Machine Learning in Signal Processing

TKP workshop 2022 – Signals and systems research group

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November 4, 2022

Nemzeti Kutatási, Fejlesztési és Innovációs Hivatal

AZ NKFI ALAPBÓL MEGVALÓSULÓ PROJEKT

Outline

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Traditional signal processing methods

Statistical signal processing

- Interpretation as random, stochastic processes
- Model-based statistical methods
- Estimation and detection theory
- E.g. telecommunications, data transmission and equalization

Transformation methods

- Time- and frequency domain transformations (e.g. Fourier, Wavelets)
- Analysis and/or filtering of signals
- Feature extraction for machine learning

Motivations

Adaptive transformation methods

- Model-based approach
- Adaptive, parametric system based on domain knowledge
- Optimized, signal-adapted representation

Machine learning applications

- Model-based approach $\rightarrow$ data-driven approach
- Model-based feature extraction
- Model-driven deep learning architectures

Applications

Anomaly detection

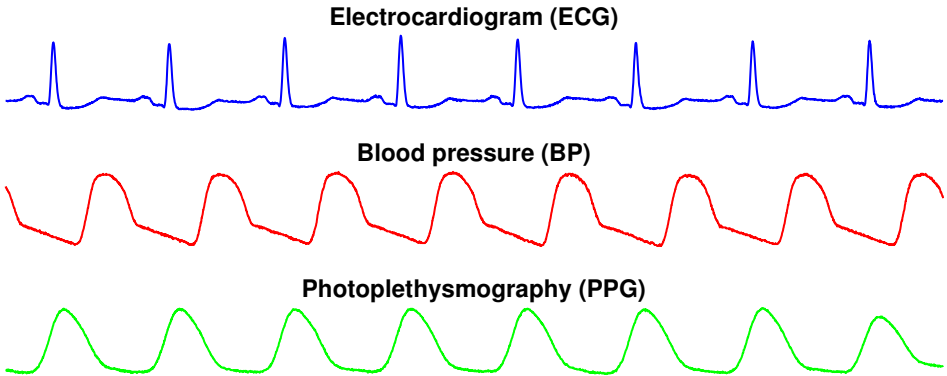
- Biomedical signal processing
- Physiological status monitoring, support systems for medical experts
- Combination of model-based methods with machine learning

Telecommunications

- Signal processing for wireless communications
- Performance and security enhancement
- Combination of model-based methods with machine learning

Outline

Biomedical signals



Source: VitalDB (PhysioNet)

Motivations

Previous methods

- Domain knowledge: signal morphology
- Adaptive transformations with variable projection
- Traditional machine learning approach

  Model-based feature extraction with black-box machine learning
- Model-driven neural network construction (VPNet)

  Domain knowledge incorporated into the network architecture

Applications

- ECG: arrhythmia classification, segmentation, compression, ...
- EEG: seizure detection, sleep state detection, ...

Research I.

Goal

- Anomaly detection with ECG and BP
- Expectation: multiple parameters $\Longrightarrow$ more reliable detection

Methodology

- Open-access multi-parameter datasets
  (MIT-BIH Polysomnographic Database, MIMIC III (PhysioNet))
- Joint adaptive model of ECG and BP, based on physiological connection
- Multi-parameter feature extraction for machine learning
- Identification of optimal feature set
- Future: multi-parameter model-driven neural network construction

Research II.

Goal

- BP estimation using ECG and PPG
- Hidden anomaly detection on BP

Methodology

- Open-access multi-parameter datasets (VitalDB, MIMIC III (PhysioNet))
- Model-based analytical methods and model-driven machine learning

Cooperations

- University Medical Center Göttingen (Germany)
- Institute of Signal Processing, Johannes Kepler University Linz (Austria)

Outline

Motivations

Research focus

- Physical layer of wireless communications
- Noisy multipath channel, *unique word* (UW)-OFDM transmission scheme
- Data equalization during the transmission

Previous methods

- Domain knowledge: channel model, channel estimate
- Traditional approach: statistical signal processing equalization
- Theoretically optimal estimators are unrealizable in practice

  Practical approximations are suboptimal

Research I.

Goal

- Performance enhancement of equalization (optimal bit-error-ratio)
- Model-based $\rightarrow$ data-driven approach with neural networks

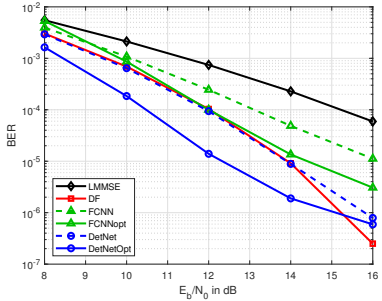
Methodology

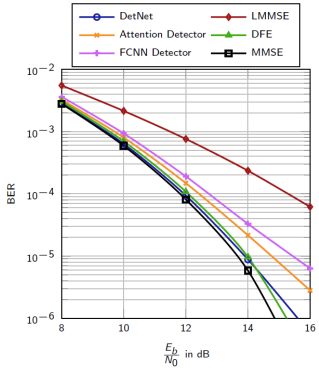
- Domain knowledge $\rightarrow$ known architectures (fully-connected, attention)
- Model-driven neural networks (deep unfolding)
- End-to-end learning: optimal transmitter-receiver setup

Cooperations

- Institute of Signal Processing, Johannes Kepler University Linz (Austria)
- JKU LIT eSPML Lab, Silicon Austria Labs (Linz, Austria)

Results





[1] G. Bognár, S. Baumgartner, O. Lang, M. Huemer. Neural Network Optimal UW-OFDM, Proc. of the 55th Annual Asilomar Conference on Signals, Systems, and Computers, 2021.
[2] S. Baumgartner, G. Bognár, O. Lang, M. Huemer. Neural Network Approaches for Data Estimation in Unique Word OFDM Systems, to be submitted.

Research II.

Goal

- Security enhancement of data transmission
- Physical layer encryption

Methodology

- Model-based statistical signal processing approach
- Future: model-driven neural networks, end-to-end learning

Cooperations

- Institute of Signal Processing, Johannes Kepler University Linz (Austria)
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Thank you for your attention!

Project no. TKP2021-NVA-29 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the TKP2021-NVA funding scheme.