University of Ljubljana
Faculty of Computer and Information Science

BIOMEDICAL SIGNAL AND IMAGE PROCESSING

Master degree, 1st / 2nd year

Lecturer: Prof. Franc Jager, PhD
Assistant: As. Žiga Pirnar, MSc

Course: 63514

Course description

- The course introduces techniques and procedures for analysis of biomedical signals and images like:

  - Cardiology signals
    * electrocardiogram - ECG

  - Neurophysiology signals
    * electromyogram – EMG (electrohysterogram - EHG)
    * *(electroencephalogram – EEG; See course: Human-Computer Interaction)*

  - Medical images
    * computed tomography images – CT images

  with the emphasis on problems of biomedical researches.

Course description

- We will recognize how we can automatically detect and classify heart beats and then, non-invasive and punctually, within 24-hour electrocardiogram signals, detect transient ischaemic disease, which is one of the most terrible heart diseases, and if we do not discover it punctually, it may lead to heart infarct.

- We will recognize how we can, using some non-linear signal processing techniques, analyze electromyograms recorded from the abdomen of a pregnant women early during pregnancy (23 week), estimate, or try to predict, danger of pre-term birth.

- We will also recognize techniques of analysis of 2- and 3-dimensional tomographic images with the aim of extraction and visualization of anatomic structures of human body organs.

Course syllabus

- Introduction to Biomedical Signal and Image Processing

- Data Acquisition
- Digital Filters
- Fourier Transform
- The Z Transform
- Frequency-Domain Analysis of Digital Filters

- Electrocardiogram (ECG) and Detecting Transient Ischaemia
- Feature Extraction, Shape Representation and Processing of the ECG

- Spectral Analysis
- Electromyogram (EMG) and Predicting Pre-Term Delivery
- Non-Linear Signal Processing Techniques

Course syllabus

- Image Filtering and Enhancement
- Edge Detection and Segmentation of Images
- Computed Tomography (CT) and Visualization of Human Organs

- Algorithms to Detect Transient ST Segment Episodes

- Performance Measures and Evaluation

- (Semi-Automatic Graphic Editing Tools to Annotate Ambulatory ECG Records)
- (Selected topics)

Topics

- The topics cover:

  - Representation of international standardized databases of signals and images (*MIT/BIH DB*, *LTST DB*, *TPEHG DB*, *TPEHGT DS*, *CTIMG DB*)

  - Techniques for noise extraction
  - Spectral analysis, modeling

  - Techniques for feature extraction from signals and images (filtering techniques, principal components, Karhunen-Loeve transform, sample entropy, edge detection, contour extraction)
  - Analysis and visualization of diagnostic and morphology feature-vector time series, and anatomic structures

  - Event detection, clustering, classifications

  - Metrics, techniques and protocols for performance and robustness evaluation of biomedical computer systems

Environments, sites, and tools for laboratory sessions

- Web classroom

- PhysioNet site, *http://www.physionet.org*
  (source of resources in the field of biomedical signal and image processing)

  - Databases: MIT/BIH DB, LTST DB, TPEHG DB, TPEHGT DS
  - Software: ATM tools, wfdb library, lightWAVE, gnuplot

- Home pages of Laboratory for Biomedical Computer Systems and Imaging (LBCSI),
  http://lbcsi.fri.uni-lj.si
  - Databases: LTST DB, TPEHG DB, TPEHGT DS, CTIMG DB

- Ubuntu 18.04 (LTS), Linux

- C, (C++)

- Matlab

Literature

- Sornmo Leif, Laguna Pablo, Bioelectrical Signal Processing in Cardic and Neurological Applications, 2005, Elsevier Inc.

- Clifford Gari D, Azuaje F, McSharry Patrick E (Editors), Advanced Methods and Tools for ECG Data Analysis, 2006, Artech House Inc.

- Proakis J G, Manolakis D G, Digital Signal Processing, 2014, Prentice Hall Inc. (in our library)

- Gonzales Rafael C, Woods Richard E, Digital Image Processing, 3rd Edition, 2008, Pearson Prentice Hall.

  Gonzales Rafael C, Woods Richard E, Digital Image Processing, 4th Edition, 2018, Pearson Prentice Hall.

- Oppenheim Alan V, Schafer Ronald W, Discrete-Time Signal Processing, Third Edition, 2014, Pearson Education Limited. (in our library)

- Lyons Richard G, Understanding Digital Signal Processing, Third Edition, 2011, Pearson Education, Inc. (in our library)

Laboratory sessions, quiz, exam, grading

- Laboratory assignments (each assignment has to be submitted and explained ongoing):
  1. Analysis of electrocardiogram (ECG) signals
     and analysis of electromyogram (EMG) signals (Max: 45 - 55 points)
  2. Analysis of computed tomography (CT) images (Max: 55 - 65 points)

  → Obligatory: 50 points; Max: 120 points

- Quiz during the semester (by your choice) → Max: 20 points
- Exam at the end of semester: → Obligatory: 50 points; Max: 100 points

- How the preliminary grade (5 – 10) will be composed?

$$\textit{Total score} = \text{round}\left(\left(\text{Laboratory points} + \text{Quiz} + \text{Exam}\right) / 2\right)$$

$$\begin{aligned}
\textit{Total score} &\leq 49 && \rightarrow 5\\
50 \leq \textit{Total score} &\leq 59 && \rightarrow 6\\
60 \leq \textit{Total score} &\leq 69 && \rightarrow 7\\
70 \leq \textit{Total score} &\leq 79 && \rightarrow 8\\
80 \leq \textit{Total score} &\leq 89 && \rightarrow 9\\
90 \leq \textit{Total score} && && \rightarrow 10
\end{aligned}$$

- Oral exam is obligatory.

Physionet / Computing in Cardiology Challenges

- Physionet / 2014 Computing in Cardiology Challenge

  - Robust Detection of Heart Beats in Multimodal Data

  - Students at this course participated at the prototype challenge
  - The actual challenge started on January 2014 and ended on January 2015

  - Urška Pangerc (student at this course) obtained the 2nd, 3rd, 6th, and the final 1st place during the phases I, II, III, and the follow-up phase (end of February 2015) of the competition of the actual challenge (which was not student competition) among 47 international teams (*http://physionet.org/challenge/2014*)

PhysioNet / 2014 Computing in Cardiology Challenge

Focus issue entry	Score (%)
Pangerc and Jager (2015)	93.64
Johnson *et al* (2015)	91.50
Antink *et al* (2015)	90.70
DeCooman *et al* (2015)	90.02
Galeotti *et al* (2015)	89.73
*Vollmer M	89.55
Pimentel *et al* (2015)	89.13
Mollakazemi *et al* (2015)	88.85
*Krug J	88.34
Gieraltowski *et al* (2015)	88.07
C-code sample entry	87.38
M-code sample entry	85.04

Source: Silva I, Moody B, Behar J, Johnson A, Oster J, Clifford GD, Moody GB, Editorial: Robust Detection of Heart Beats in Multimodal Data, Physiological Measurement, 36:1629–1644, 2015. (*http://iopscience.iop.org/0967-3334/36/8/1629*)

Physionet / Computing in Cardiology Challenges

- Physionet / 2020 Computing in Cardiology Challenge
  - The topic has not been decided yet

- Participating at the topics from the past challenges is possible (see: *http://physionet.org/challenge/*)