VIBE PROJECT

Virtual Biomedical and STEM/STEAM Education

2021-1-HU01-KA220-HED-000032251

Funded by the European Union

Erasmus+

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

PÉCSI TUDOMÁNYEGYETEM UNIVERSITY OF PÉCS

U.PORTO

Politechnika Śląska

DEX innovation centre

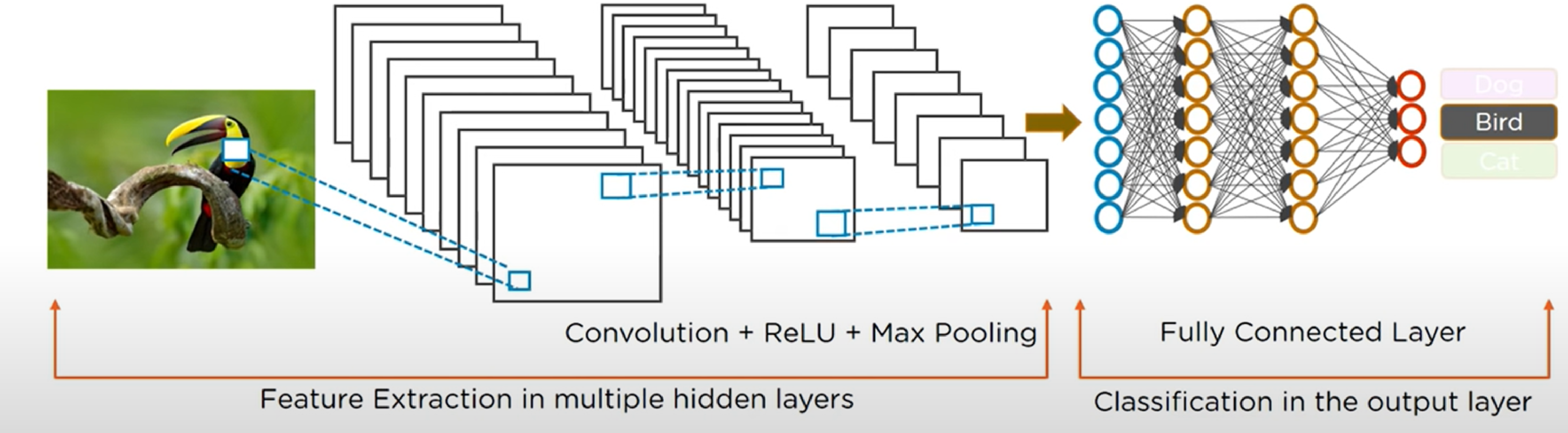
VIBE PROJECT

PATTERN RECOGNITION IN BIOMEDICAL ENGINEERING

ADVANCED TECHNIQUES IN PATTERN RECOGNITION - FROM FEATURES TO RECOGNITION SYSTEMS

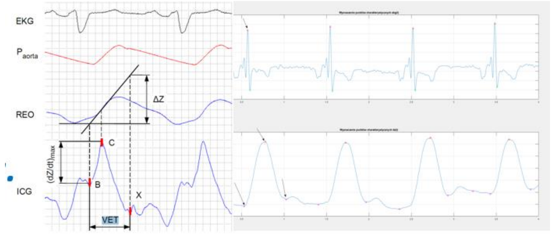
The total process of object recognition using CNNs

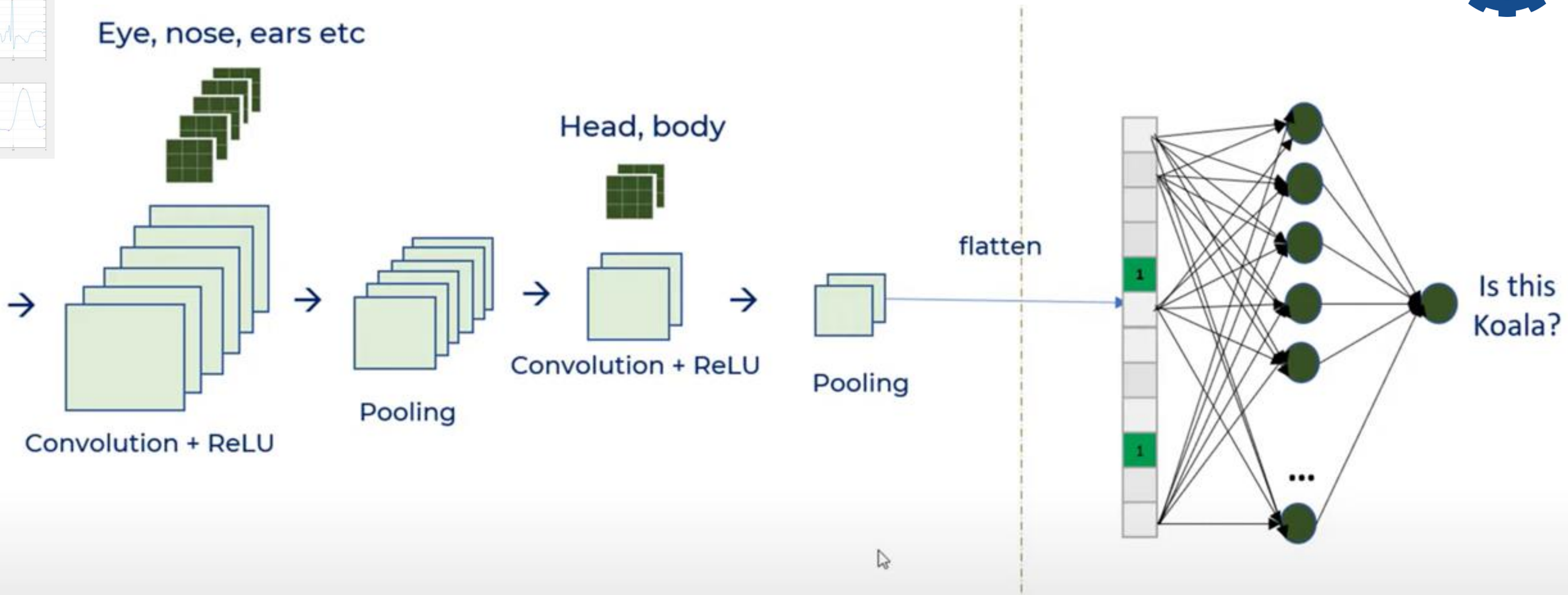
Lets see the entire process how CNN recognizes a bird



Source: https://medium.com/ml-cheat-sheet/convolutional-neural-networks-186870efbf71

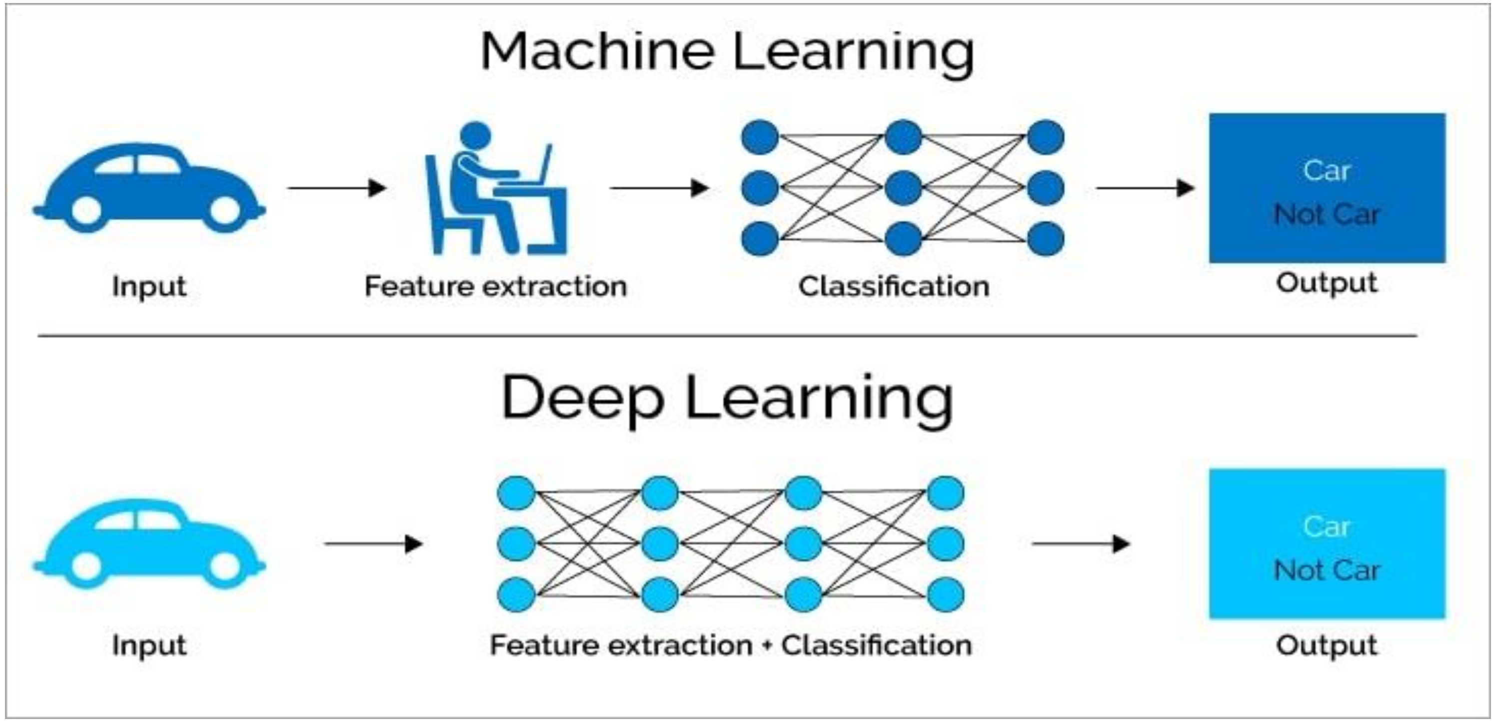
Total process of object recognition using CNNs





Source: https://medium.com/ml-cheat-sheet/convolutional-neural-networks-186870efbf71

Barn owl or apple? This example indicates how challenging learning from samples is – even for machine learning.
Source: https://viso.ai/deep-learning/deep-learning-vs-machine-learning/



Source: https://levity.ai/blog/difference-machine-learning-deep-learning

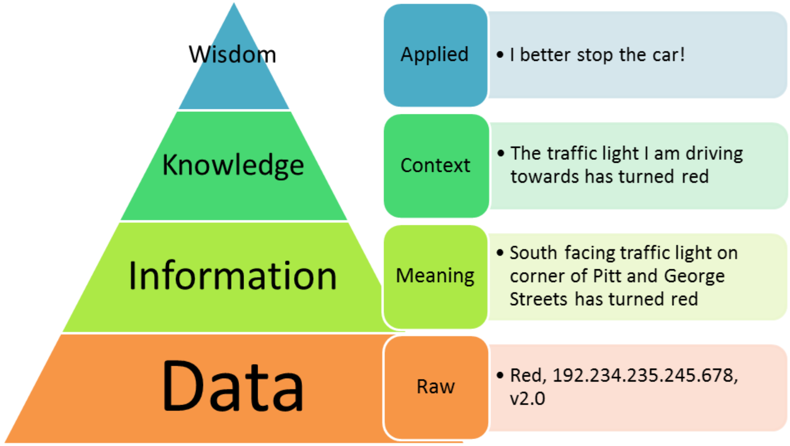
In deep neural networks (DNN), knowledge is abstractly represented by weights (numbers) in the context of the problem being analyzed.

Agenda

- Short intro (*back to the past.. *): why digital? ..signal processing (DSP),

- Our tools from DSP - How we can 'look at' signals in digital form and process them:
  - Time domain methods (→ T_Features)
  - Frequency domain methods (→ F_Features)
  - Time-Frequency domain methods (→ T-F_Features)

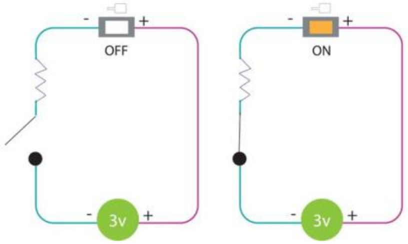
- Use cases from the area of modern Biomedical Engineering:
  - Different application examples but a common 'denominator', which are DSP methods



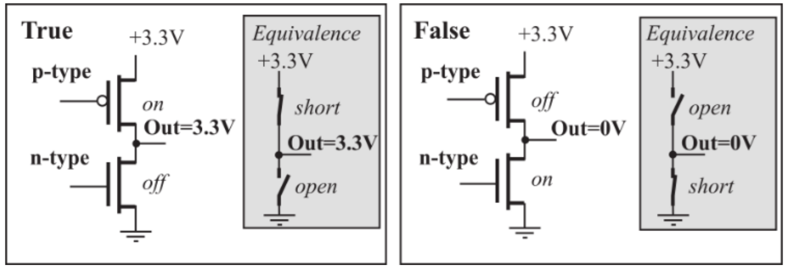
Source: https://youthgrowth.in/dikw-data-information-knowledge-and-wisdom/

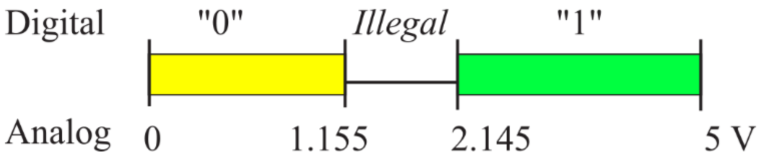
Intro: but why ‚digital' processing? …

Technology :
Only two electrical states to store: 0/1, H/L, T/F
(On/Off; H/L, 1/0, +U/GND)



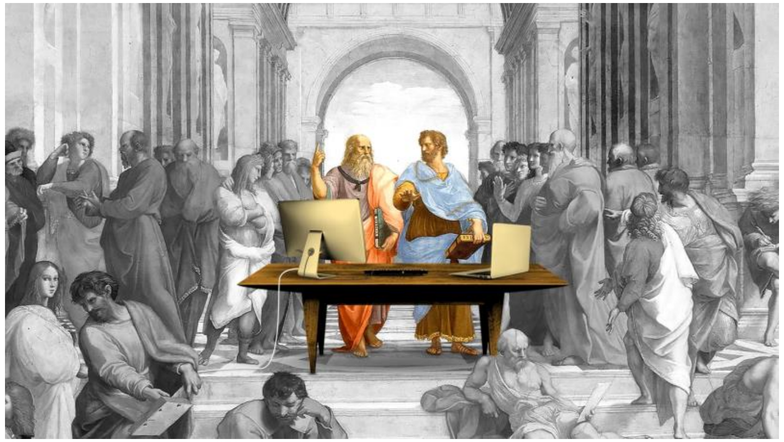
Computers store all information as a sequence of 0 i 1



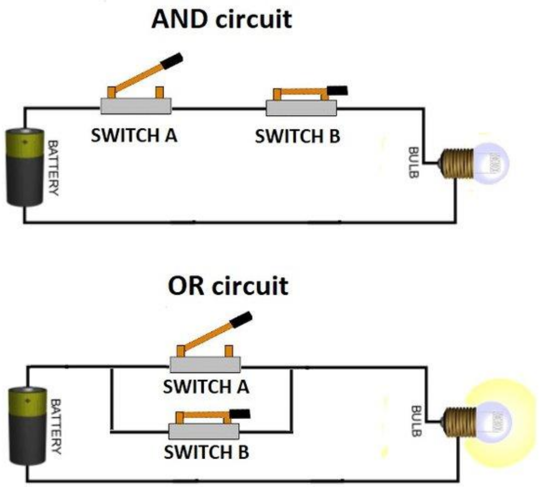


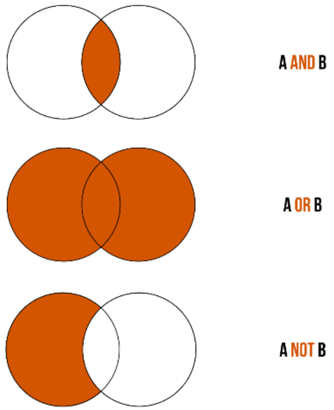
Source: Original work by the author.

Two level LOGIC development (T/F) – a discipline of science much older than mathematics and goes back to the very beginnings of European science, namely ancient Greece. Even then, it was already performing as a basic tool of philosophical thinking.

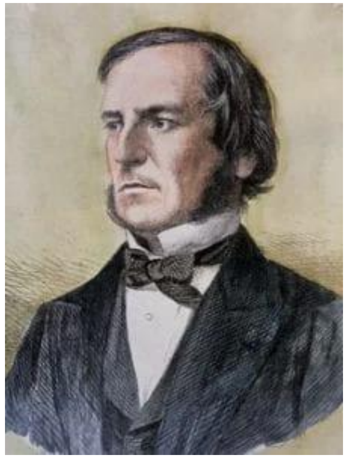


Source: How Aristotle Created the Computer





Boole'a Algebra



Source: https://pl.wikipedia.org/wiki/Algebra_Boole%E2%80%99a

has been valid and in use since the idea of the first computers in the 1930s, 1940s until today …

Alan Turing

A genius ahead of the era

- In the 1930s he laid the foundations of theoretical computer science with binary 0/1 data representation,
- He defined the term: "computation" ,
- He proposed a computational model called the Turing machine.

What did he have at his disposal at that time ...?

- *A sheet of paper,*
- *A pencil and ...*
- *??*

Source: https://en.wikipedia.org/wiki/Alan_Turing

He created the concept of a computer, with binary 0/1 data representation, which according to its basic principle still works today (of course, technology has made great progress).

Alan Turing, 1933-1936,

What can an abstract man count with his own head, a piece of paper, an eraser and a pencil.

a brilliant mathematician, cryptologist …

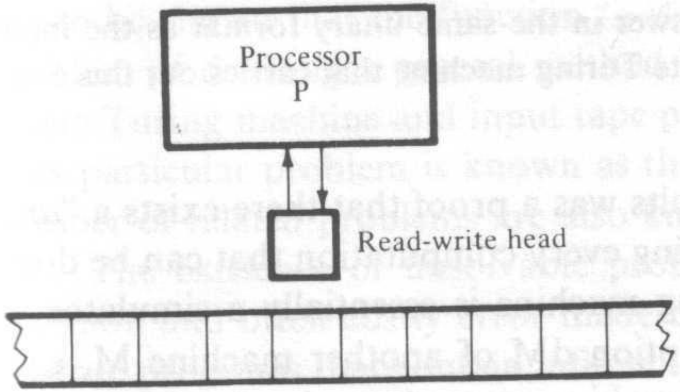


FIGURE 1.2
A Turing machine.

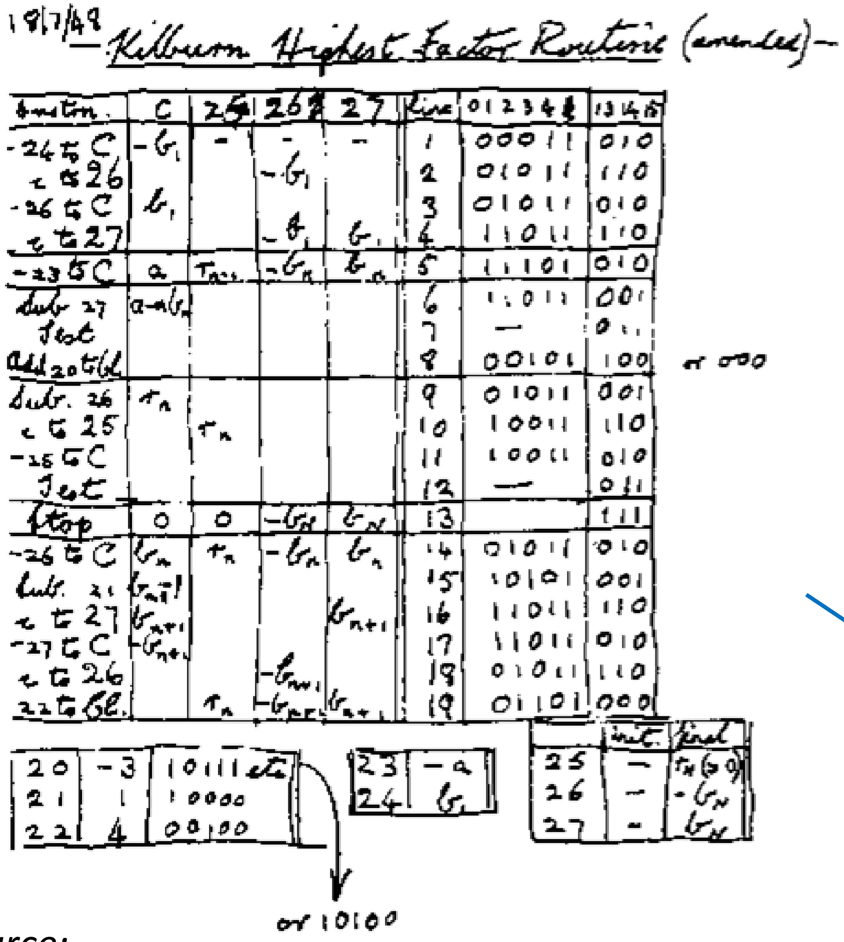
$$b\ \underbrace{1\,1\cdots1}_{n_1}\ b\ \underbrace{1\,1\cdots1}_{n_2}\ b$$

Instruction				Comments
s_0	b	R	s_0	
s_0	1	R	s_1	Move read-write head to right across n_1
s_1	1	R	s_1	
s_1	b	1	s_2	Replace blank between n_1 and n_2 by 1
s_2	1	L	s_3	Move read-write head to left
s_3	1	L	s_3	
s_3	b	R	s_4	End of 1s reached; backspace
s_4	1	b	s_5	Delete leftmost 1
s_5	b	H	s_0	$n_1 + n_2$ now on tape

FIGURE 1.3
A Turing machine program to add two unary numbers.

