Dresden University of Technology

ComNets Deutsche Telekom Chair of Communication Networks

Fakultät Elektrotechnik und Informationstechnik

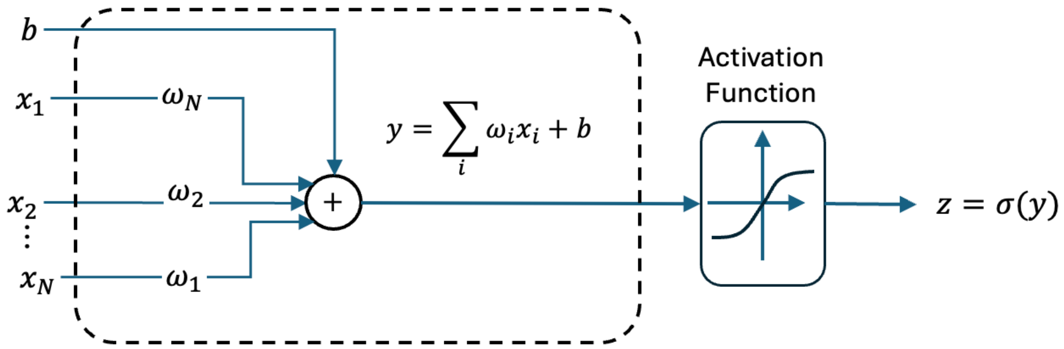
Institut für Nachrichtentechnik, Deutsche Telekom Professur für Kommunikationsnetze

Neural Network–Based Signal Detection in Noisy Channels: Performance and Robustness Evaluation

Project topic for Oberseminar Informationstechnik 2025/2026

Description:

Neural networks (NNs) are becoming relevant in modern communication systems, particularly for tasks such as signal detection, equalization, and modulation classification. Traditional receivers are designed analytically for known channel models (e.g., AWGN channels) and can achieve optimal performance. However, in practical or nonlinear environments, NNs can learn to perform similar detection tasks without explicit mathematical models.



In this project, a (feedforward) NN will be designed, trained, and evaluated for signal detection in a simulated communication system. The focus is on understanding the robustness and reliability of such NN-based detectors under realistic constraints, including limited training data, channel noise variation, and neuron-level faults.

The project will begin by implementing a communication channel where transmitted symbols are affected by noise. The task is to design a NN-based receiver in Python (using PyTorch or TensorFlow) to recover the transmitted symbols. The network's behavior will be analyzed through a series of changed boundary conditions — varying dataset size, signal-to-noise ratio (SNR), and artificially injected neuron or weight faults.

Tasks:

1. Literature and Background
    - Study fundamentals of communication channels and noise models (e.g., AWGN).

    - Review basic neural network architectures and training principles.
2. Baseline Implementation
    - Implement a transmission channel in Python (generate random bits, map to symbols, add noise).
    - Implement the analytical (optimal) detector for BER comparison.
3. NN Design and Training
    - Build a (feedforward) NN for bit detection using a framework such as PyTorch.
    - Train the model for different SNRs and dataset sizes.
    - Evaluate the NN-based detector's performance versus the optimal baseline.
4. Robustness and Sensitivity Analysis
    - Analyze the impact of varying training dataset size on BER.
    - Investigate robustness to neuron or weight faults (simulate failures in hidden layers).
    - Study generalization: train at one SNR, test at others.
5. Visualization and Evaluation
    - Produce reproducible plots showing, e.g., BER vs. SNR, BER vs. training dataset size, BER vs. neuron fault probability.
    - Summarize findings and interpret trade-offs between accuracy, data efficiency, and fault robustness.

Keywords: Machine Learning, Neural Networks, Communication Systems, Bit Error Rate, Fault Tolerance, Signal Detection, Noise
Language: English, German
Contact: pit.hofmann@tu-dresden.de