4ACEs Workshop
20 - 21 January 2025, Budapest, Hungary
Visegrad Fund

Data Acquisition for Biomedical Signal Processing

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Outline

- About DIPteam
- X-Ray/magnetic data acquisition
  - Spine 3D model reconstruction
- Optical/electrical data acquisition
  - PPG and ECG prototype
  - Commercial sensors evaluation experiment

About DIPteam

- We exist since 2007, on the Department of Electronics
- Beginnings: research colaboration with NXP-Software
- Rapidly outgrew the “DIP” acronym, but we are keeping it :)
- Topics: Digital image, video, audio, multimedia
- Researchers:
  - Students from later years of bachelor studies.
  - Master students.
  - PhD students.
  - Professors from the Department of Electronics.
  - Personnel footprint: more than 20 researchers throughout history, today most of them around the world, most with master's degrees, some with doctorates, with successful careers in science and industry

About DIPteam

- What we do: scientific research, applications, projects
- Some of the work:
  - Digital video processing for mobile platform, (NXP-Software - Eindhoven)
  - Super-resolution for widespread use (Texas Instruments - Dallas, TX)
  - Crane control via computer vision (Seavus)
  - Software for collection and recording of tolls on Macedonian highways (PESR)
  - Control of toll collection via video monitoring (PESR)
  - Video-based conditional access system (FEEIT)
  - License plate detection and recognition (FEEIT)
  - Categorization of vehicles for toll collection (PESR)
  - Road fee collection control system (PESR)
  - Intelligent transport system: detection and recognition of objects and events in traffic (ITek Systems, FITR)
  - Intelligent cash register: recognition of products in a store (Alfa-Zet Sys., Belgium)
  - Detection of packages and transport bags in LIDAR depth maps (Mikrosam)
  - Quality control of laying composite materials (Mikrosam)

About DIPteam

- Permanently open call for cooperation and admission of new members
- Opportunity to work on interesting and current issues
- Opportunity for postgraduate studies and advancement in academic status
- Scholarships for researchers working on projects funded by partners
- More information:
- Website: https://dipteam.feit.ukim.edu.mk/

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Reconstruction of a 3D model of the spine using magnetic resonance imaging

Master thesis,
Martina Petrovska

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The research

The lumbar spine, a key component of the human skeletal system, is often subject to pathological changes.

CT protocols

- Convention for scanning bone structures.
- Short scan time.
- Average slice thickness from 0.6 to 1 mm.
- Uses ionizing radiation.

MRI protocols

- All surrounding tissues, fat, and organs are visible.
- Quite a long scan time.
- Average slice thickness of 3 to 4 mm.
- Does not use ionizing radiation.

Proposed MRI protocol

- More prominent bone structures.
- Scans only one full vertebra to reduce scan time.
- 1 mm slice thickness.
- Does not use ionizing radiation.

The research

The research is a combination of:

- Working with magnetic resonance images
- Developing machine learning algorithms
- Testing segmentation methodologies

Primary motive:

- Potential application of 3D spinal modeling in pediatric cases.