Source: https://en.wikipedia.org/wiki/Alan_Turing

SMALL-SCALE EXPERIMENTAL MACHINE



Source: *https://it.wikipedia.org/wiki/Small_Scale_Experimental_Machine*

SSEM (another name for Baby) is the first computer based on the von Neumann technique mentioned earlier. For the first time in history on this computer ran a program stored in its memory (June 21, 1948) this program was created by Tom Kilburn – one of the first Programmers ☺ (his manuscript can be seen in the photo).

The creators, the "geniuses" of computer science wrote the first programs directly in the machine language of the computer: 0110 0101 .

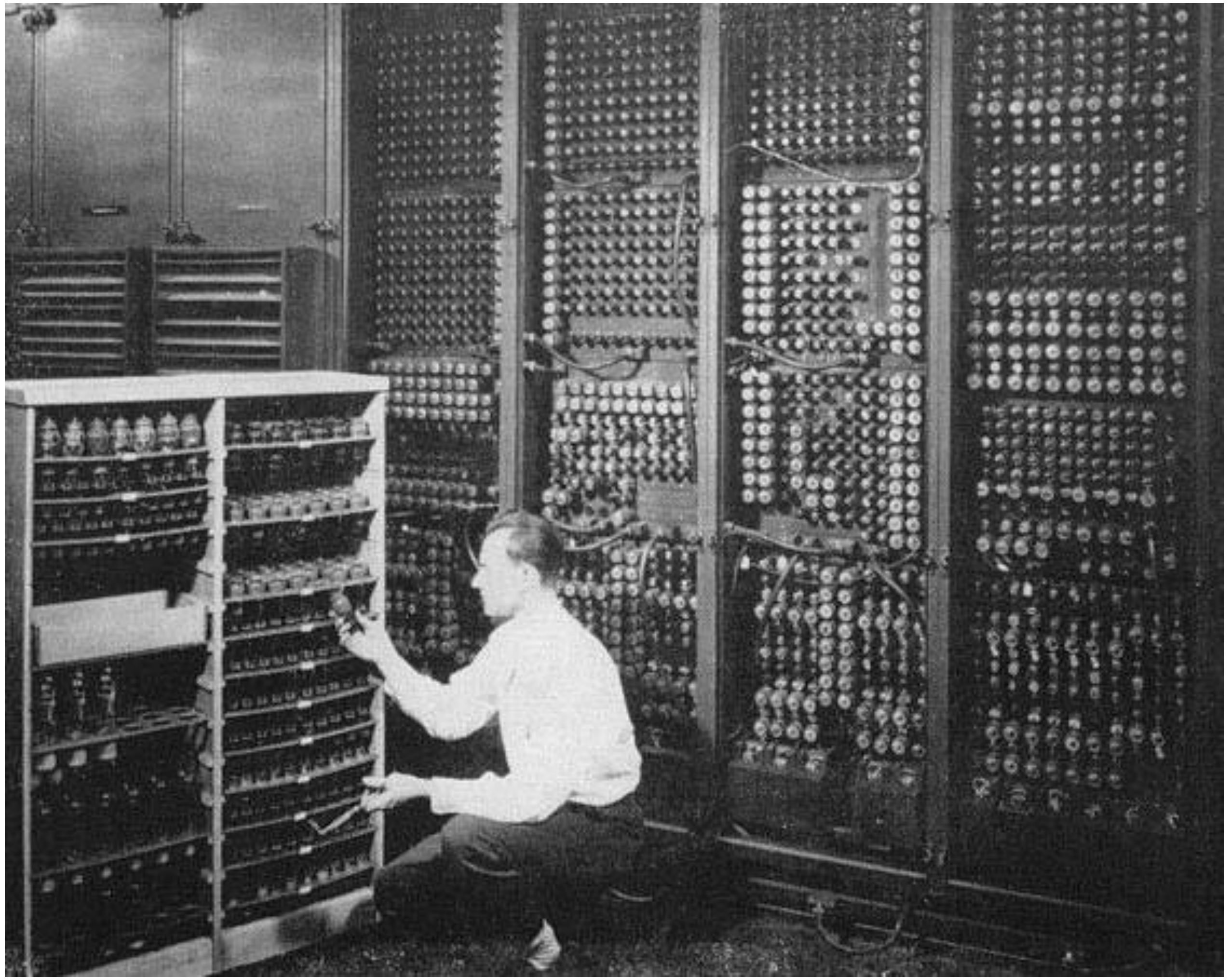
See the brief history of programming languages:

https://www.youtube.com/watch?v=mhpslN-OD_o

ENIAC 1944

ENIAC 1944 - one of the first computers

(not to be confused with calculators, shown earlier - a computer works according to a program, it is programmed and performs a set of tasks specified by a human)

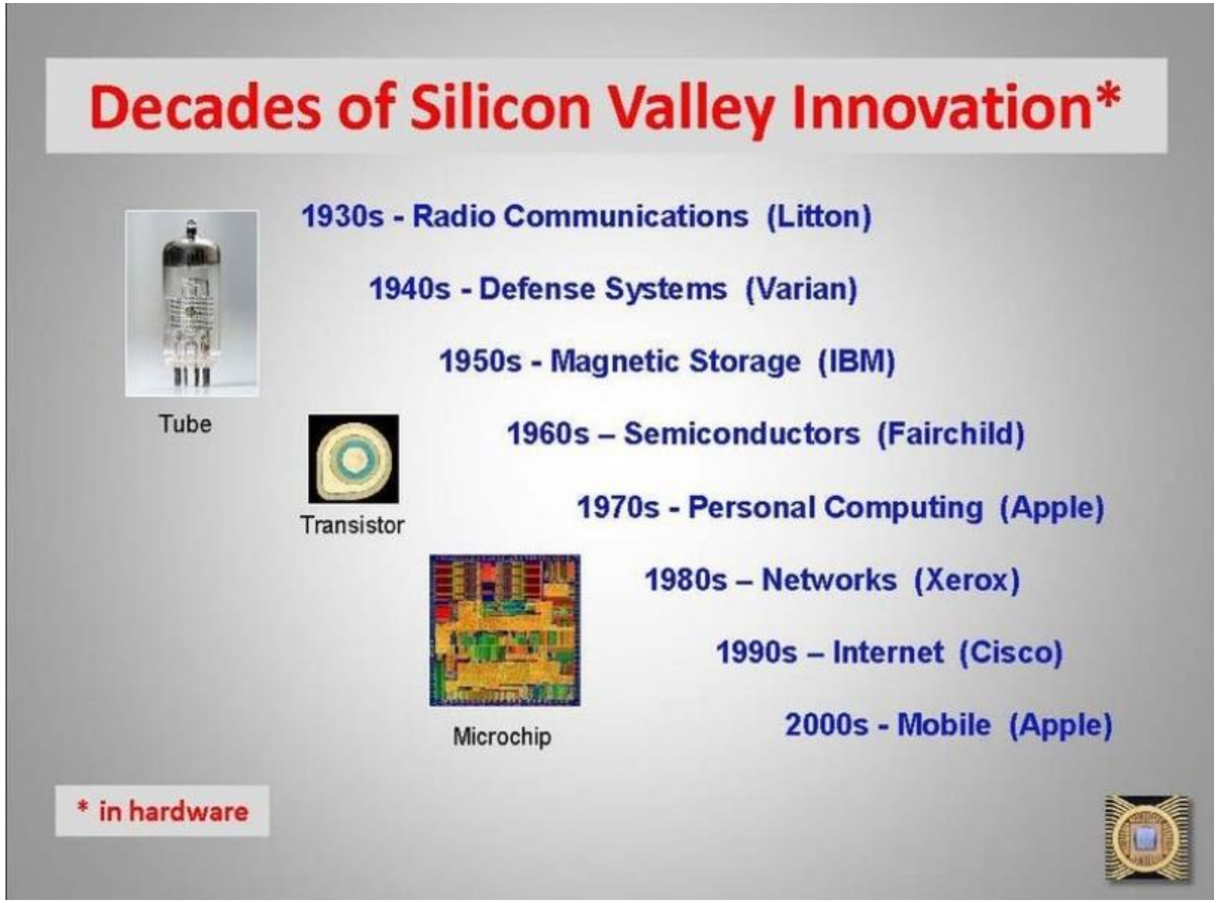


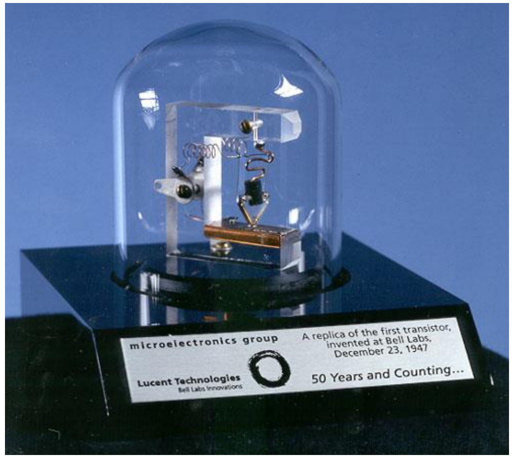
12 x 6 m
30 tons
70,000 resistors
10 000 capacitors
6,000 switches
18,000 el. lamps
100,000 operations/s

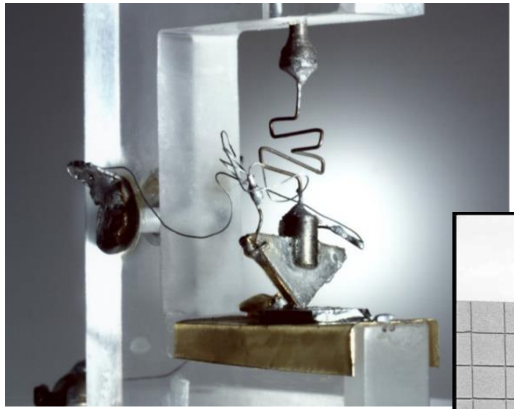
Source: https://en.wikipedia.org/wiki/ENIAC

Erasmus+
VIBE PROJECT
Silesian University of Technology

Silicon revolution: semiconductors, TRANSISTORS enable to ‚store' 0/1, H/L







Souce: John Bardeen, William Shockley and Walter Brattain at Bell Labs, 1948

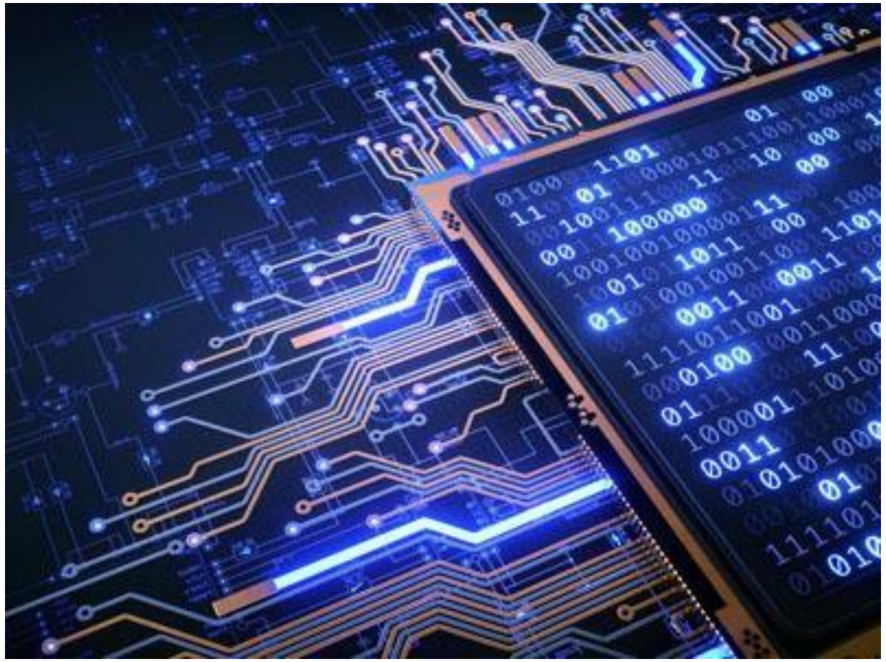
https://www.pbs.org/wgbh/americanexperience/features/silicon-timeline-silicon/
https://computerhistory.org/blog/silicon-valley-a-century-of-entrepreneurial-innovation/

Source: https://en.wikipedia.org/wiki/History_of_the_transistor

Semiconductor scientists and engineers hold a secret meeting at San Francisco's Clift Hotel to discuss forming their own firm, under the leadership of Robert Noyce. The men would come to be known as the "Traitorous Eight."

For a computer, any information (data, image, sound, char, graphic, etc.)

is a NUMBER !!



Source: https://www.istockphoto.com/pl/obrazy/binary-numbers

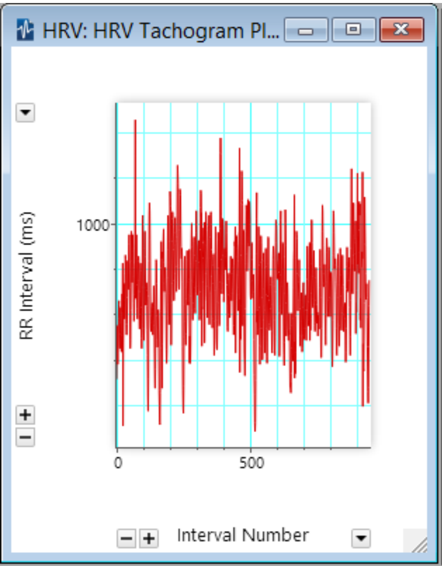
Therefore, they are created to implement mathematical algorithms in discrete form,

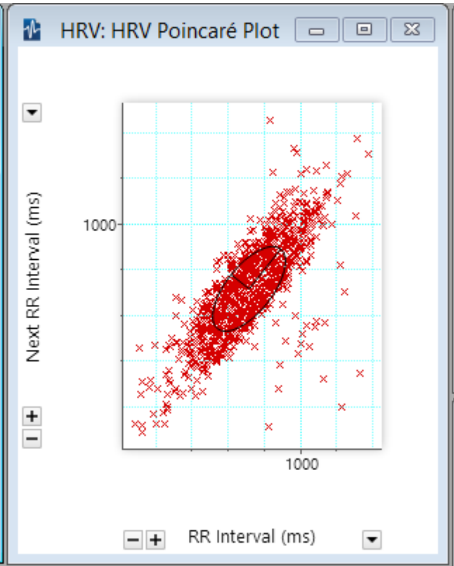
that is: DSP - Digital Signal Processing methods → Features .

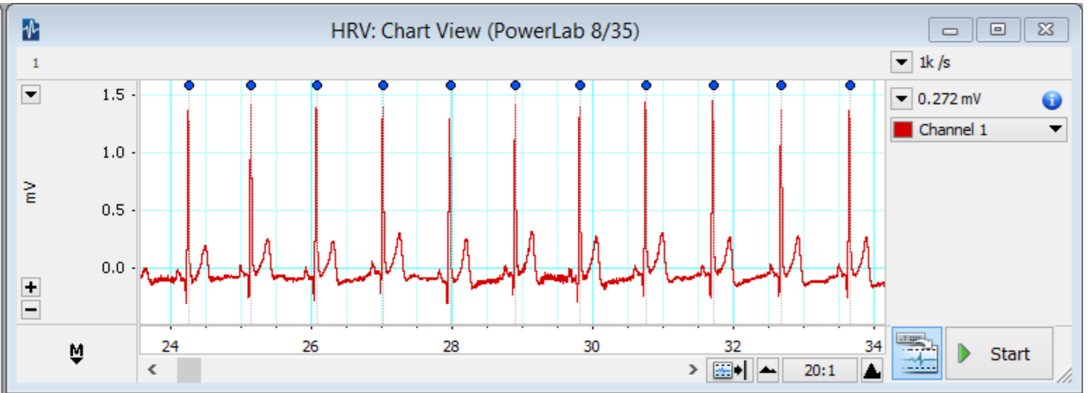
Erasmus+ Silesian University of Technology

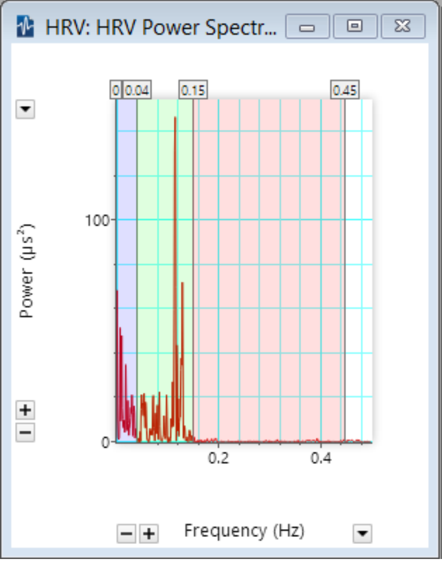
Methods: T, F, T-F signal representation to look at the digital signals from different perspectives

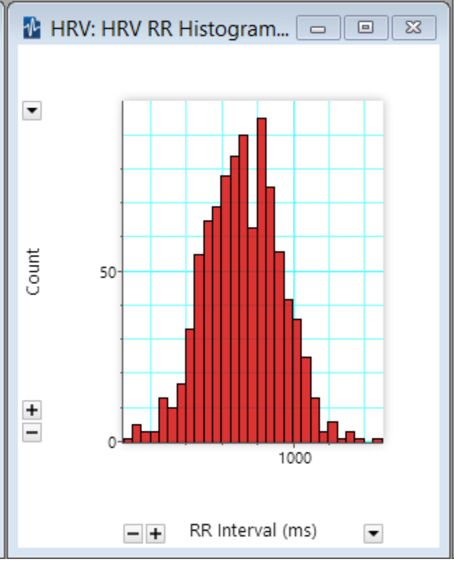
Heart Rate Variability (HRV) complex example – *how many important diagnostic features can we calculate!*











HRV: HRV Report

GENERAL

Analysis Start	Block: 1, 0 s
Analysis End	Block: 1, 15:00
Total Included Beats	946
Included Normal Beats	946
Included Ectopic Beats	0

TIME-DOMAIN

Average RR	944 ms
Median RR	944 ms
SDRR	42.16 ms
SDARR	7.206 ms
CVRR	0.04466
Average Rate	63.69 BPM
SD Rate	2.863 BPM
SDSD	28.49 ms
RMSSD	28.47 ms
pRR50	4.017 %

FREQUENCY-DOMAIN

VLF Band	0 - 0.04 Hz
LF Band	0.04 - 0.15 Hz
HF Band	0.15 - 0.45 Hz

Band	Power(µs²)	Power(%)	Power(nu)
Total	1856		
VLF	536.1	28.89	
LF	1202	64.76	91.07
HF	101.6	5.476	7.7
LF/HF		11.83	

NONLINEAR

SD1	20.14 ms
SD2	56.12 ms

Source: Original work by the author

VIBE PROJECT

Erasmus+

VIBE PROJECT VR Meets Healthcare

Silesian University of Technology

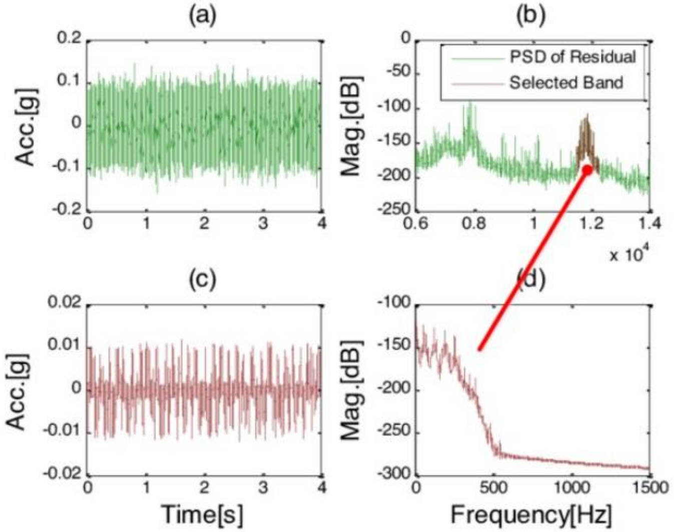
Methods: T, F, T-F signal representation to look at the digital signals from different perspectives

December, 21, 1807

"An arbitrary function, continuous or with discontinuities, defined in a finite interval by an arbitrarily capricious graph can always be expressed as a sum of sinusoids"

J.B.J. Fourier

Jean B. Joseph Fourier
(1768-1830)



How Does FT Work Anyway?

- Recall that FT uses complex exponentials (sinusoids) as building blocks.

$$e^{j\omega t} = \cos(\omega t) + j\sin(\omega t)$$

- For each frequency of complex exponential, the sinusoid at that frequency is compared to the signal.
- If the signal consists of that frequency, the correlation is high → large FT coefficients.

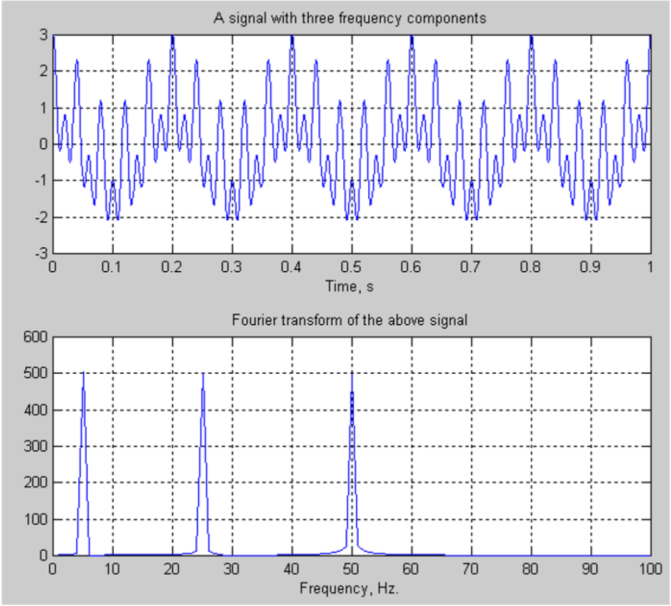
$$F(\omega) = \int f(t) e^{-j\omega t} dt \qquad f(t) = \frac{1}{2\pi} \int F(\omega) e^{j\omega t} d\omega$$

- If the signal does not have any spectral component at a frequency, the correlation at that frequency is low / zero, → small / zero FT coefficient.

