Biomedical signal processing

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Goals: Physiological signal processing, including ECG (electrocardiogram), PPG (photoplethysmography), and blood pressure, by means of adaptive transformation methods and model-based machine learning. Development environment: Matlab and Python (numpy/pytorch).

Topics:

1. **Blood pressure estimation (in progress, possible to join)**
   Estimation of continuous blood pressure using non-invasive physiological signals, like ECG and PPG. The changes of blood pressure over time may be diagnostically significant, but continuous blood pressure monitoring is currently possible only invasively, in a clinical environment. Non-invasive techniques (e.g. cuff-based methods) have limitations and they provide only discrete measurements. Estimation of blood pressure with ECG and PPG provides a non-invasive alternative, using easily obtainable physiological signals. The task is to implement the existing analytic models (see e.g. [1]), to develop estimation models using adaptive transformation techniques and neural networks, and to evaluate the models on public datasets (e.g. on VitalDB [2]).

2. **Multi-parameter physiological signals**
   Physiological anomalies (e.g. arrhythmia, blood pressure disorders) affect multiple biomedical signals (like ECG, PPG, blood pressure). The task is to investigate simultaneous, multi-parameter datasets: develop joint adaptive models, multi-parameter feature extraction, detection and classification, optimal feature selection.

3. **~~ECG processing using halfwave decomposition~~ (in progress)**
   Halfwave decomposition is a simple time-domain transformation technique that produces a 'skeleton' for the input signal (see [3], Fig. 1). Halfwave became less popular than the traditional transformation methods (like Fourier, wavelets, VarPro), but provides a lightweight alternative that can be investigated for ECG signal processing as well (including filtering, heartbeat detection, fiducial point detection, and feature extraction). The task is to implement halfwave decomposition as of [4], application to ECG signals, comparison to other transformation methods, and evaluation on the benchmark MIT-BIH Arrhythmia Database [5] (signal representation, arrhythmia detection, feature extraction for machine learning). Further tasks include to study the theoretical properties of the transformation, and to investigate the possible relation with wavelets and morphological operators.

References:

[1] J. Lee, S. Yang, S. Lee, H. C. Kim. **"Analysis of Pulse Arrival Time as an Indicator of Blood Pressure in a Large Surgical Biosignal Database: Recommendations for Developing Ubiquitous Blood Pressure Monitoring Methods."** In: *J. Clin. Med.* 8 (2019), 1773. DOI: 10.3390/jcm8111773

[2] **VitalDB.** Online: https://vitaldb.net/dataset/ (accessed 16 September 2023)

[3] J. Gotman and P. Gloor. **"Automatic recognition and quantification of interictal epileptic activity in the human scalp EEG."** In: *Electroencephalogr. Clin. Neurophysiol.* 41(5) (1976), 512–529. DOI: 10.1016/0013-4694(76)90063-8

[4] Y. Paul and S. Fridli. "Sleep states detection using halfwave and Franklin transformation." (2020). DOI: 10.21203/rs.3.rs-27562/v1

[5] **MIT-BIH Arrhythmia Database** on *PhysioNet*. Online: https://www.physionet.org/content/mitdb/ (accessed 16 September 2023)