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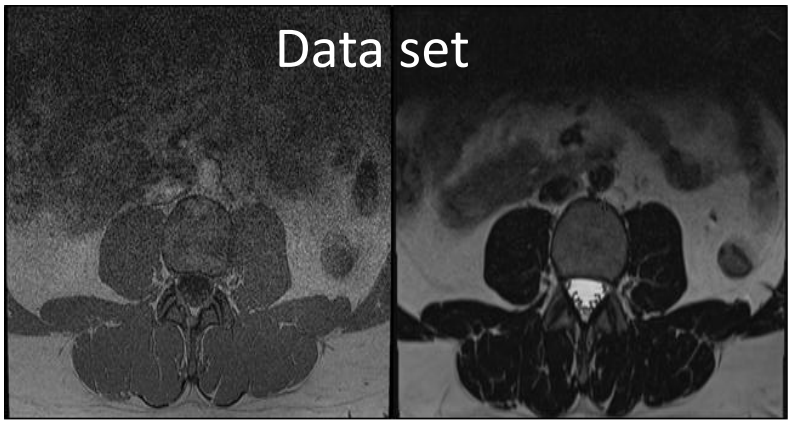
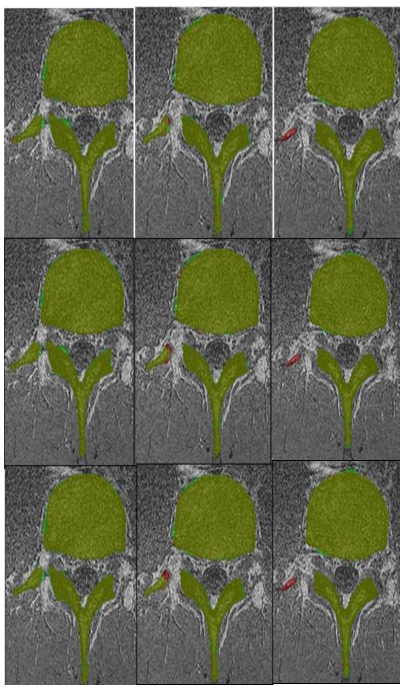
Data set



Obtained by a new imaging protocol adapted by a radiologist
Thinner slices (needed for 3D)
More noise (lower SNR)
More defined edges

Obtained by standard imaging protocol T2
Thicker slices
Less noise
Blurred edges

Results



Color legend:

Model result

Ground truth

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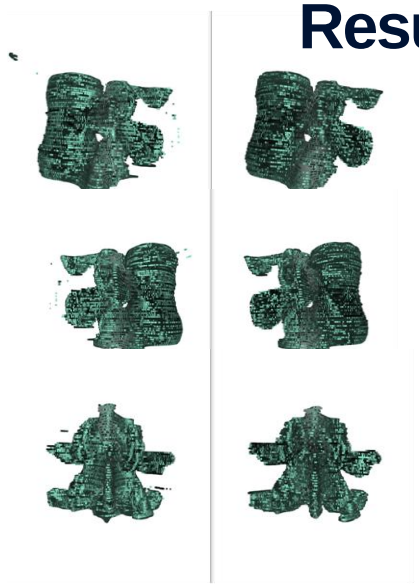
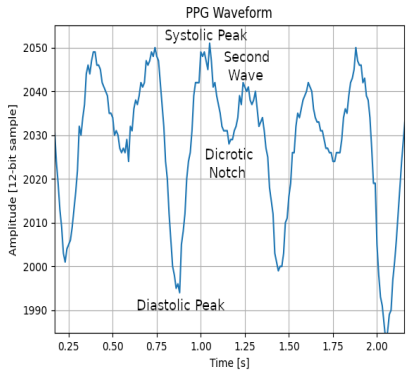
Results



Left: results from the best CNN
Right: the manual annotations

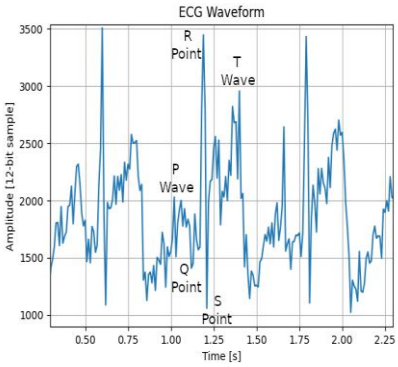
Photoplethysmography (PPG)

- **Optical method for measuring heart activity**
- **Measures changes in blood volume in local tissue (finger, wrist, etc.)**
- **Output signal directly correlated to heart's beating rate**
- **Time between neighboring peaks determines heart rate**



Electrocardiography (ECG)

- Electrical method for measuring heart activity
- Measures changes in skin potential changes caused by the electrical activity of the heart
- Output signal shows the polarization and depolarization of the heart
- Time between neighboring peaks determines heart rate