FT At Work

$$x_4(t) = \cos(2\pi \cdot 5 \cdot t) + \cos(2\pi \cdot 25 \cdot t) + \cos(2\pi \cdot 50 \cdot t)$$

$$x_4(t) \xleftrightarrow{\mathcal{F}} X_4(\omega)$$



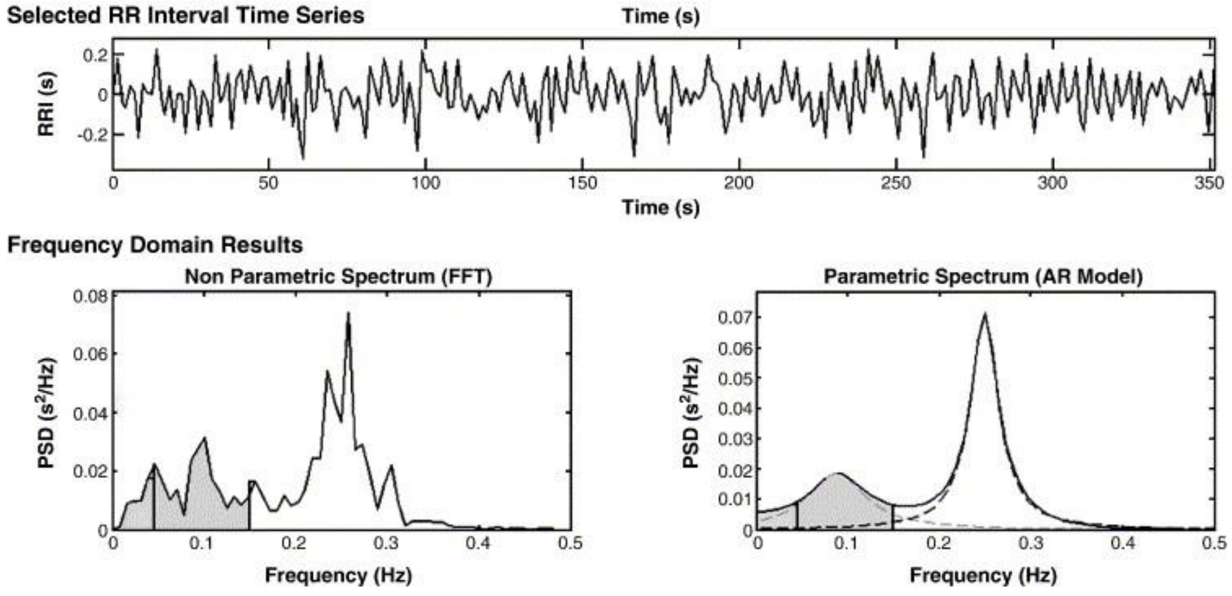
Source: Original work by the author

Mathematics and (~~Digital~~) Signal Processing have been developing for centuries....

Methods: T, F, T-F signal representation to look at the digital signals from different perspectives

Comparison of time domain and

frequency domain HRV signal representation.



https://www.sciencedirect.com/science/article/abs/pii/S0022073605002293

Methods: T, F, T-F signal representation to look at the digital signals from different perspectives

T-F hybrid representation employing the Wavelet Transform

The Wavelet Transform

- Overcomes the preset resolution problem of the STFT by using a variable length window
- Analysis windows of different lengths are used for different frequencies:
  - Analysis of high frequencies → Use narrower windows for better time resolution
  - Analysis of low frequencies → Use wider windows for better frequency resolution
- This works well, if the signal to be analyzed mainly consists of slowly varying characteristics with occasional short high frequency bursts.
- Heisenberg principle still holds!!!
- The function used to window the signal is called ***the wavelet***

The Wavelet Transform

Translation parameter, measure of time

Scale parameter, measure of frequency

A normalization constant

Signal to be analyzed

$$CWT_x^{\psi}(\tau,s) = \Psi_x^{\psi}(\tau,s) = \frac{1}{\sqrt{|s|}} \int_t x(t)\psi^*\left(\frac{t-\tau}{s}\right)dt$$

Continuous wavelet transform of the signal *x(t)* using the analysis wavelet ψ(.)

The mother wavelet. All kernels are obtained by translating (shifting) and/or scaling the mother wavelet

Scale = 1/frequency

Methods: T, F, T-F signal representation to look at the digital signals from different perspectives

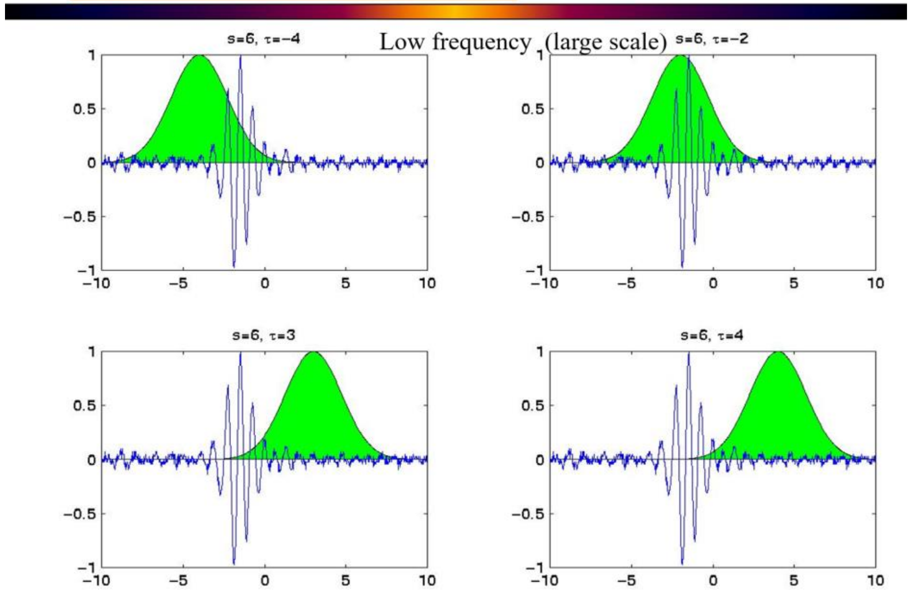
T-F hybrid representation employing the Wavelet Transform

The wavelet transform is like a microscope with adjustable focus:

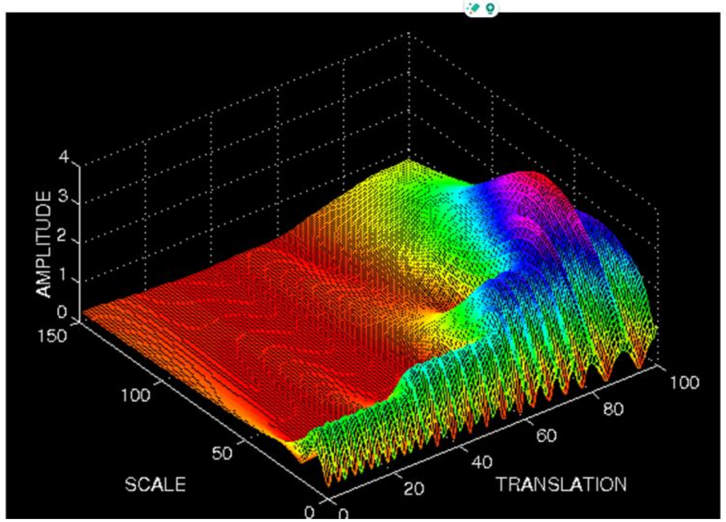
- ➢ *to see both "forest" and "trees"*

$$CWT_x^{\psi}(\tau,s)=\Psi_x^{\psi}(\tau,s)=\frac{1}{\sqrt{|s|}}\int_t x(t)\psi^*\left(\frac{t-\tau}{s}\right)dt$$

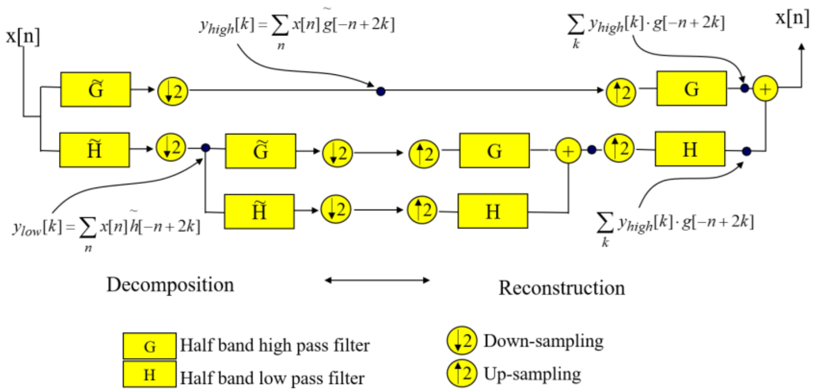
WT AT WORK



WT AT WORK



DISCRETE WAVELET TRANSFORM IMPLEMENTATION



2-level DWT decomposition. The decomposition can be continues as long as there are enough samples for down-sampling.

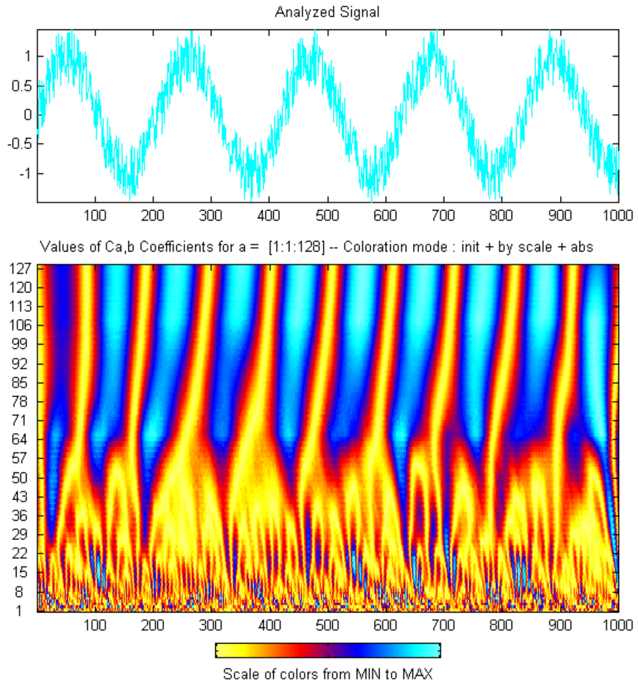
Source: Original works by the author

Development of the wavelet-neural systems (WNS) for classification and identification of chosen biomedical events.

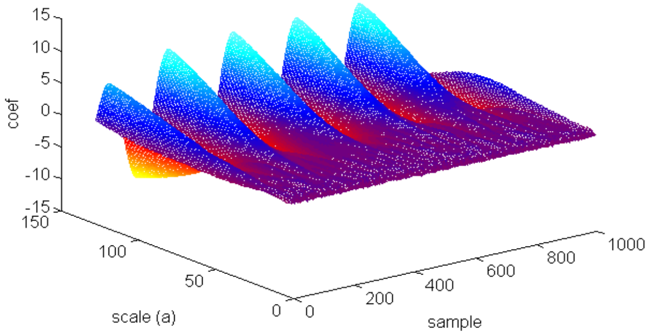
Paweł Kostka, Ph.D. project: 1996-2000,

Promoter: prof. Ewaryst Tkacz

prof. Ewaryst Tkacz



WT signal decomposition examples.



Source: Original work by the author

Methods & case: T, F, T-F signal representation to look at the digital signals from different perspectives

T-F hybrid representation employing the Wavelet Transform for HRV analysis.

An improvement of unsupervised hybrid biomedical signal classifiers by optimal feature extraction in system preliminary layer .

Paweł Kostka, Ewaryst Tkacz

Silesian University of Technology, Institute of Electronics
Division of Biomedical Electronics
Gliwice, Poland

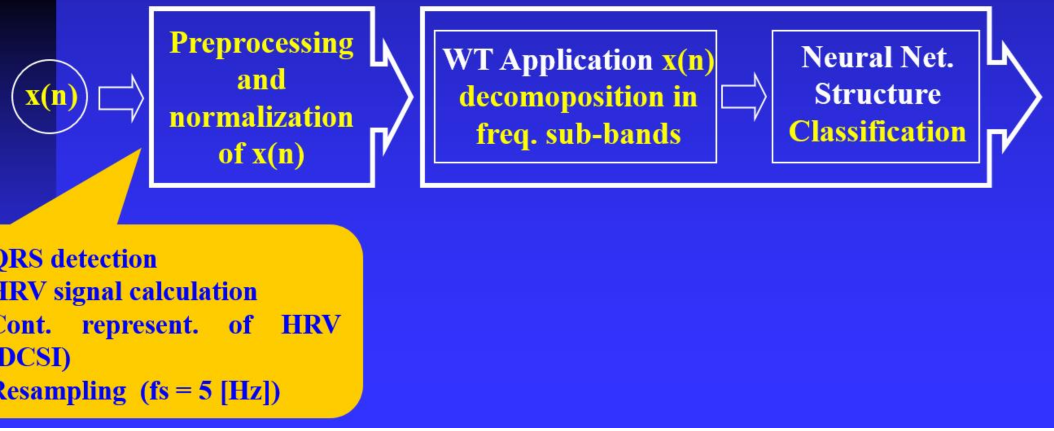
26th Annual International Conference
IEEE Engineering in Medicine and Biology Society (EMBS)
September 1-5, 2004, San Francisco California.

HYBRID SYSTEMS

- Hybrid systems combine different Artifficial Intelligence (AI) methods:
  - ❑Neural Networks
  - ❑Genetics Algorithms
  - ❑Fuzzy Sets
  - ❑Other signal processing methods

to be able do deal with complex biomedical systems.

GENERAL STRUCTURE OF WAVELET – NEURAL SYSTEM



Source: Original works by the author

Methods & case ☺: T, F, T-F signal representation to look at the digital signals from different perspectives

T-F hybrid representation employing the Wavelet Transform for HRV analysis.

New feature vector creation

Energy of wavelet component

$$E_{1,j}\{c_{i,j}\} = (c_{i,j})^2 \Rightarrow E1_{1,j}\{s(n)\} = \sum_i (c_{i,j})^2$$

The (non-normalized) Shannon entropy:

$$E_{2,j}\{c_{i,j}\} = -(c_{i,j})^2 \log(c_{i,j})^2 \Rightarrow$$

$$E_{2,j}\{s(n)\} = -\sum_i \left[(c_{i,j})^2 \log(c_{i,j})^2\right]$$

The concentration in l^P norm with $1<p<2$.

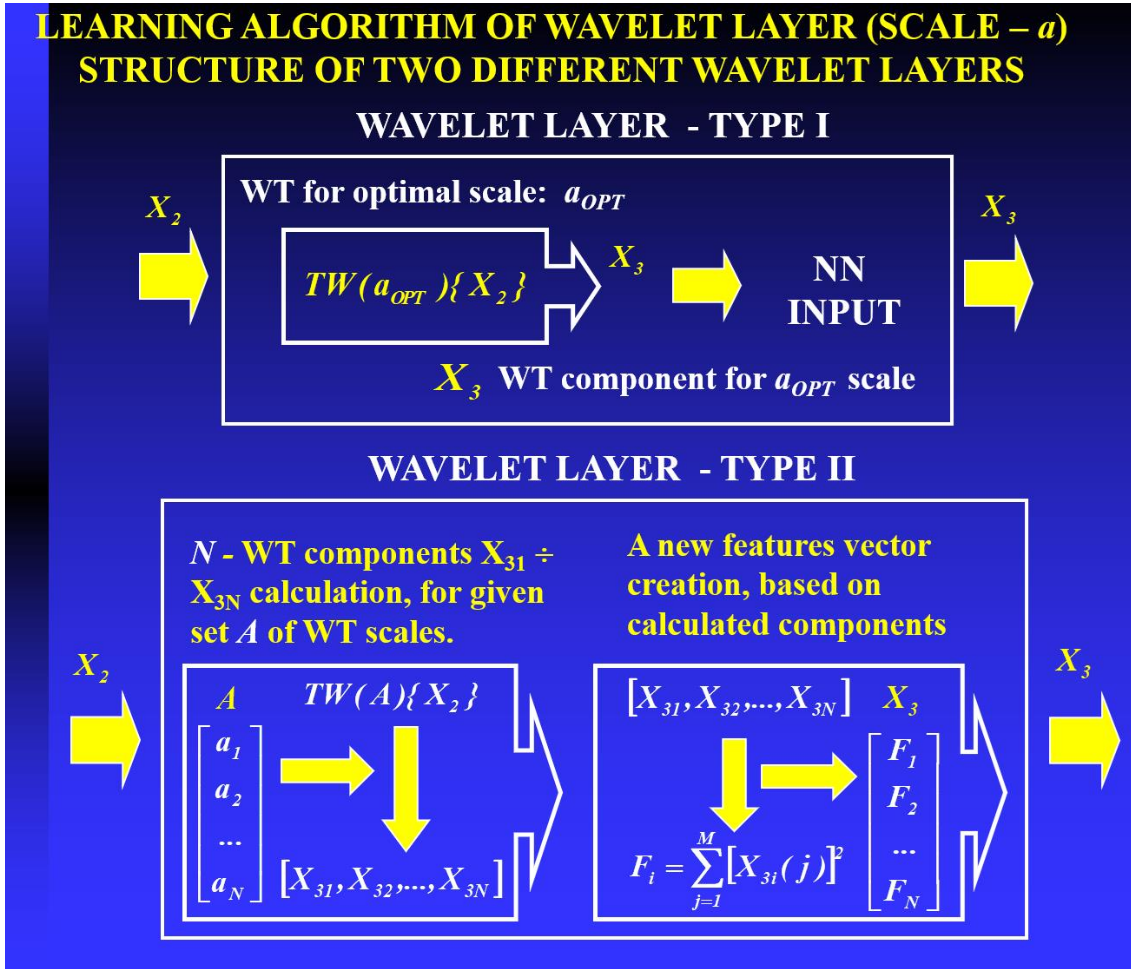
$$E_{3,j}\{c_{i,j}\} = |c_{i,j}|^P \Rightarrow$$

$$E_{3,j}\{s(n)\} = \sum_i |c_{i,j}|^P = \|s(n)\|_P^P$$

The logarithm of the “energy” entropy.

$$E_{4,j}\{c_{i,j}\} = \log(c_{i,j})^2 \Rightarrow$$

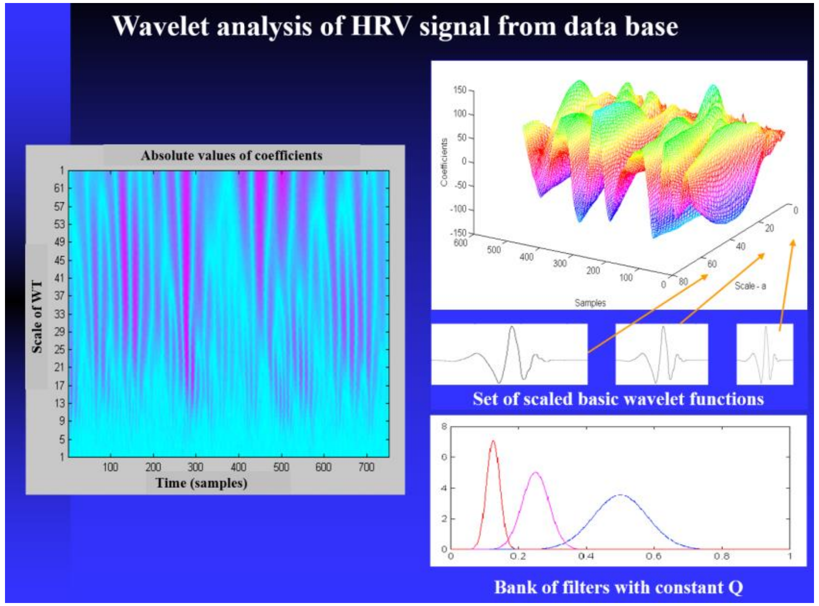
$$E_{4,j}\{s(n)\} = \sum_i \log(c_{i,j})^2$$

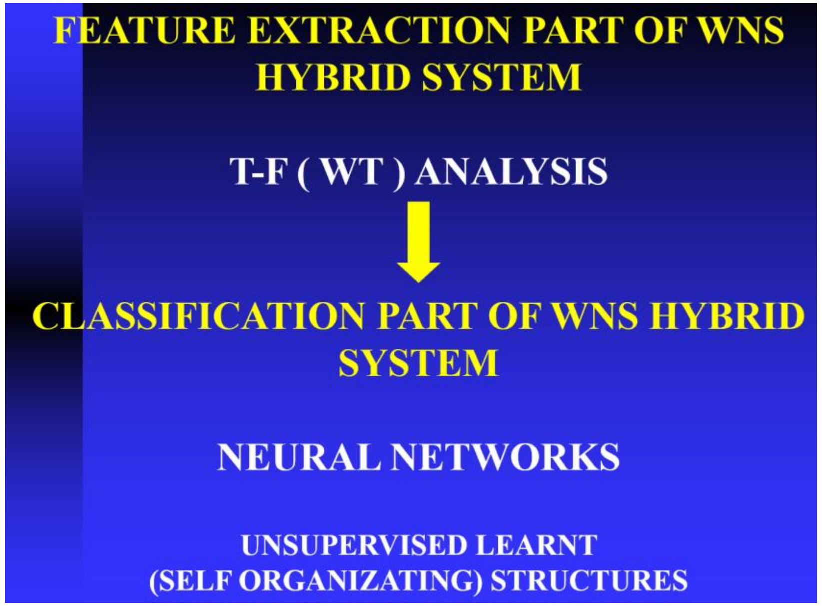


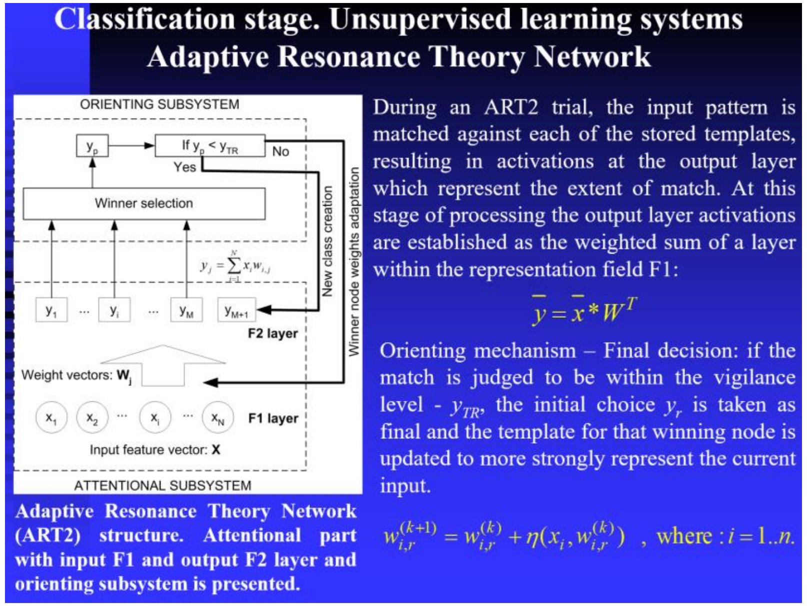
Source: *Original works by the author*

Methods & case: T, F, T-F signal representation to look at the digital signals from different perspectives

T-F hybrid representation employing the Wavelet Transform for HRV analysis of patients with Coronary Artery Disease.







