsiness Monitoring

Company: Rede Expresso, Grupo Barraqueiro



Collaborative Projects

AUTOmatic multiMOdal drowsiness detecTIon for smart Vehicles - AUTOMOTIVE

POCI-01-0145-FEDER-030707 -PTDC/EEI-EEE/30707/2017

Inesc-tec, CardioID, ISEL, Lusofona

FCT-COVID: DSAIPA/DS/0117/2020 Modelos de Previsão de Desenvolvimento da COVID-19 em Doentes de Risco para uma Medicina de Precisão

https://generationmobi.ceiia.com/

Funded by the **Portugal 2020 Funding Scheme**, Generation.Mobi is a research, development and validation project for a new generation dynamic mobility management system, based on the concept of a social network of interactive bicycles and interoperable with the city's ecosystem.

https://cardioleather.eu/

Funded by the **Portugal 2020 Funding Scheme**, CardioLeather is a research, development project for the creation of all the supply-chain of intelligent leather for biosignal acquisition and processing.

Collaborative Projects

https://idreamsproject.eu/wp/

A project financed by the **Horizon 2020 Program**, aims to create a platform to define, develop, test and validate a "Safety Tolerance Zone" to prevent drivers from exceeding driving limits, mitigating risks in real time and after the trip.
The i-DREAMS consortium is composed of 13 partners, researchers and companies, from 8 European countries.

https://valu3s.eu/

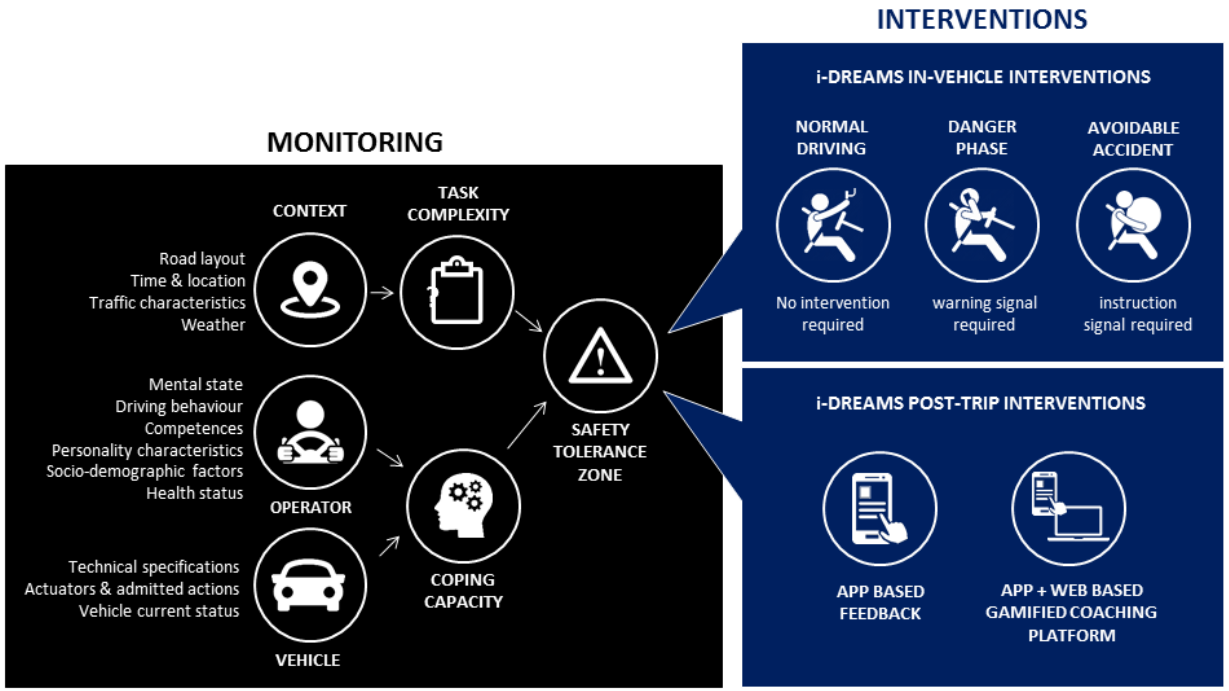
A project receiving funding from the ECSEL Joint Undertaking (JU) aiming to evaluate the state-of-the-art verification and validation (V&V) methods and tools, and design a multi-domain framework to create a clear structure around the components and elements needed to conduct the V&V process

From research to the Industry

iDREAMS Concept

H2020 i-DREAMS 81471-2 | Human Factors in Transport Safety

Setup a framework for the definition, development, testing and validation of **a context-aware 'safety tolerance zone' for on-road driving, within a smart Driver and Road Environment Assessment and Monitoring System**.