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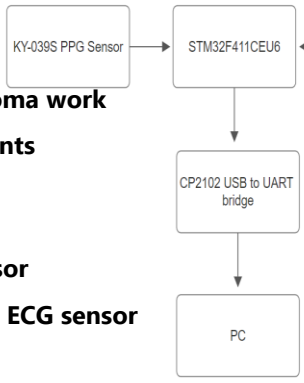
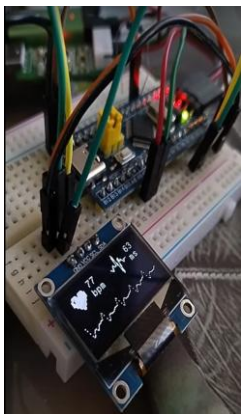
Prototyping a heart rate monitor

- Marko Petrov, diploma work
- Hardware components
  - STM32F411CEU6 microcontroller
  - KY-039S PPG sensor
  - SHIELD-EKG-EMG ECG sensor
- Software
  - Tresholding algorithm
  - Options for using PPG or ECG signal





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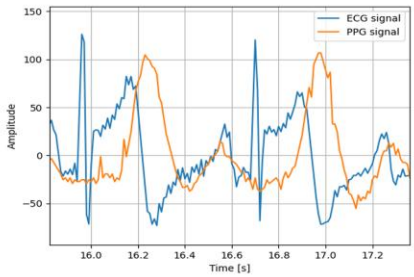
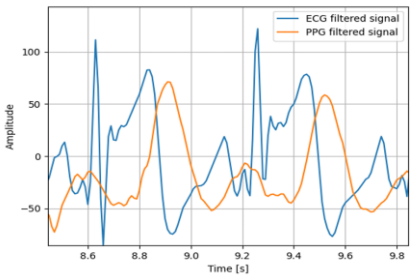
Processing the sensor signals

- **Digital filtering**
  - **0.5Hz high pass filter for DC offset removal**
  - **25Hz low pass filter for high-frequency noise removal**



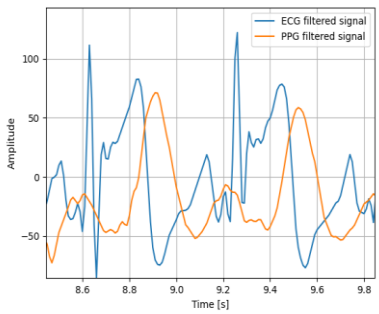
Raw signals

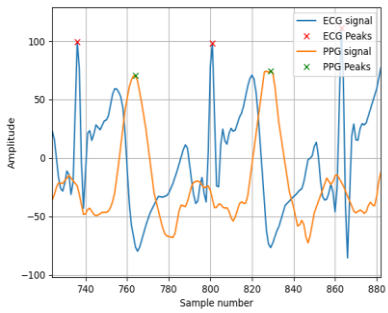


Filtered signals

Processing the sensor signals

- **Tresholding and non-maxima supression**
  - **Finding peak candidates**
  - **Finding peaks in local groups of peak candidates**
- **Finding R-R interval**
  - **Using distance between peaks for calculation of heart's beating rate**





Performance comparison between PPG and ECG based heart rate sensors

Conference paper,
Marko Petrov, Branislav Gerazov, Tomislav Kartalov and Nikola Jovanovski

Published on 16th International Conference ETAI 2024, Struga, Macedonia

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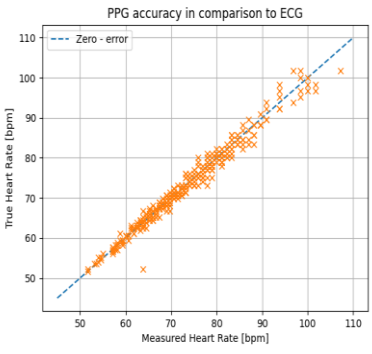
Different signals – same algorithm