Source: Original works by the author

Methods & case : T, F, T-F signal representation to look at the digital signals from different perspectives

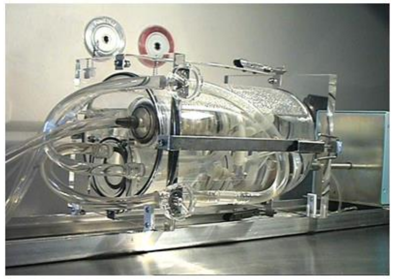
T-F hybrid representation employing the Wavelet Transform for biomedical curves modeling.

Case: Modelling of the Heart Valve Prostheses (HVP) Flow Q, based on pressures: P_{IN} & P_{OUT} during valve test.

DRIVER UNIT

Pneumatic driving wave

VALVE TESTER



MOCK CIRCULATORY SYSTEM

VALVE IN QUALIFICATION TESTER

OBJECT OF TESTED VALVE PROSTHESES

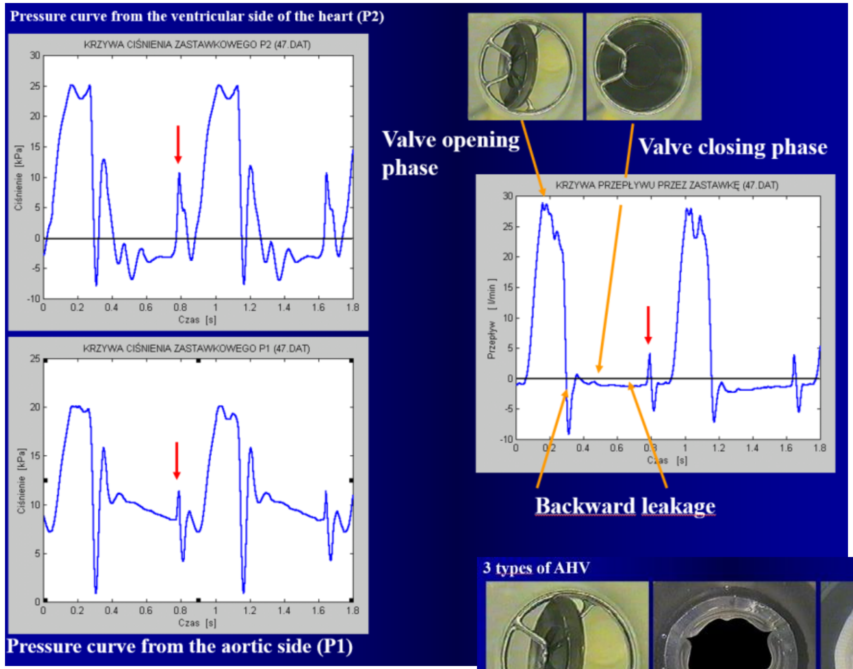
Results analysis
Test card of valve prostheses

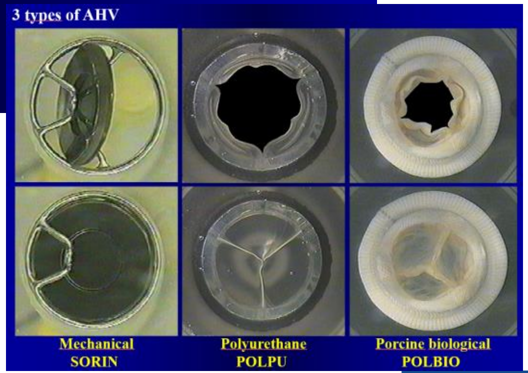
TEST RESULTS

- recorded pressure and flow signals: *P(t), Q(t)*
- video records of valve performance during test

Valve passport (parameters)

- **Back-flow**
- **Pressure gradient**
- **Openning area**





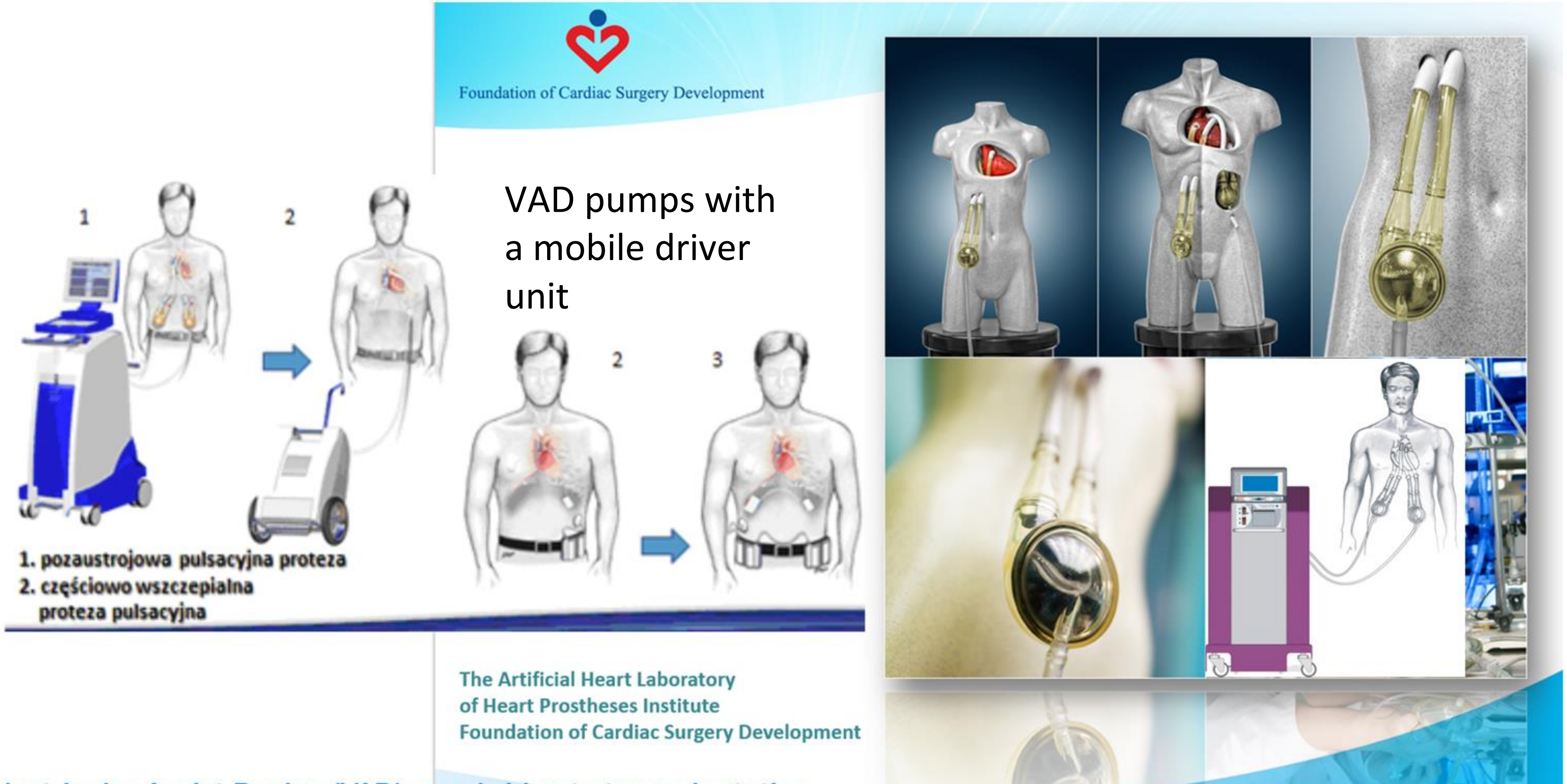
Source: Original works by the author

Methods & case ☺: T, F, T-F signal representation to look at the digital signals from different perspectives

T-F hybrid representation employing the Wavelet Transform for detection of characteristic points of VAD control curves.

Institute of Heart Prostheses (Foundation for Cardiac Surgery Development)

Source: www.frk.pl



Ventricular Assist Device (VAD) as a bridge to transplantation

VIBE PROJECT

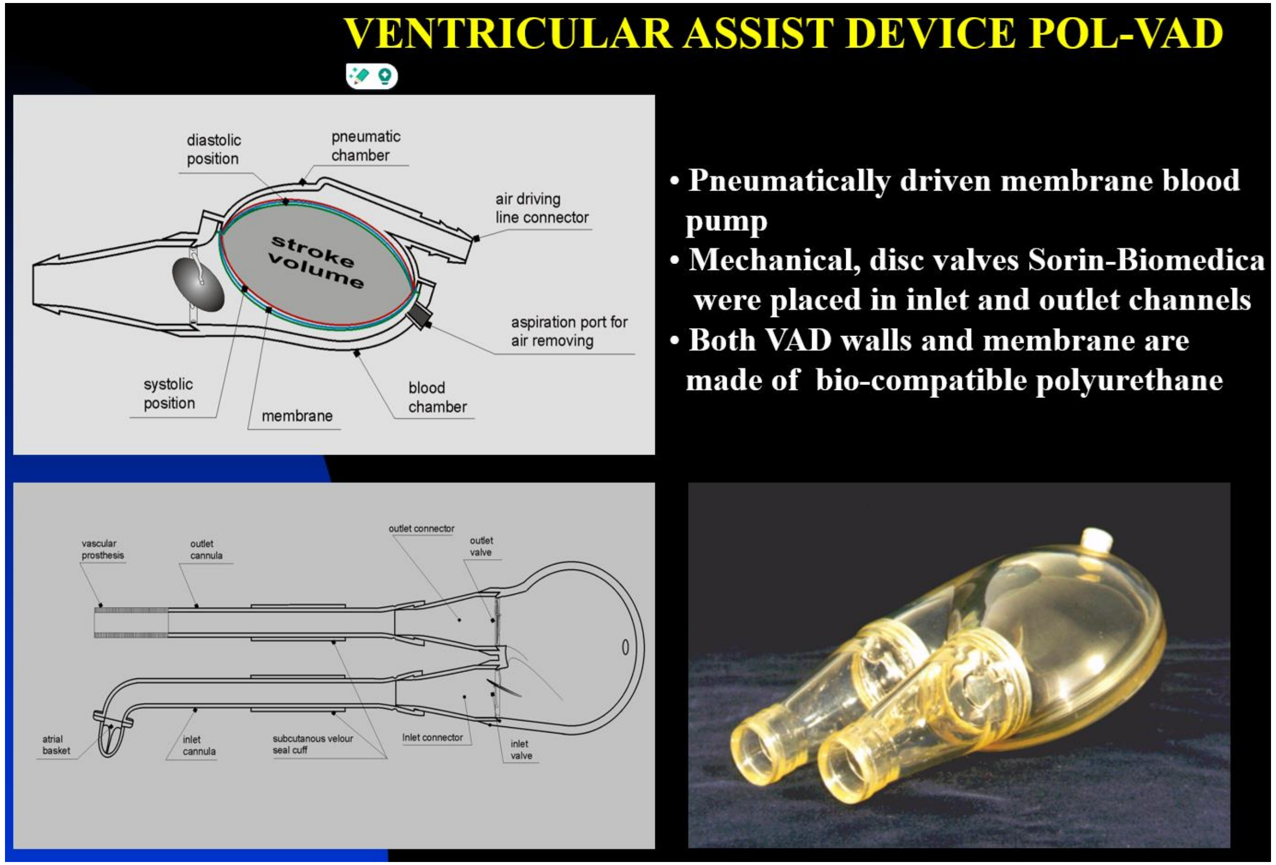
Erasmus+

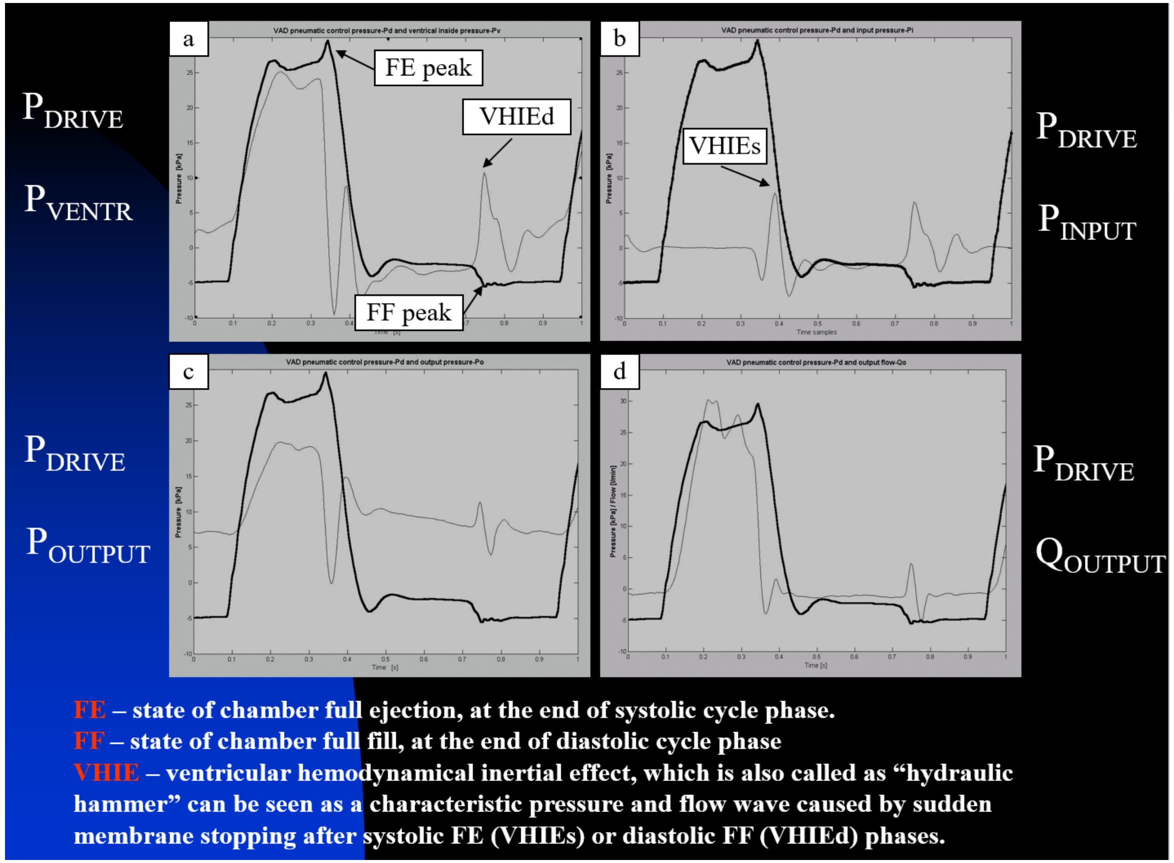
Silesian University of Technology

Methods & case ☺: T, F, T-F signal representation to look at the digital signals from different perspectives

T-F hybrid representation employing the Wavelet Transform for detection of characteristic points of VAD control curves.

It is very important in the VAD control process (***the hydraulic pump is controlled by a pneumatic wave - compressible***)





Source: Original works by the author

Methods & case ☺: T, F, T-F signal representation to look at the digital signals from different perspectives

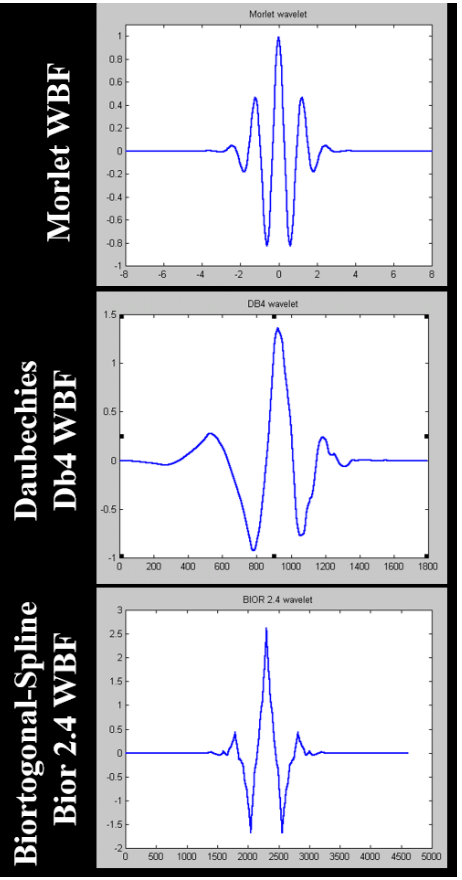
T-F hybrid representation employing the Wavelet Transform for detection of characteristic points of VAD control curves.

It is very important in the VAD control process (***the hydraulic pump is controlled by a pneumatic wave - compressible***)

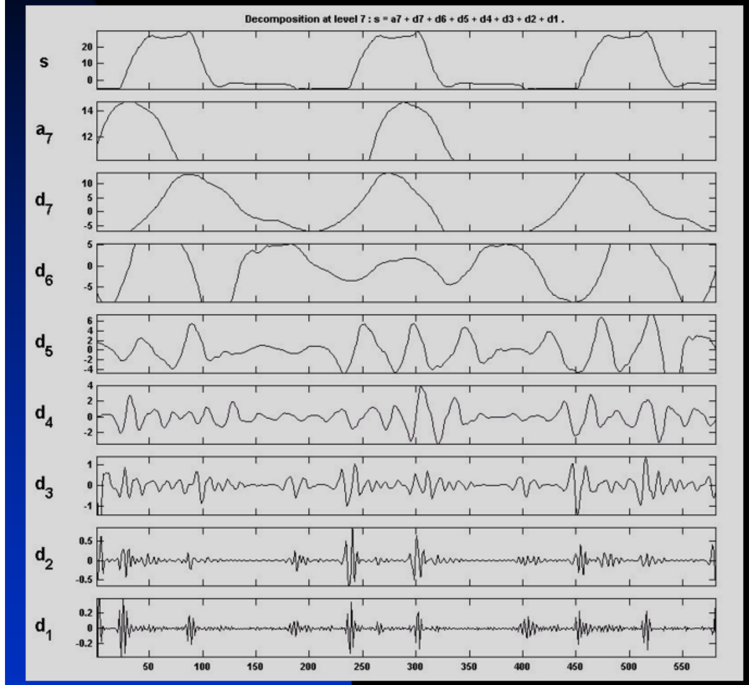
Wavelet Transform →
Basic function selection

Main features of WBF:

- **Ortogonality**
- **Biortogonality**
- **Compact support**
- **Symmetry**
- **Regularity and smoothness**
- **Number of vanishing moments**
- **Analytical formula of basic function**
- **Interpolation**
- **Rational coefficients**



MULTILEVEL, WAVELET DECOMPOSITION OF VAD DRIVEN SIGNAL P_D, ACCORDING TO MALLAT ALGORITHM.



FREQUENCY SUB-BANDS RANGE

(based on frequency analysis of pressure and flow signals)

d_2 : 31.25 ÷ 62.5 [Hz]
d_3 : 15.63 ÷ 31.25 [Hz]
d_4 : 7.81 ÷ 15.63 [Hz]
d_5 : 3.90 ÷ 7.81 [Hz]
d_6 : 1.95 ÷ 3.90 [Hz]
d_7 : 0.98 ÷ 1.95 [Hz].