TECHNISCHE UNIVERSITÄT MÜNCHEN

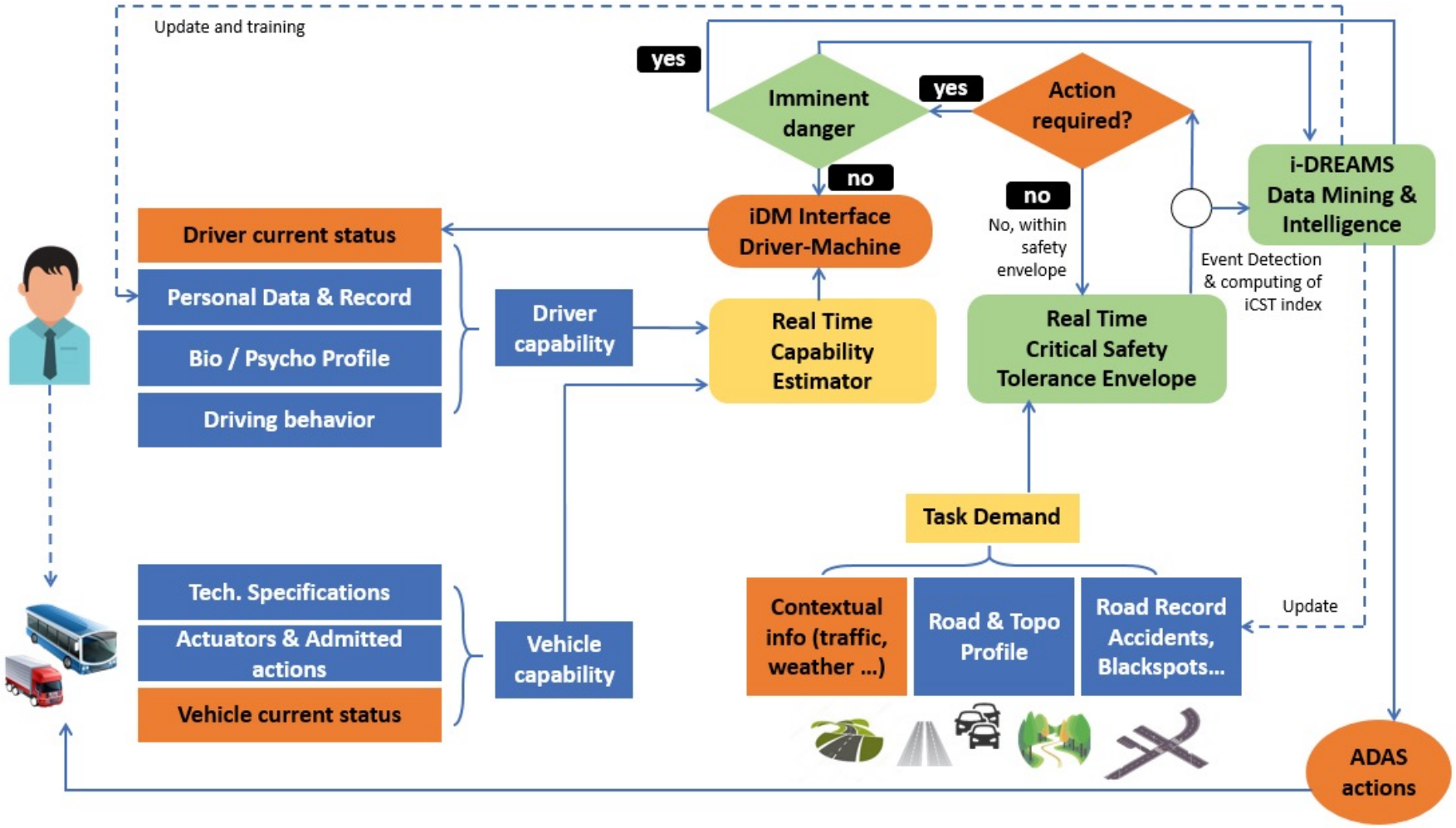
TU Delft Delft University of Technology

Loughborough University

imob TRANSPORTATION RESEARCH INSTITUTE UHASSELT

National Technical University of Athens

i-DREAMS Framework



cardio4id

Modes

Countries	Vehicles
	150
	75
	150
	75
	150

Edge Computer Device

- Communication Interfaces
  - 2 CAN interfaces [Mobileye + FMS]
  - Bluetooth (BLE/ BT)
  - LTE-4G
  - Wifi
  - GPS
- Sensors
  - Video CameraUVC
  - Inercial Unit (Accelerometer+ Gyroscpece)
- Computation capability
  - Quad core Cortex-A72 64-bit SoC @ 1.5GHz
  - Compatible with TPU compatible, e.g Google Coral
- FMS Connection
  - Driver ID
  - Ecodriving

Physiological Data Collection

- Features:
  - Driver Physiological monitoring
  - Heart-rate variability (HRV)
  - Drowsiness indication based on Karolinska Sleepiness Scale (KSS)
- Communication Interfaces
  - BLE

Test Vehicles

Valu3s use-case

Automotive

cardiowheel

HealthCare

Challenges to be solved

- Verify security and integrity of transmission model
- Test accuracy, reliability, and robustness of classification models under uncertainty and in un-cooperative environments; integration in simulator-based testing
- Formal specification and verification of functional and non-functional of embedded real-time properties related to safety and security
- Create a complete specification of the software to be deployed (a smaller version o CardioID's implementation using the MARS domain specification language being developed within the scope of VALU3S)
- Identify safety properties related to timing that can be observed and verified upon runtime of the system
- Formal cryptographic analysis to ensure proven-correct protocols being used

Potential V&V Methods

- HW-in-the-loop test to simulate the system behaviour when injecting test scenarios
- Faults in data transmission and their effects on performance. The experiments are to be done in driving simulator.
- **Other V&V methods and tools in analysis by VALU3S partners for this use case**

References

CardioID Affilitions/Partnership

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management by measurement

IMR TECHNOLOGIES
SAVING LIVES THROUGH INNOVATION

ituran
TECHNOLOGY DRIVEN BY PEOPLE

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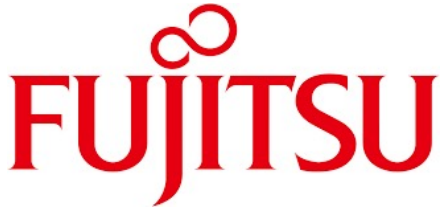
BARRAQUEIRO
TRANSPORTES, SA

ARVAL


FUJITSU

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Thank you.

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