- **Running a tresholding algorithm on PPG and ECG sensor signals recorded at the same time**
  - **Results show success**
- **Using ECG as a reference**
  - **More robust system**
- **Tresholding requires batch processing**
  - **What about real time application?**



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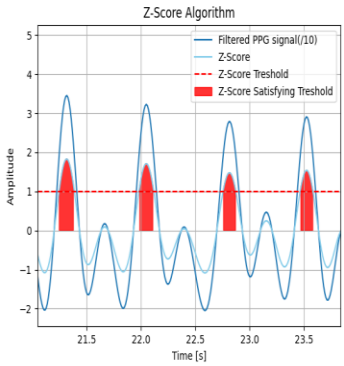
Using statistics as a tool

- A peak detection algorithm based on a statistical model – standard score (Zscore)
  - Number of standard deviations a sample is from a signal's moving average
- What about non-maxima suppression?
  - Taking the first sample solves the problem

$$Zscore = \frac{X - \mu}{\sigma}$$



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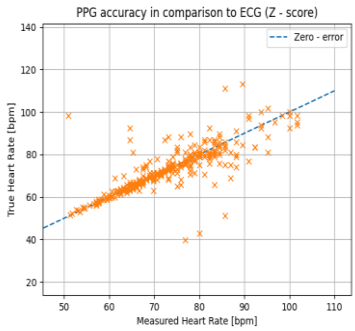
Different algorithm .. same chart?

- More errors are evident in the real time application.
  - Filtering performance – not substantial
    - The signal's changing DC offset affects the moving average
  - PPG's nature – substantial
    - Interference from ambient light, moving artifacts, etc.



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What about commercial?

- **Commercial heart rate monitors have really robust algorithms**
  - **Most of them are closed-source :(**
  - **Does it help?**

* Courtesy of Garmin Ltd.

Built-in Optical Heart Rate Sensor **Chest Strap Heart Rate Monitor**

What about commercial?

* Courtesy of Garmin Ltd.

Built-in Optical Heart Rate Sensor
Convenient for all day monitoring
Does not require an additional accessory

Chest Strap Heart Rate Monitor
Can give greater accuracy in activities with lots of motion
Can provide Running Dynamics data
Can provide heart rate data for activities where wearing a watch is not possible or the watch does not support optical heart rate (e.g. swimming)

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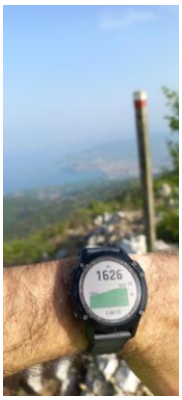
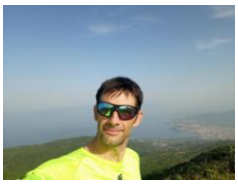
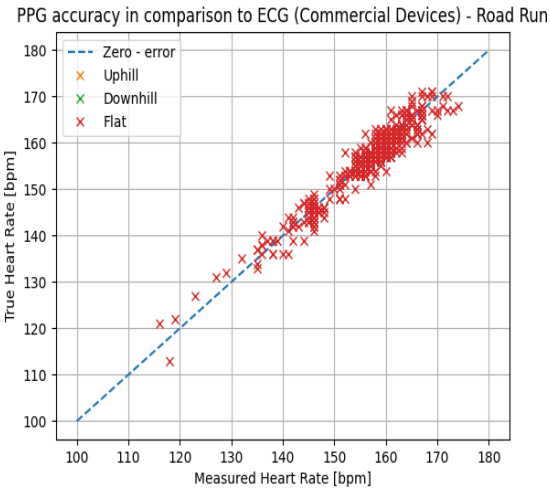
What about commercial?