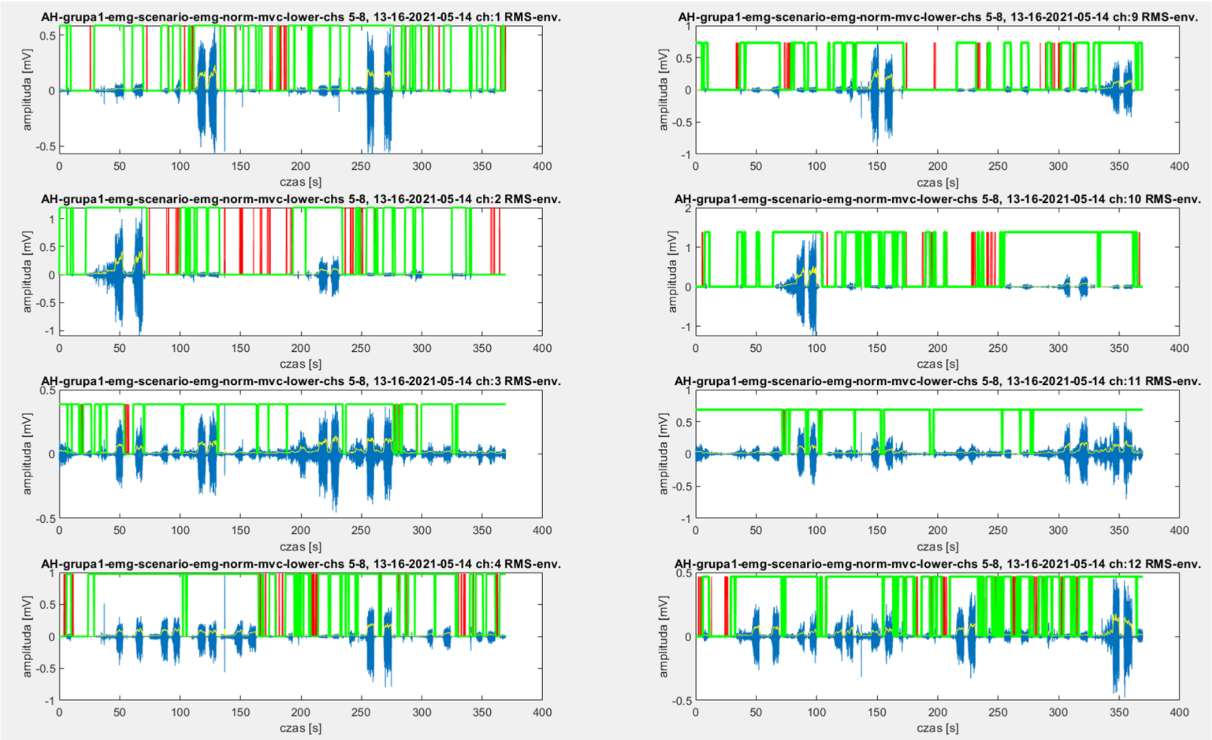
key peaks proved easier to classify e.g. from the D2 component,

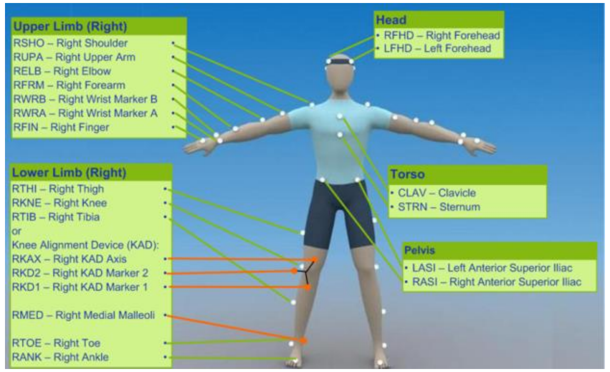
Source: Original works by the author

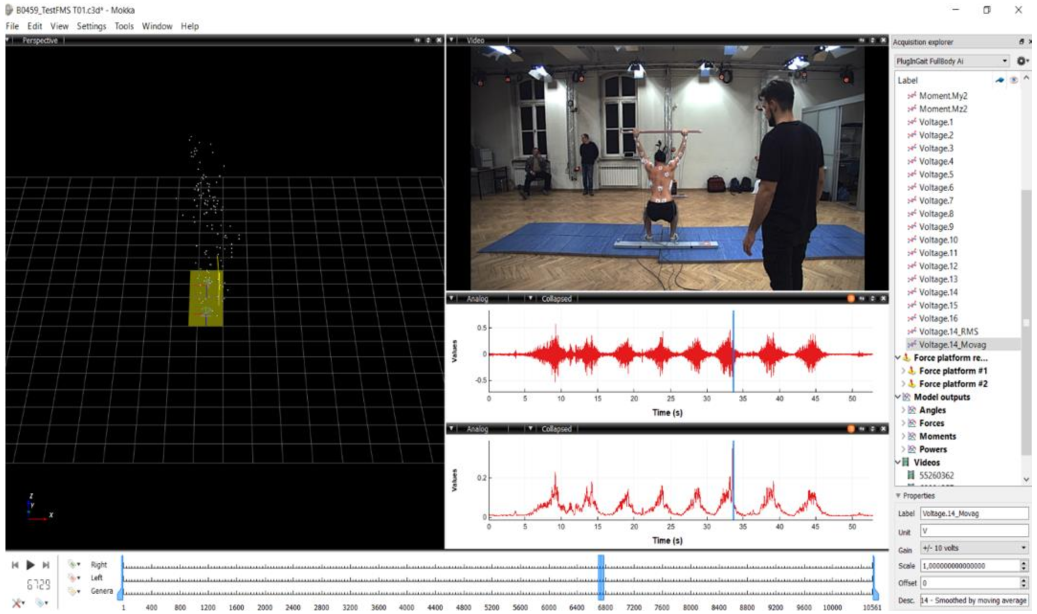
Use case (Each of the following cases is a separate story ☺ and project) :

EMG(t) signal on-line analysis from real-time measurements, during the examination of a group of professional athletes. *Toward predictive detection of possible injury*.

- T, F, T-F multimodal biomedical signal processing,
- emg(t) filtration with an optimized filter cascade;
- development of an algorithm for determining causal muscle activity;







VIBE PROJECT

Erasmus+

Source: Original works by the author

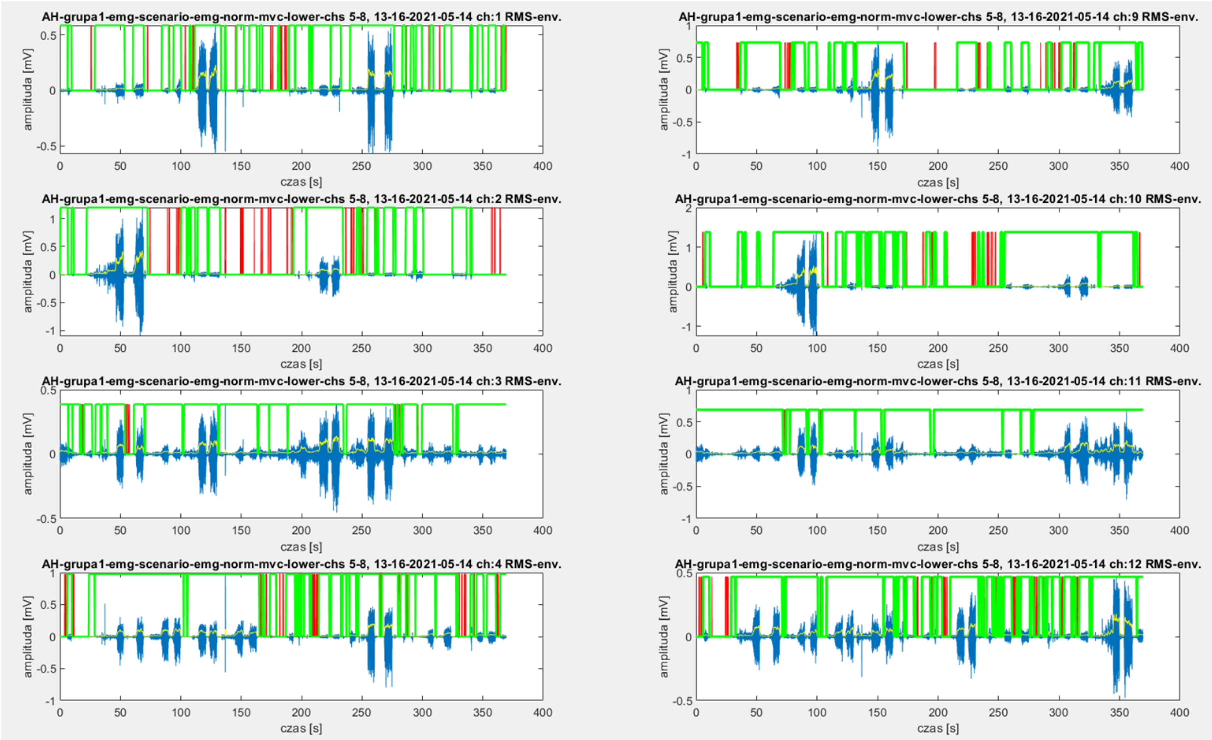
Use case (Each of the following cases is a separate story ☺ and project) :

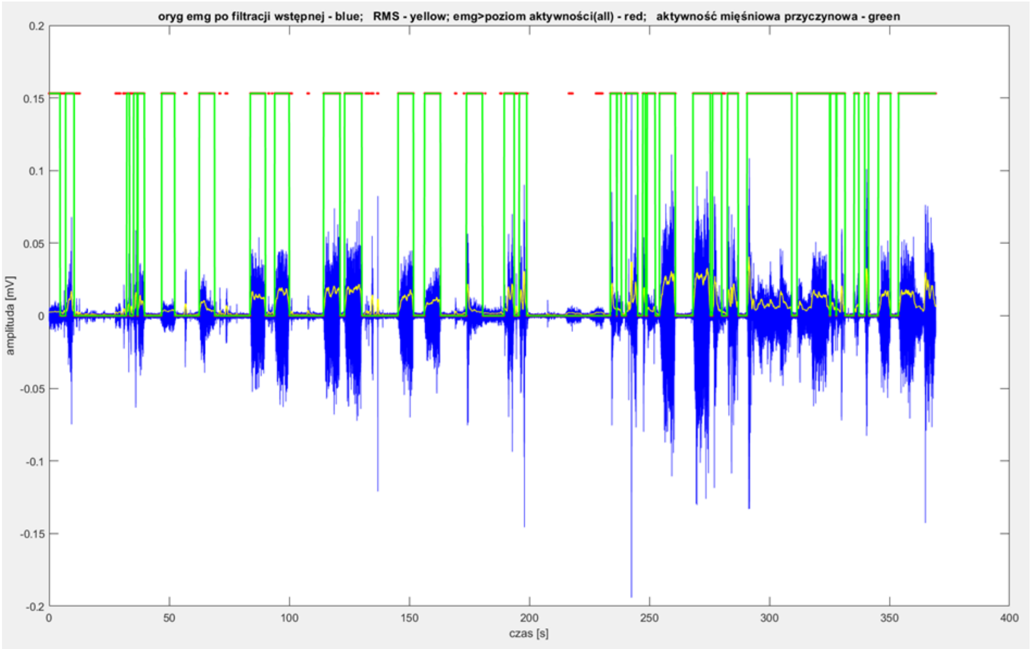
EMG(t) signal on-line analysis from real-time measurements, during the examination of a group of professional athletes. *Toward predictive detection of possible injury*.

- T, F, T-F multimodal biomedical signal processing,
- emg(t) filtration with an optimized filter cascade;
- development of an algorithm for determining causal muscle activity;

VIBE PROJECT

Erasmus+



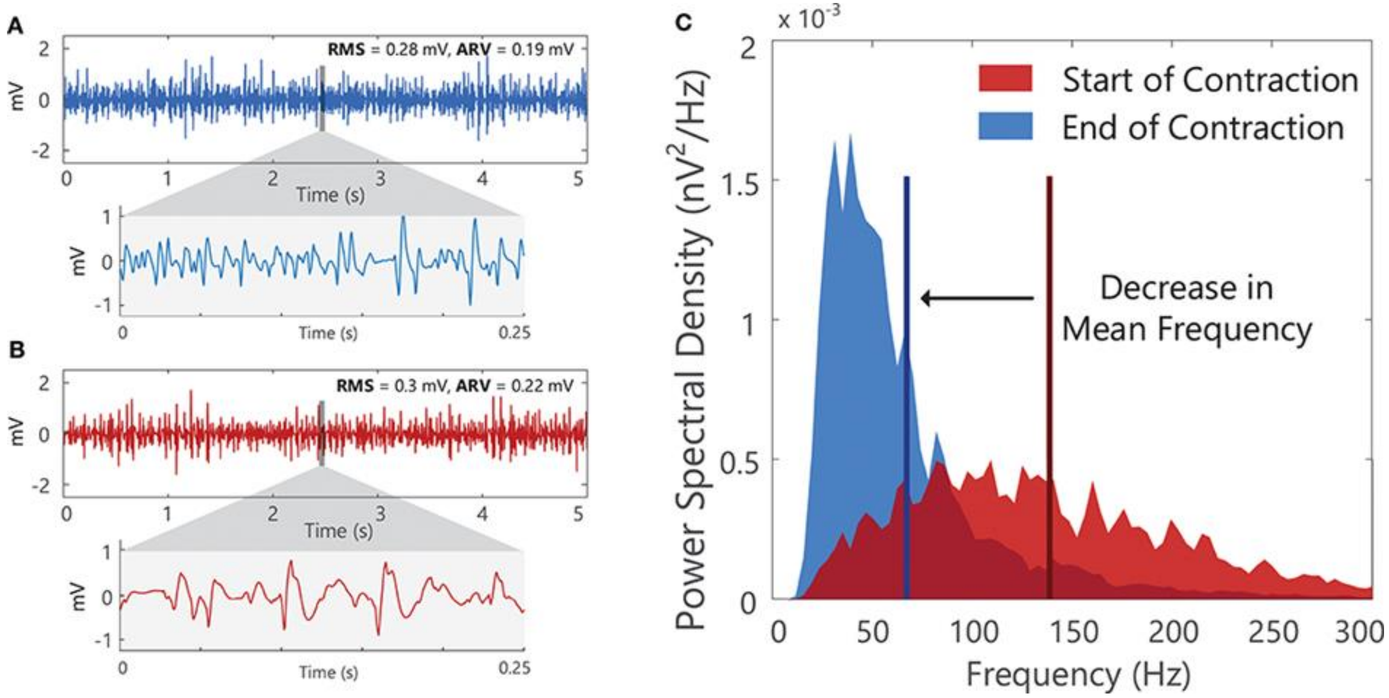


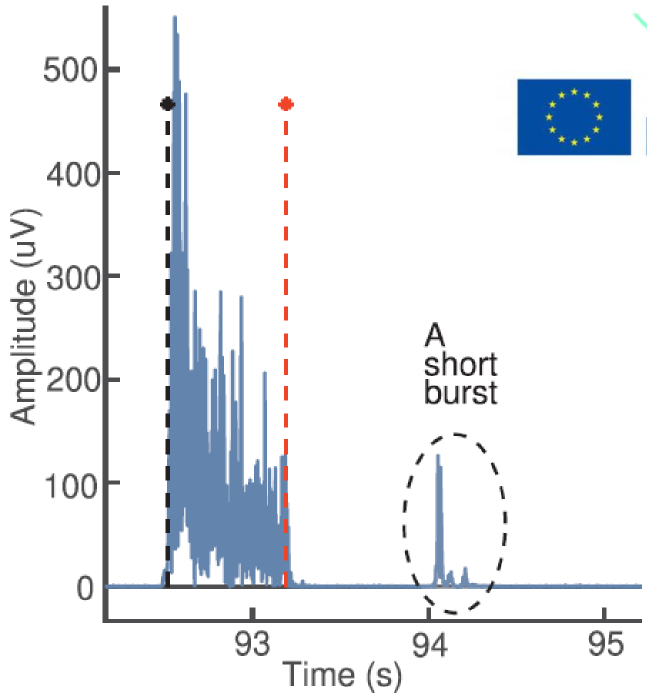
Source: Original works by the author

Use case:

EMG(t) signal on-line analysis from real-time measurements, during the examination of a group of professional athletes. *Toward predictive detection of possible injury.*

- burst artefacts (‚outliers') removal;
- frequency analysis of emg(t) in activation state;

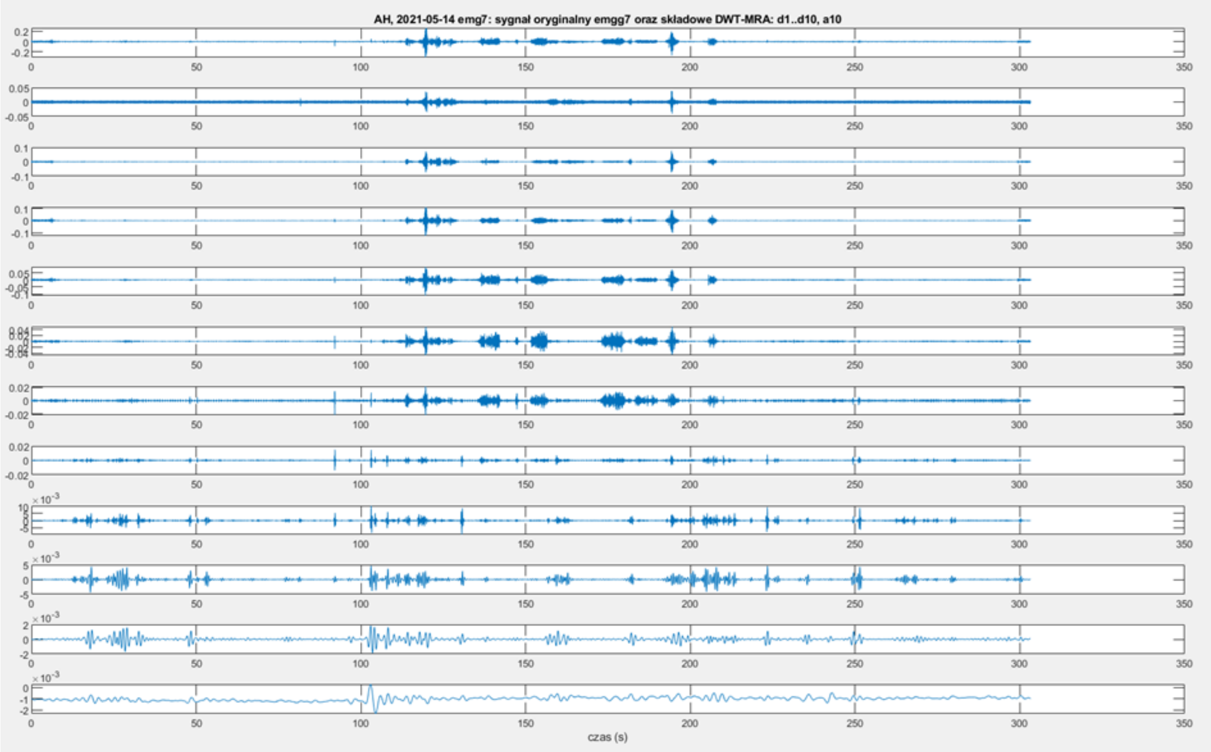


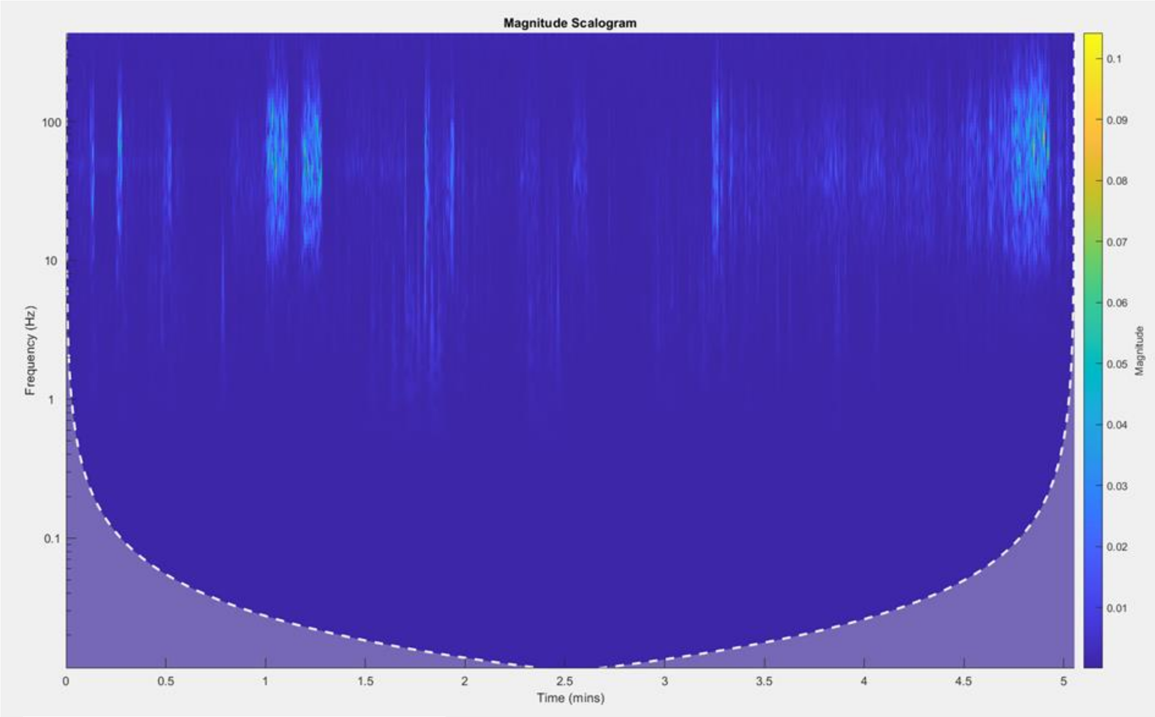


Source: Original works by the author

Use case:

- T-F wavelet emg(t) signal analysis;
- multi-level DWT signal decomposition;
- *db4, bior 2.4, 3.5, symlet6 – wavelet;*





AH, 2021-05-14, lower MVC, emg7(t)

Levels	energy_by_scales
{'D1' }	1.4845
{'D2' }	2.1464
{'D3' }	5.6277
{'D4' }	8.7217
{'D5' }	4.9273
{'D6' }	1.2118
{'D7' }	0.39971
{'D8' }	0.38503
{'D9' }	0.2369
{'D10'}	0.044175
{'A10'}	0.32305

energy_total =

table

sum_energy_by_scales
25.508

Source: Original work by the author

Use case

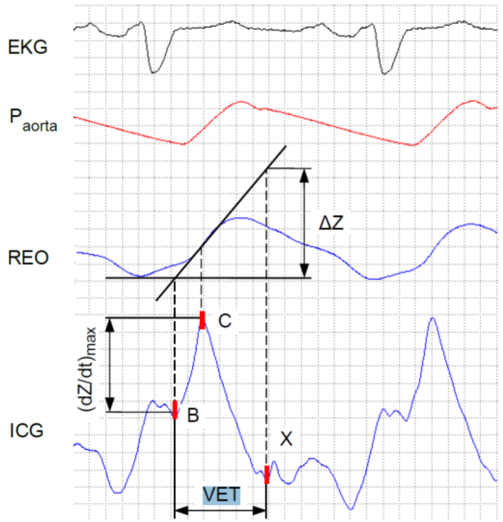
(Stroke volume & Cardiac output estimation from ecg(t)&Z(t) altern. for USG):

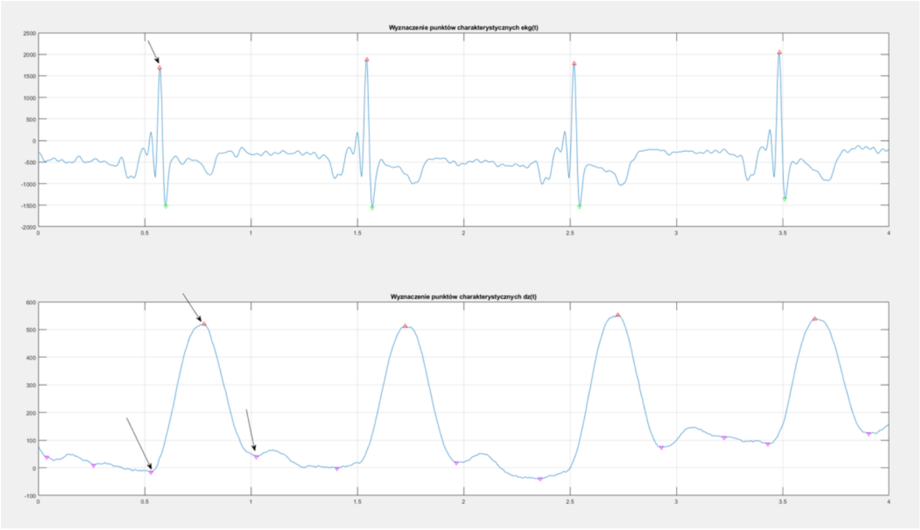
Relevant diagnostic features extraction from multimodal, multichannel biomedical signal measurement systems using sophisticated digital signal processing (DSP) methods developed in the time (T), frequency (F), and hybrid T-F domains.

Stroke volume (SV) estimation, based on non-invasive, widely accessible *ecg(t)*&*Z(t)* signals

from Kubicek formula:

$$SV = \rho * \left(\frac{L}{Z_0}\right)^2 * \left(\frac{dZ}{dt}\right)_{max} * t_{VET} \qquad [cm^3 = ml]$$





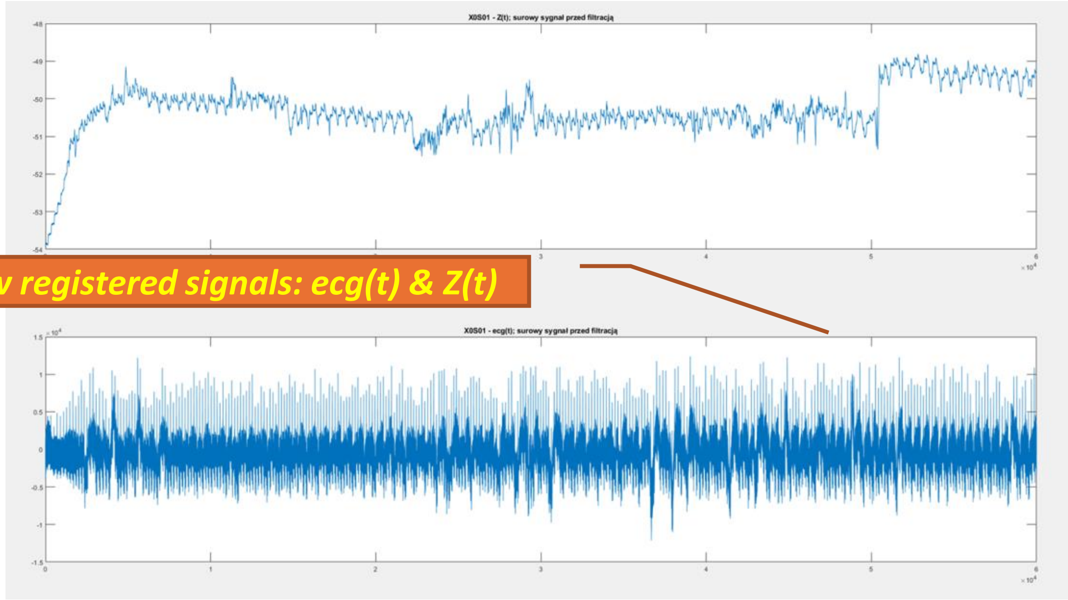
Custom design of multimodal – multichannel biomedical data acquisition system for ecg(t) & Z(t)

Source: Original work by the author

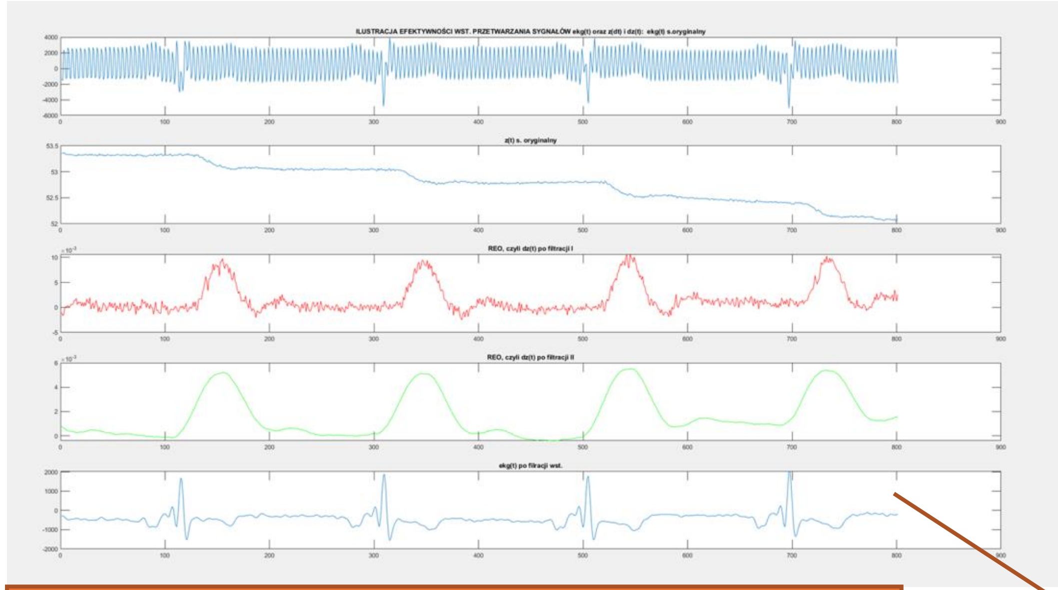
Use cases:

Estimation of Stroke Volume (SV) and Cardiac Output (=SV*HR) based on non-invasive, widely accessible ECG(t) and Z(t) signals.

Effect of raw, noisy input signals ‚cleaning’ using developed DSP methods (filter banks)



raw registered signals: ecg(t) & Z(t)

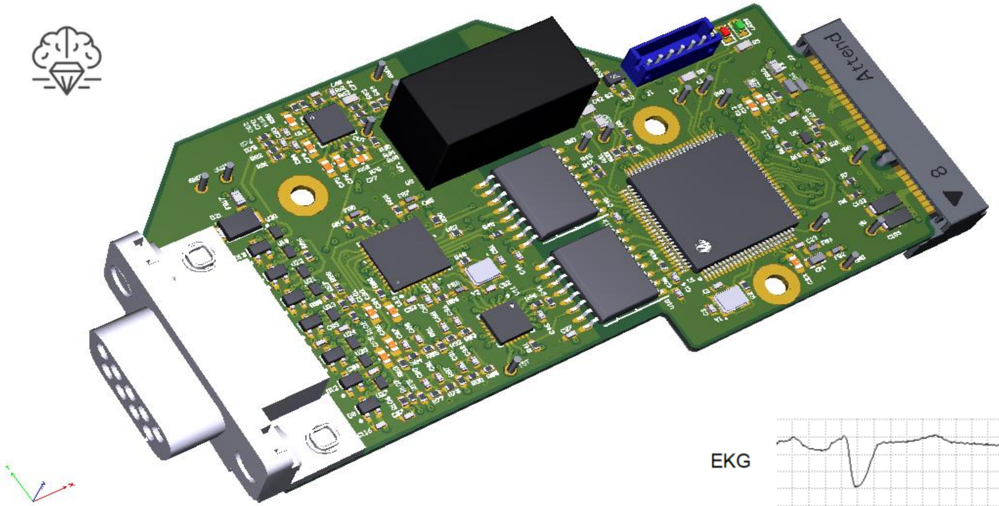


The same„cleaned’ signals after our DSP algorithms

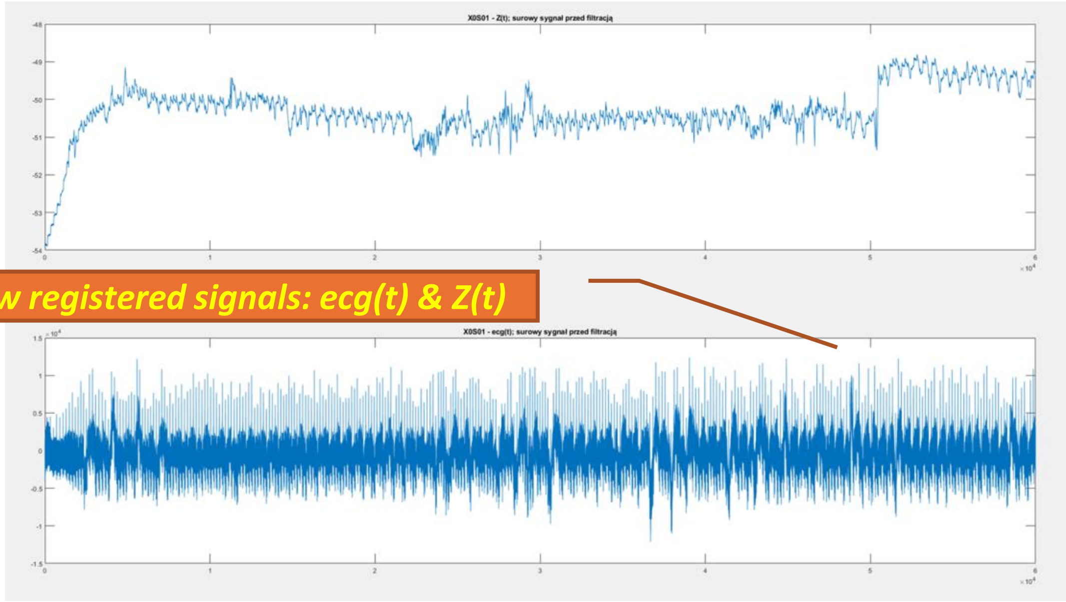
Source: Original work by the author

Our research: *from raw data to diagnostic data & knowledge*

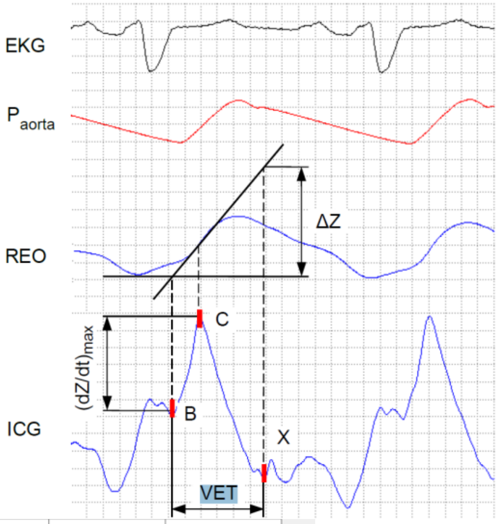
„REO" project results: hardware & biomed. data processing

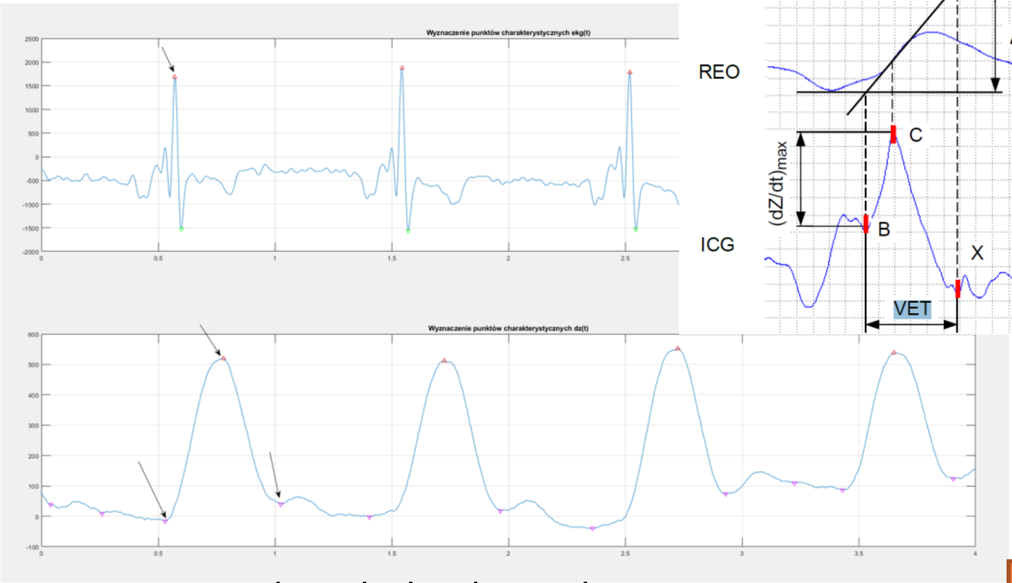


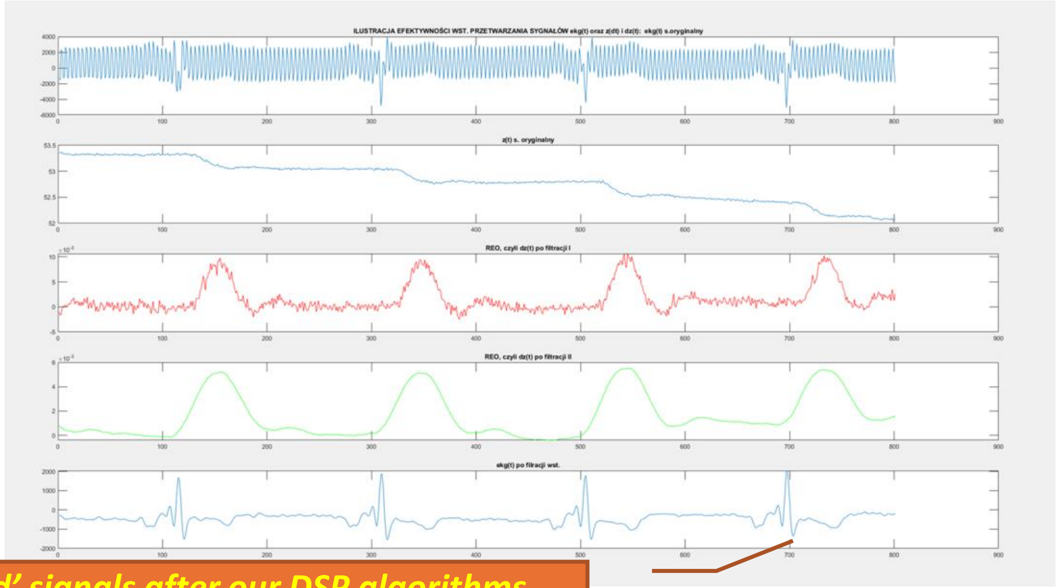
custom design of multimodal – multichannel biomedical data registration system



raw registered signals: ecg(t) & Z(t)







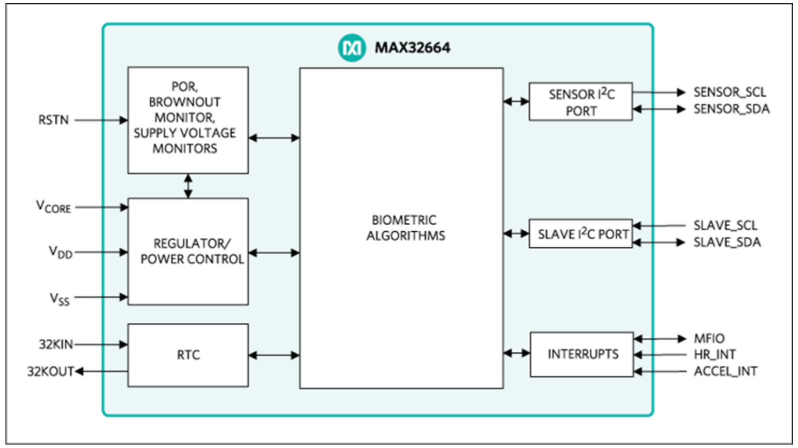
„cleaned' signals after our DSP algorithms

Source: Original works by the author

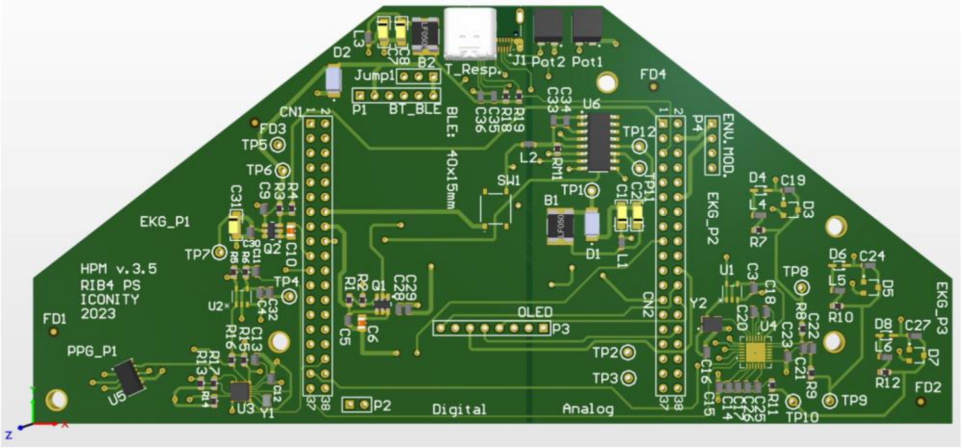
Use case: Design of a system for recording & processing physiological signals, including the respiratory curve at home (*from hospital to home idea*) - integrated with the measurement of environmental parameters.

In a hardware domain, the state-of-the-art personalized data acquisition systems was developed, by means of System on Integrated Chip (SoIC) type systems: Analog Front-End (AFEs) chips.

- Use of the modern AFE's SOiC systems, including Ultralow Power Biometric Sensor Hub: MAX32664 integrated with other specialized AFEs.



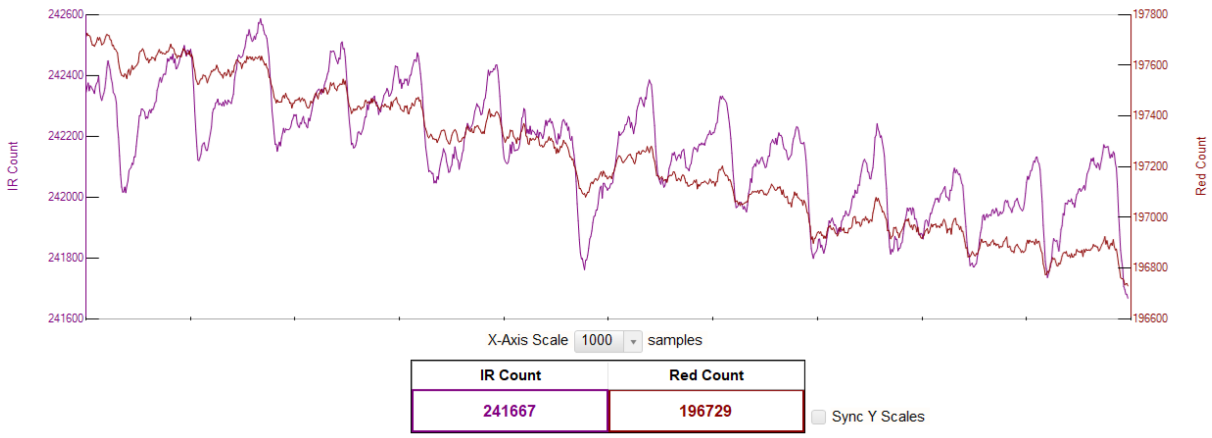
source: https://www.analog.com/en/products/max32664.html



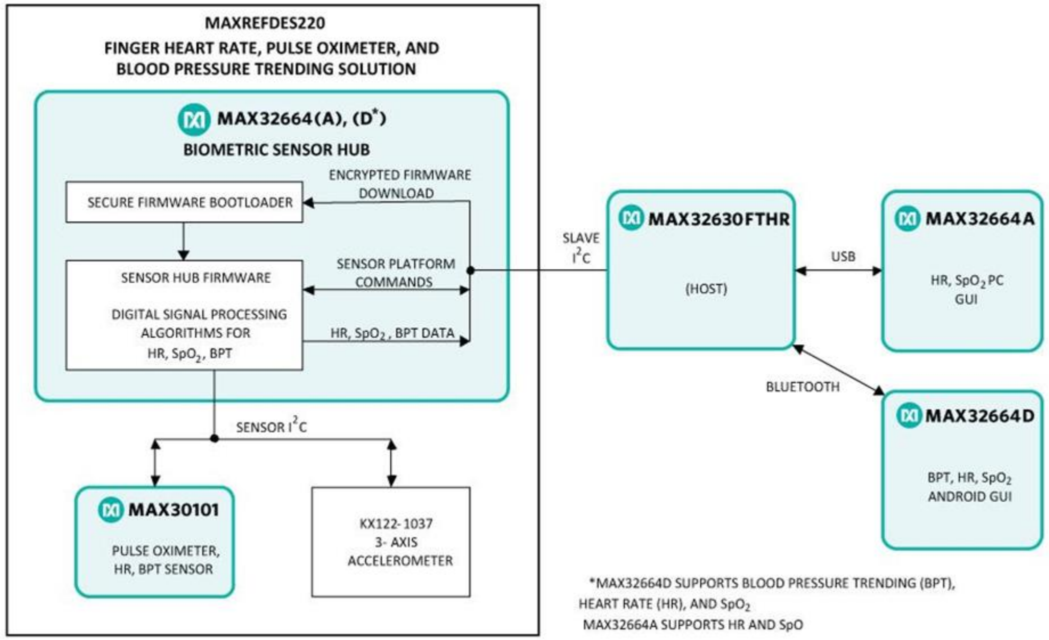
Custom design PCB for HR, ECG, SpO2, Resp. Rate, Temp. & enviromental parameters measurement.