- Real-world scenarios
  - Mountain biking, running on trails, running on asphalt
  - Substantial difference in performance





PPG vs. ECG (commercial)



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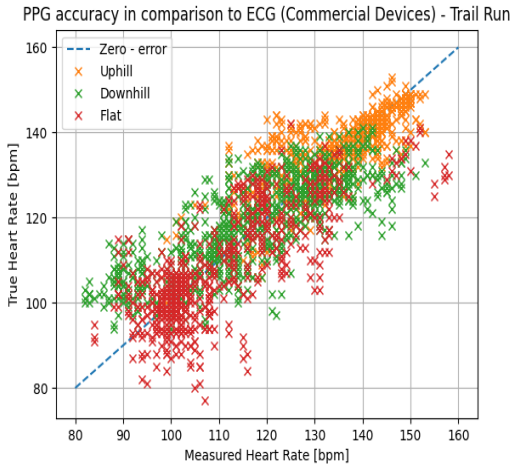

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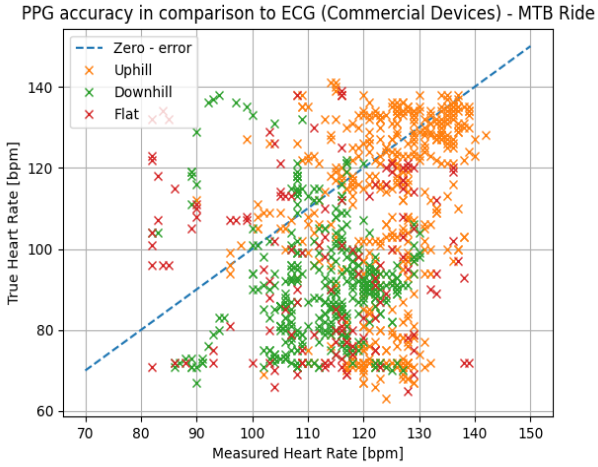

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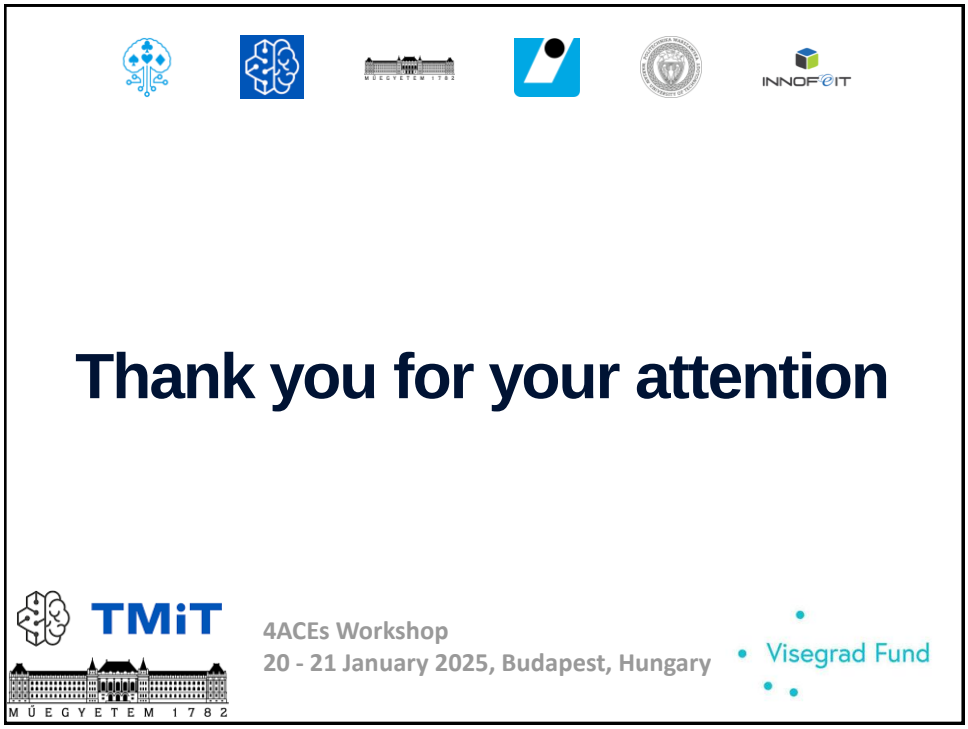
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