Source: Original work by the author

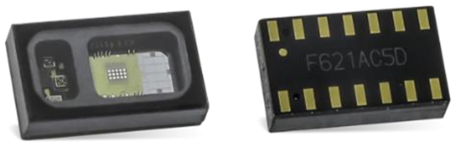
Use case: PPG (SpO2, HR) AFE integration in a custom multichannel, multimodal system.

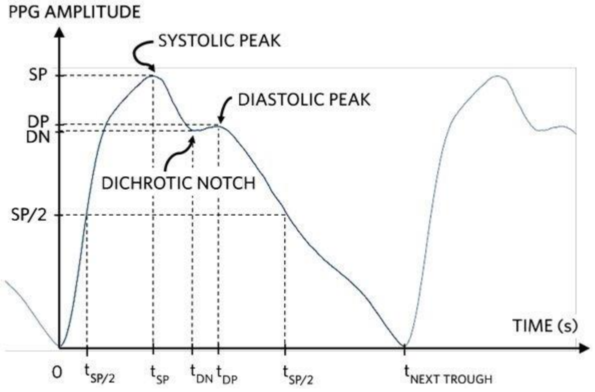


HR (bpm)	HR Confidence (%)	RR Value	SpO2 (%)	R Value	Algo Status	Algo Status Code
81.3	96	0.740	96.9	0.466	FINGER_DETECTED	3



Raw PPG signals from AFE from convenient evaluation board (my finger on my desk ☺)





Source: Original work by the author

Drivers activity recognition

Natalia Piaseczna, MSc BEng,

Promoter: Dariusz Komorowski, Ph.D., D.Sc., BEng., Prof. of SUT,

Associate Promoter: Rafał Doniec, Ph.D., BEng.,

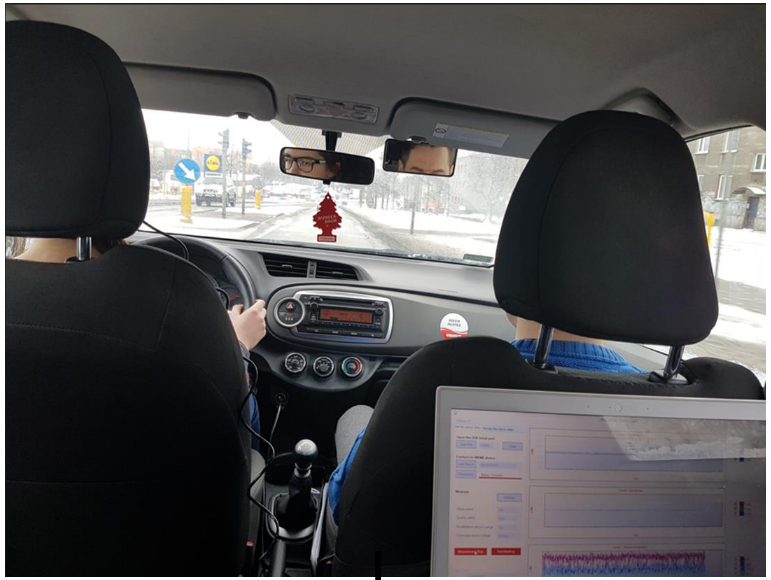
Department of Medical Informatics and Artificial Intelligence, Faculty of Biomedical Engineering,
Silesian University of Technology

natalia.piaseczna@ieee.org

Aim of the study

1. Developing methodologies for analysis and classification and EOG data in the context of driving
2. Investigating the impact of vision impairment factors on driving safetyDevelopment of methods for identifying the level of driver experience
3. Analysis of the differences between driving in real and simulated conditions
4. Development of methods for predicting car accidents
5. Creation of a database of data acquired under simulated conditions containing different types of activities of the person driving the vehicle.

Experimental setup



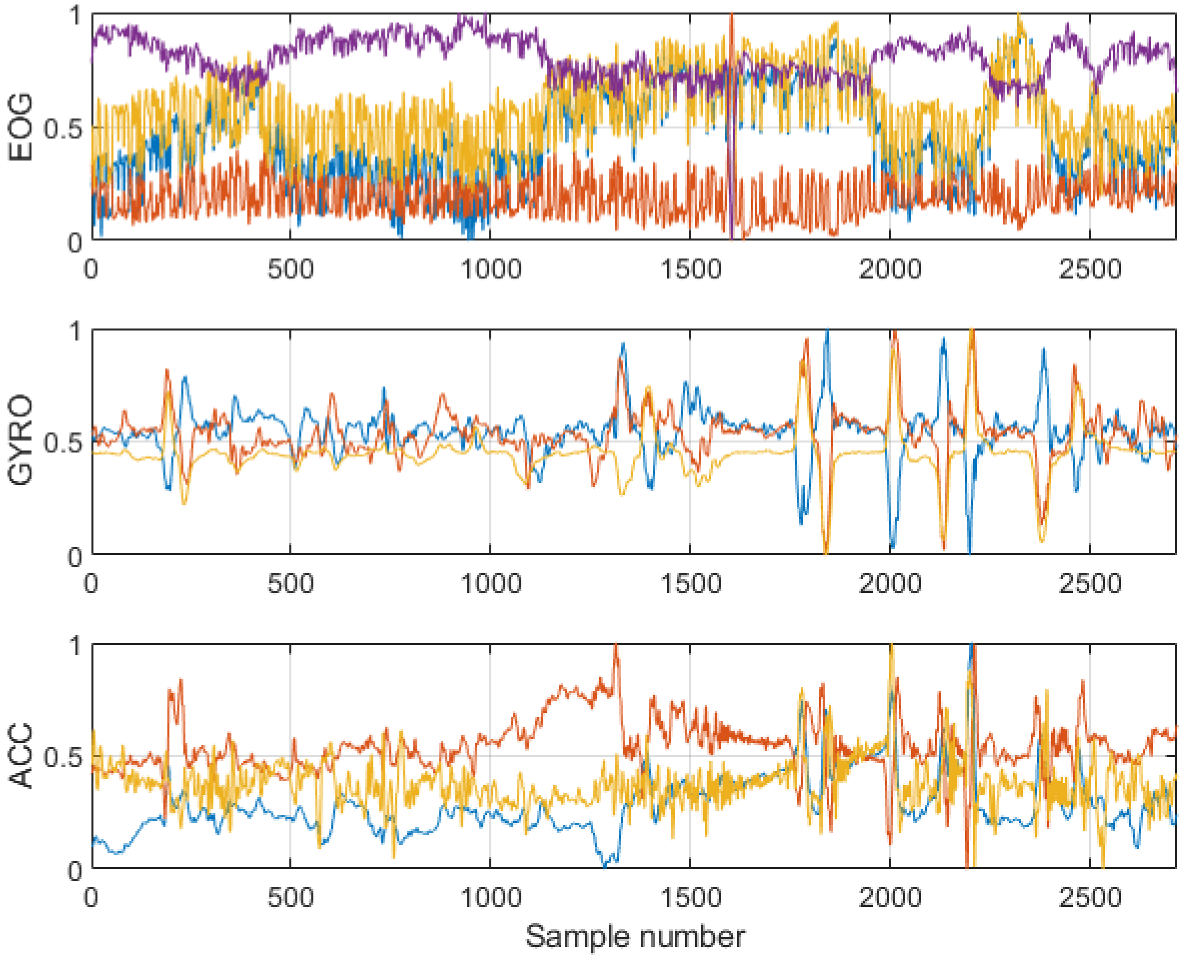
Real road conditions
car, laptop with dedicated software

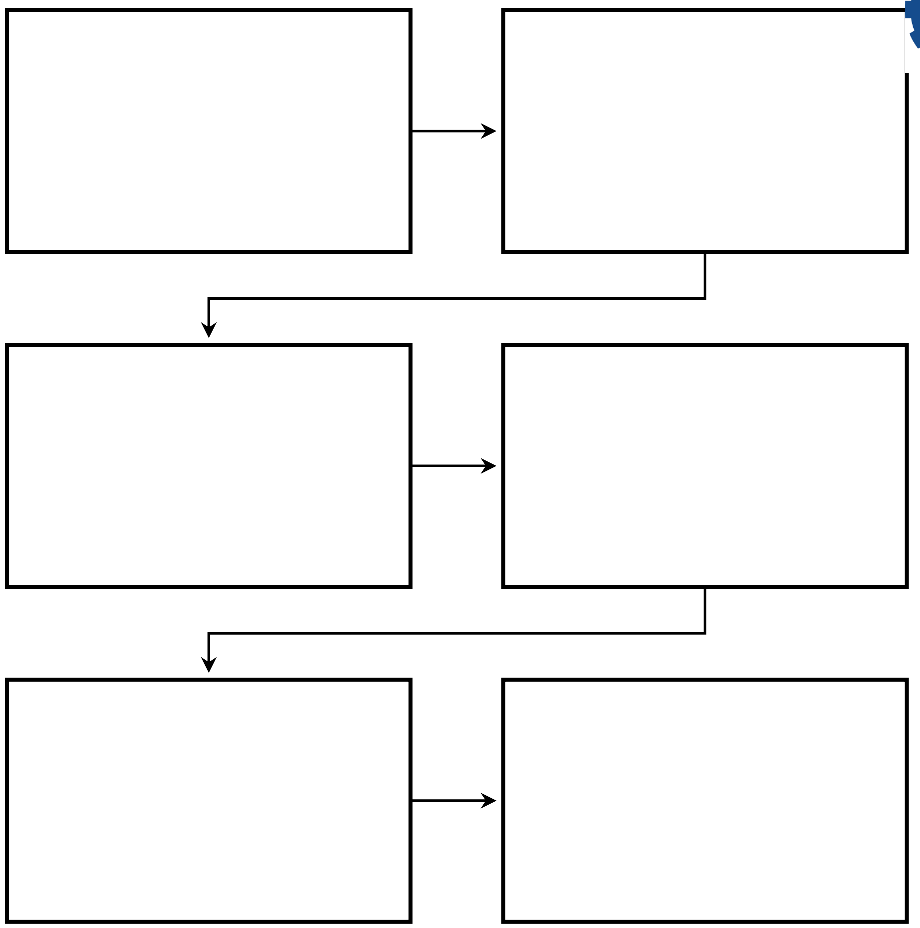
Simulated conditions
car simulator, laptop with dedicated software

Data acquisition
JINS MEME ES_R academic pack, 3-point EOG, 3-axes accelerometer and gyroscope

Source: Original work by the authors

General methodology





Source: Original work by the authors

Publications

1. Classification of recorded electrooculographic signals on drive activity for assessing four kind of driver inattention by bagged trees algorithm: a pilot study, DOI:10.1007/978-3-031-38430-1_18
2. The detection of alcohol intoxication using electrooculography signals from smart glasses and machine learning techniques, DOI:10.1016/j.sasc.2024.200078
3. Does glucose affect our vision? A preliminary study using smart glasses, DOI:10.1109/IEEECONF58974.2023.10404616
4. Sensor-based classification of primary and secondary car driver activities using convolutional neural networks, DOI:10.3390/s23125551
5. Classification of roads and types of public roads using EOG smart glasses and an algorithm based on machine learning while driving a car, DOI:10.3390/electronics11182960
6. The classifier algorithm for recognition of basic driving scenarios, DOI:10.1007/978-3-030-49666-1_28
7. Recognition of drivers' activity based on 1D convolutional neural network, DOI:10.3390/electronics9122002
8. Recognition of basic driving scenarios, ISBN 978-1-5386-1312-2

Analysis of heart rate variability based on electrocardiograms, seismocardiograms and gyrocardiograms

Szymon Sieciński, Ph.D., BEng.

Research assistant at the Institute of Medical Informatics, University of Lübeck, Germany

(Email: szymon.siecinski@uni-luebeck.de)

Lecturer at the Department of Clinical Engineering, Academy of Silesia, Katowice, Poland

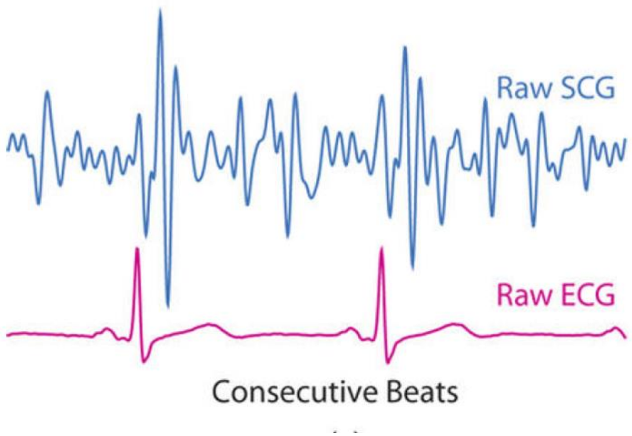
(Email: szymon.siecinski@akademiaslaska.pl)

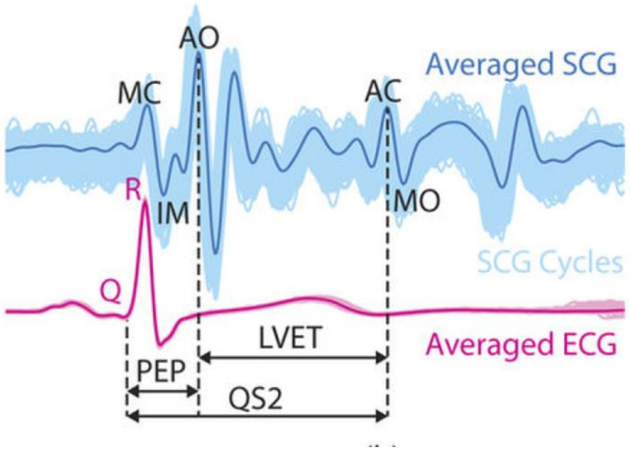
ORCID: 0000-0002-3801-3144

Promoter: Paweł Kostka, Ph.D., D.Sc., BEng., Prof. of SUT,

UNIVERSITÄT ZU LÜBECK
INSTITUTE OF MEDICAL INFORMATICS

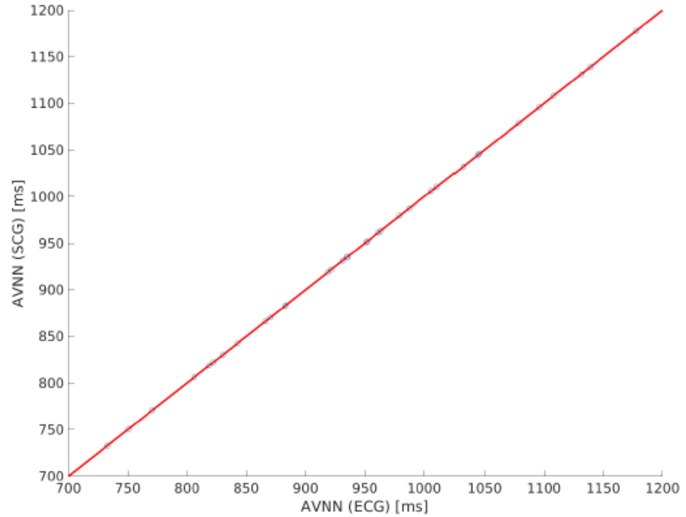
Seismocardiogram (SCG) example:

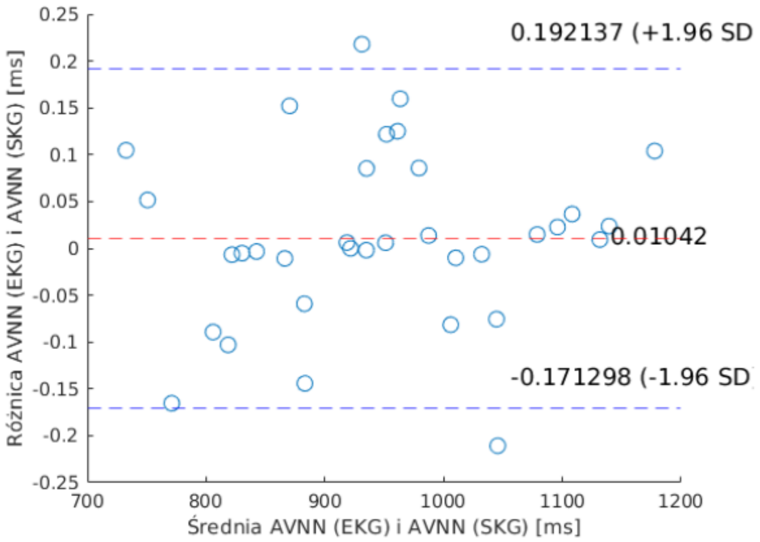




Analysis steps:

- Detection of heartbeats in ECG & SCG signals;
- Calculation of heartbeat intervals(NN) for each signal analyzed;
- Perform HRV analysis separately for each signal:
  - Temporal analysis (AVNN, SDNN, RMSSD, pNN50),
  - Frequency analysis (TP, LF, VLF, HF, LF/HF),
  - Nonlinear analysis (SD1, SD2, SD1/SD2, EA, VAI, VLI)





AVNN compliance analysis for ECG and SCG: a) correlation, b) Bland-Altman graph

Source: Original work by the author

OPEN

SUBJECT AREAS:

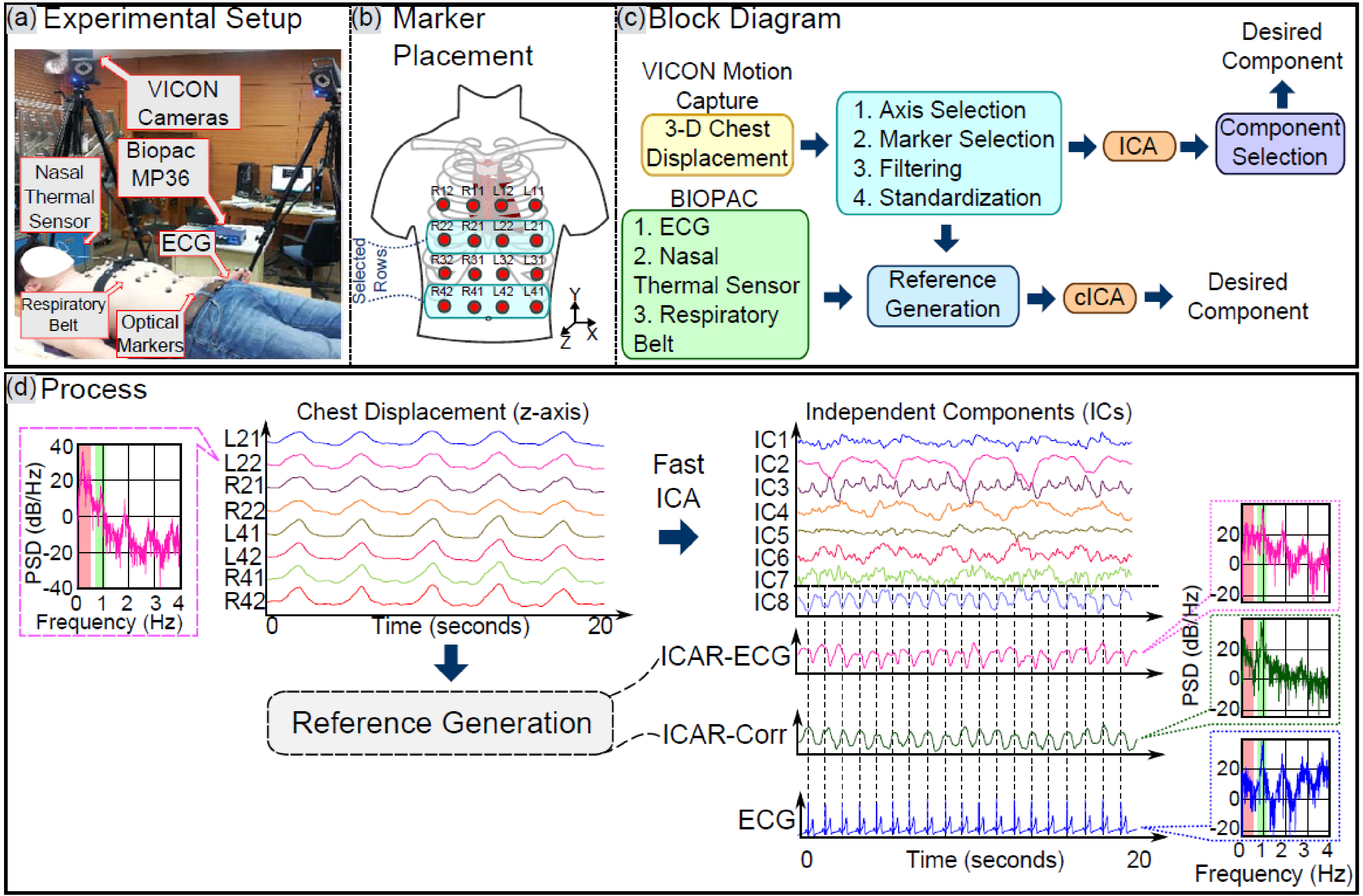
MEDICAL IMAGING

BIOMEDICAL ENGINEERING

Surface Chest Motion Decomposition for Cardiovascular Monitoring

Ghufran Shafiq & Kalyana C. Veluvolu

School of Electronics Engineering, College of IT Engineering, Kyungpook National University, Daegu, South Korea 702-701.



Biomedical signal acquisition and processing methods for “wearable” systems

Marek Czerw MSc, Eng.

Implementation PhD

Promoter: Paweł Kostka, Ph.D., D.Sc., BEng., Prof. of SUT,

Associate Promoter: Janusz Wróbel, Ph.D., D.Sc., BEng.,

Łukasiewicz Research Network – Krakow Institute of Technology,

Center for Biomedical Engineering Zabrze, SUT.

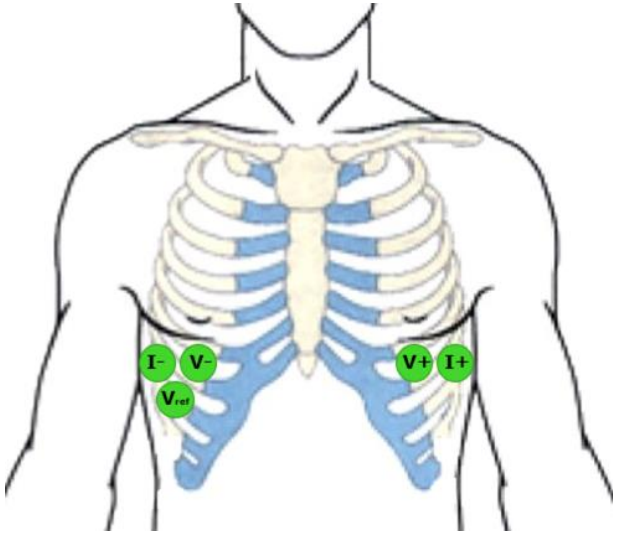
marek.czerw@kit.lukasiewicz.gov.pl

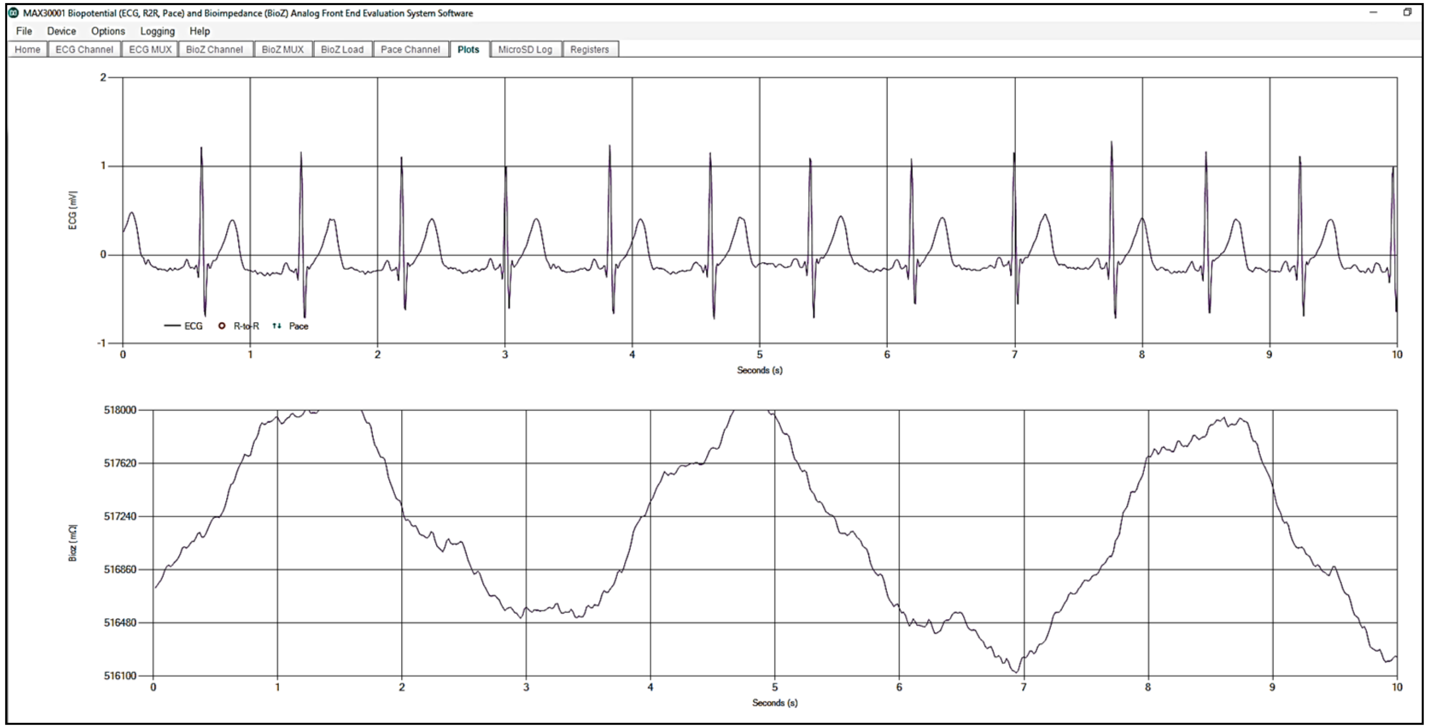
janusz.wrobel@kit.lukasiewicz.gov.pl

Łukasiewicz
Krakowski Instytut Technologiczny

Development of measurement methods for biomedical parameters
(including HRV & Respiratory curve → Respiratory Rate RR[brpm]+other resp. params.)

Integrated measuring transducer for ECG and bioimpedance recording





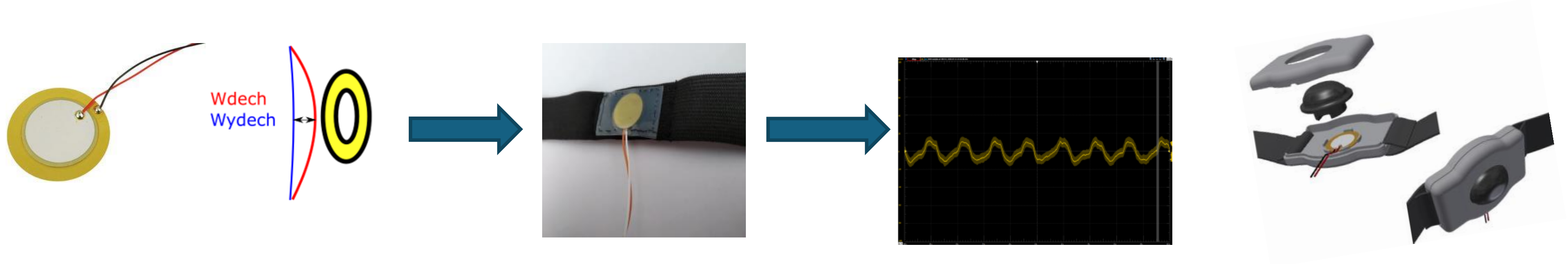
The impedance Z is measured by introducing an alternating electric current of F=50kHz, and I_{RMS}=1mA through two electrodes, and measuring the voltage with the receiving electrodes, an ECG is also recorded from the same electrodes

Łukasiewicz
Krakowski Instytut Technologiczny

Source: Original work by the author

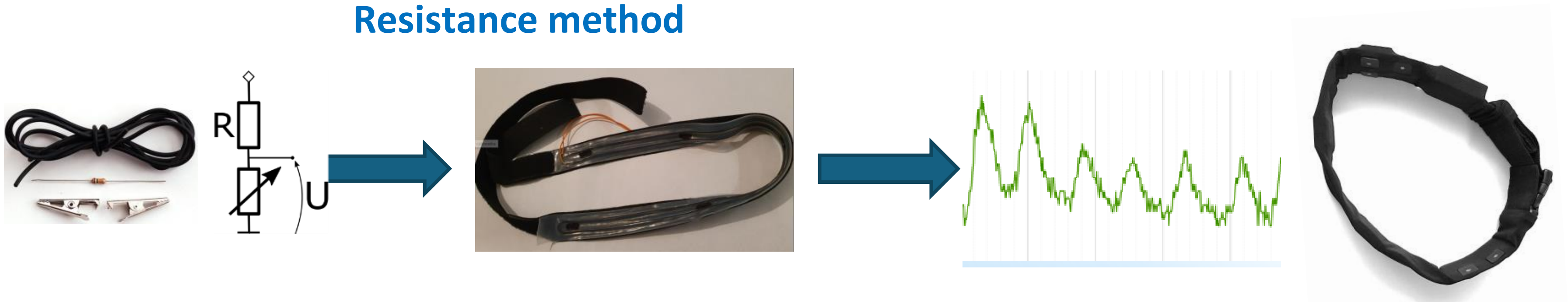
Comparison of methods for measuring respiratory parameters

Piezoelectric method



The movement of the chest caused by inhalation and exhalation causes a change in pressure on the piezo diaphragm, which in turn produces tension proportional to the movement of the chest

Resistance method

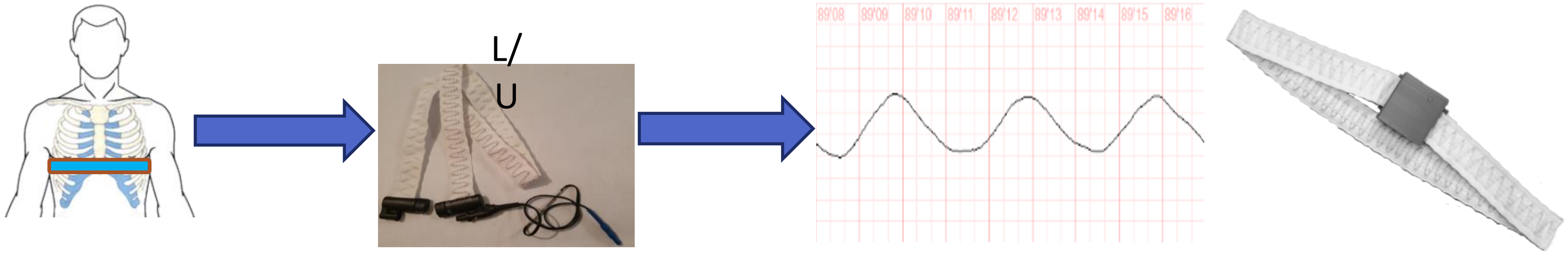


A method of monitoring breathing using a conductive tape that changes its resistance when stretched

Łukasiewicz
Krakowski Instytut Technologiczny

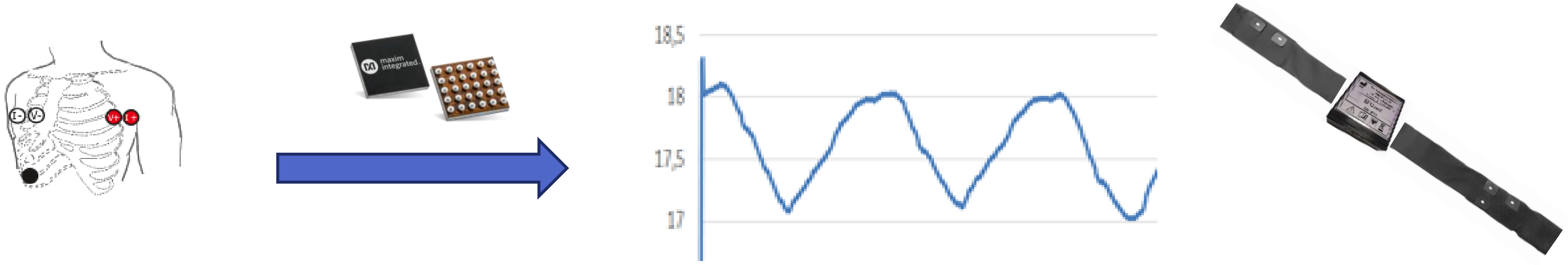
Source: Original work by the author

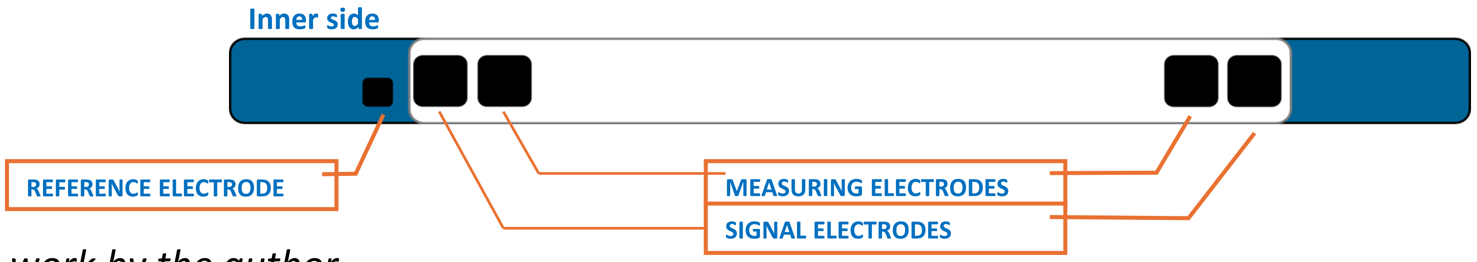
Induction method: involves converting changes in inductance into PWM pulse width and then into a change in voltage.



Rheographic method: involves recording changes in chest impedance during breathing using a dedicated integrated transducer.

During inspiration, there is an increase in the volume of gas in the chest which decreases the conductivity and the area of the chest increases and with it the measured impedance .

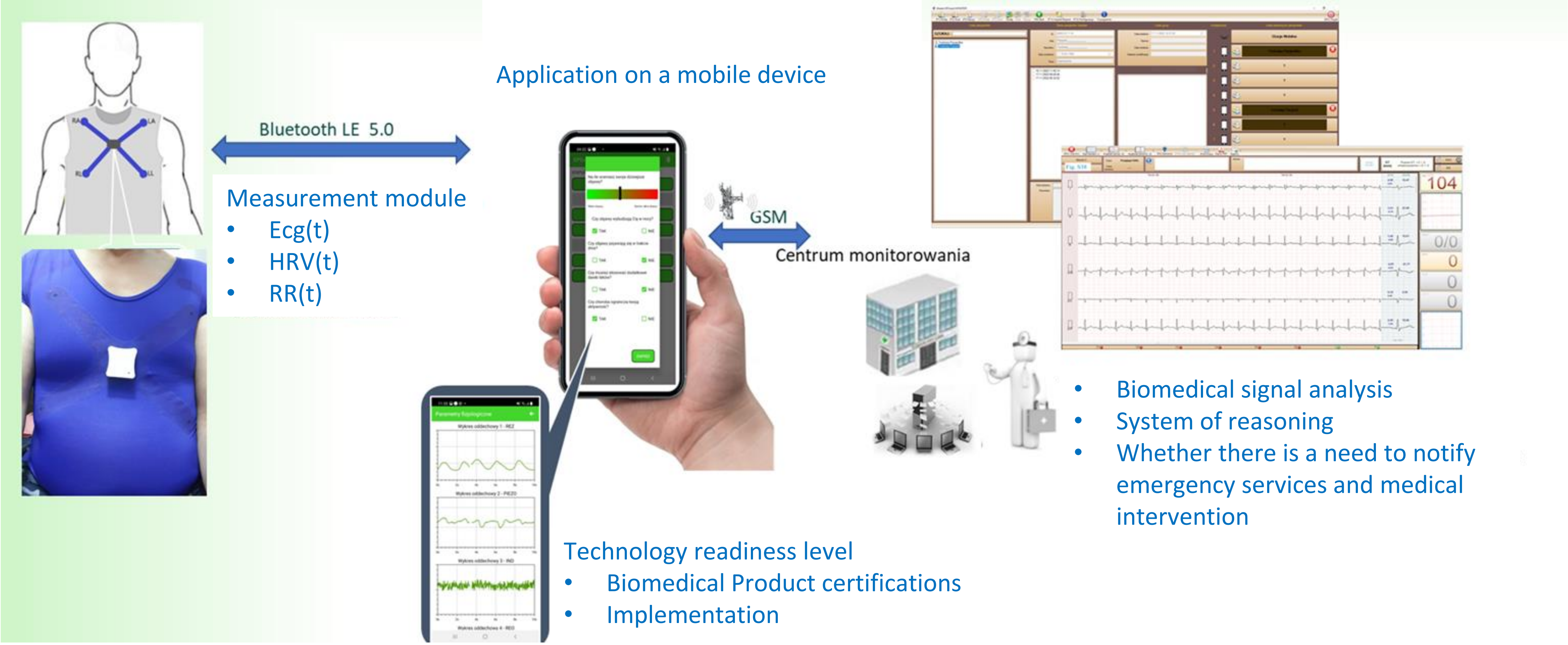




Source: Original work by the author

Łukasiewicz
Krakowski Instytut Technologiczny

Structure of a final wearable system for biomedical signal acquisition and processing



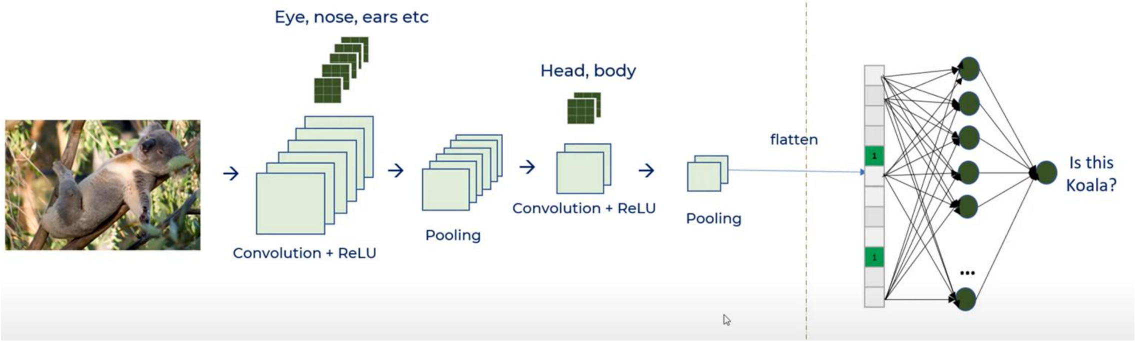
Source: Original work by the author

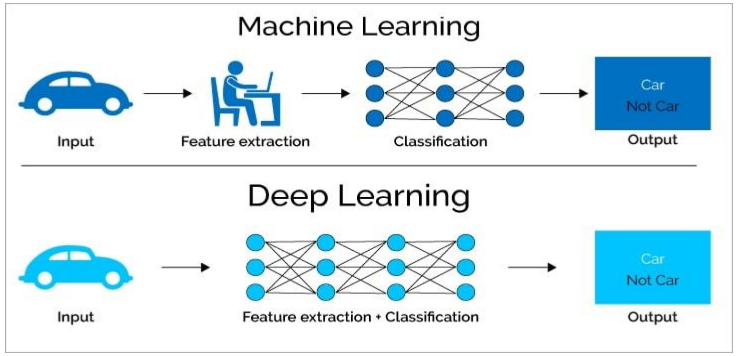
Łukasiewicz
Krakowski Instytut Technologiczny

Conclusions

- DSP and feature extraction (FE) - probably still relevant in specialized tasks, especially e.g. for processing 1-dimensional, multimodal signals;

- Deep Learning methods (without an explicit FE stage) in processing:
  - Images,
  - Movies,
  - Audio
  - Text,





- Deep learning AI with CNN networks is, of course, already working effectively in the role of 'creative' - generative

VIBE Project

Virtual biomedical engineering and stem/steam education

Basic information

Project ID: VIBE
Project start date: 1 November 2021
Project end date: 31 October 2024
Coordinator: University of Pécs, Pécs, Hungary

Partners

Universidade do Porto, Porto, Portugal

DEX Innovation Centre, Liberec, Czech Republic

Silesian Univ. of Technology, BE faculty, Poland.

https://vibe-project.pte.hu/

Project outcomes

- Spreading and widening the knowledge and awareness of VR/AR-based learning
- Higher number of students interested in STEM/STEAM or medical fields and increased level of diversity
- More immersive and overall improved VR environment
- A completely new curriculum (Biomedical Engineering BSc) developed using the VR platform as a co-creation and collaboration tool.
- Maintaining the international cooperation network established in the project beyond the scope of EU funding.

VIBE Project

Virtual biomedical engineering and stem/steam education

Basic information

Project ID: VIBE
Project start date: 1 November 2021
Project end date: 31 October 2024
Coordinator: University of Pécs, Pécs, Hungary

Partners

Universidade do Porto, Porto, Portugal
DEX Innovation Centre, Liberec, Czech Republic
Silesian Univ. of Technology, BE faculty, Poland.

https://vibe-project.pte.hu/

I would like to thank our partners very much for:

- *cooperation,* ✓
- *support,* ✓
- *motivation* ✓