Fachhochschule Nordwestschweiz
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P-Wave Detection in Multi-Channel Esophageal Electrocardiography: A Hybrid Model Approach

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Master-Thesis, Specialization Biomedical Engineering

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Introduction

The introduction of esophageal ECG (Fig. 1) aims to enhance diagnostics for atrial pathologies. However, the indirect detection of P-waves still poses a challenge for commercially available systems [1]. This work seeks to explore a hybrid approach incorporating model-based signal processing and machine learning to address this challenge.

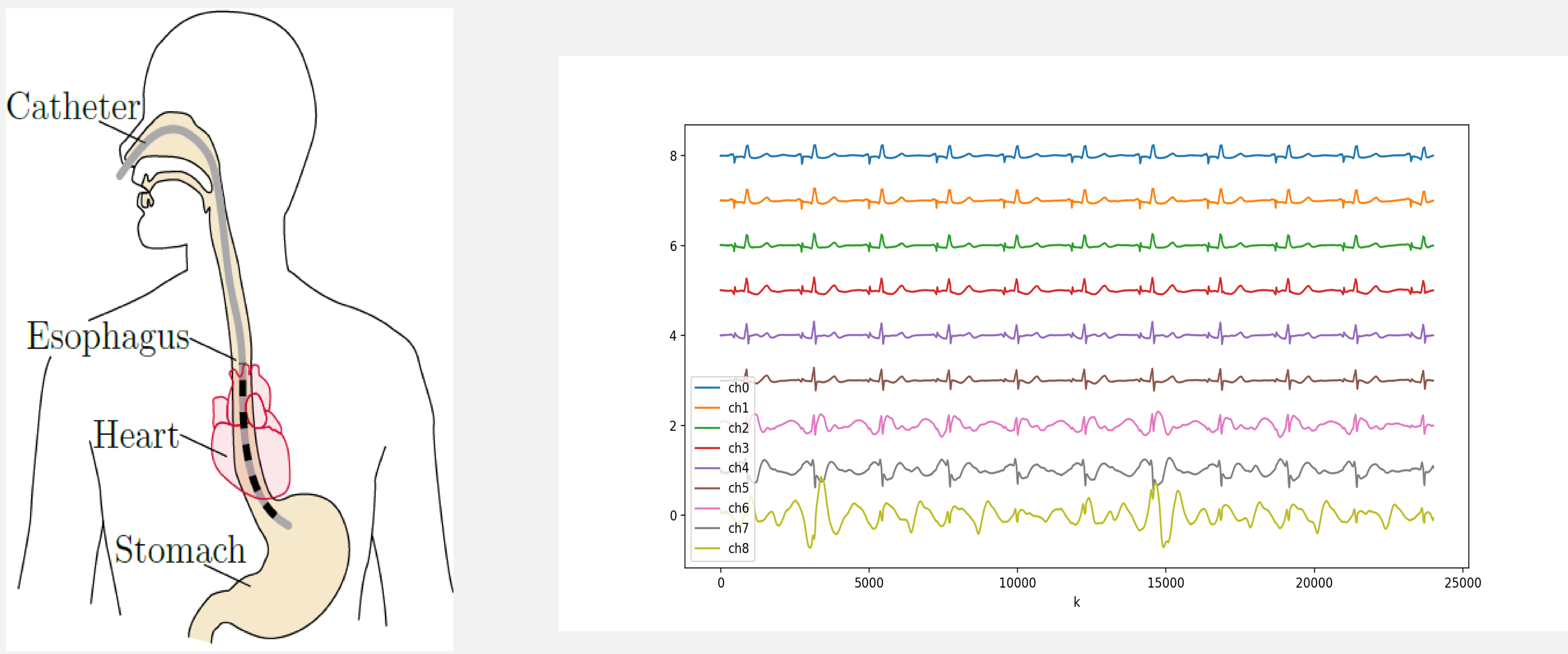

Figure 1: Schematic representation of the application of the esophageal ECG and a real signal. [2][3]

Methods

Model-based signal processing is used for the generation of the input data for the following model. The probability of occurrence of an edge is calculated with different parameters (L , α and $l = 200$), that consider the surrounding signal values (Fig. 2). [4]
The obtained data is fed into a random forest or neural network and the accuracy is determined.

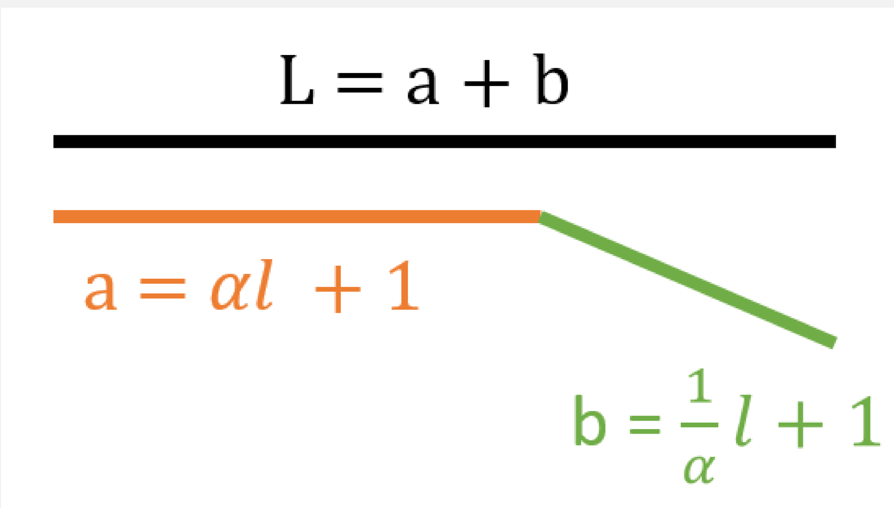

Figure 2: Schematic representation of the parameters used for the calculation of the features via a model-based signal processing approach.

Results

Tab. 1 shows the accuracy results for both approaches per signal-to-noise ratio (SNR).

SNR	Random forest [%]	Neural network [%]
198.00	100.00 ± 0.00	100.00 ± 0.0
2.43	98.82 ± 3.74	99.84 ± 0.18
1.04	91.85 ± 1.03	96.79 ± 1.87
0.92	82.43 ± 2.10	90.57 ± 3.71

Table 1: Accuracy results for the random forest and a 3-layer fully connected feed-forward neural network.

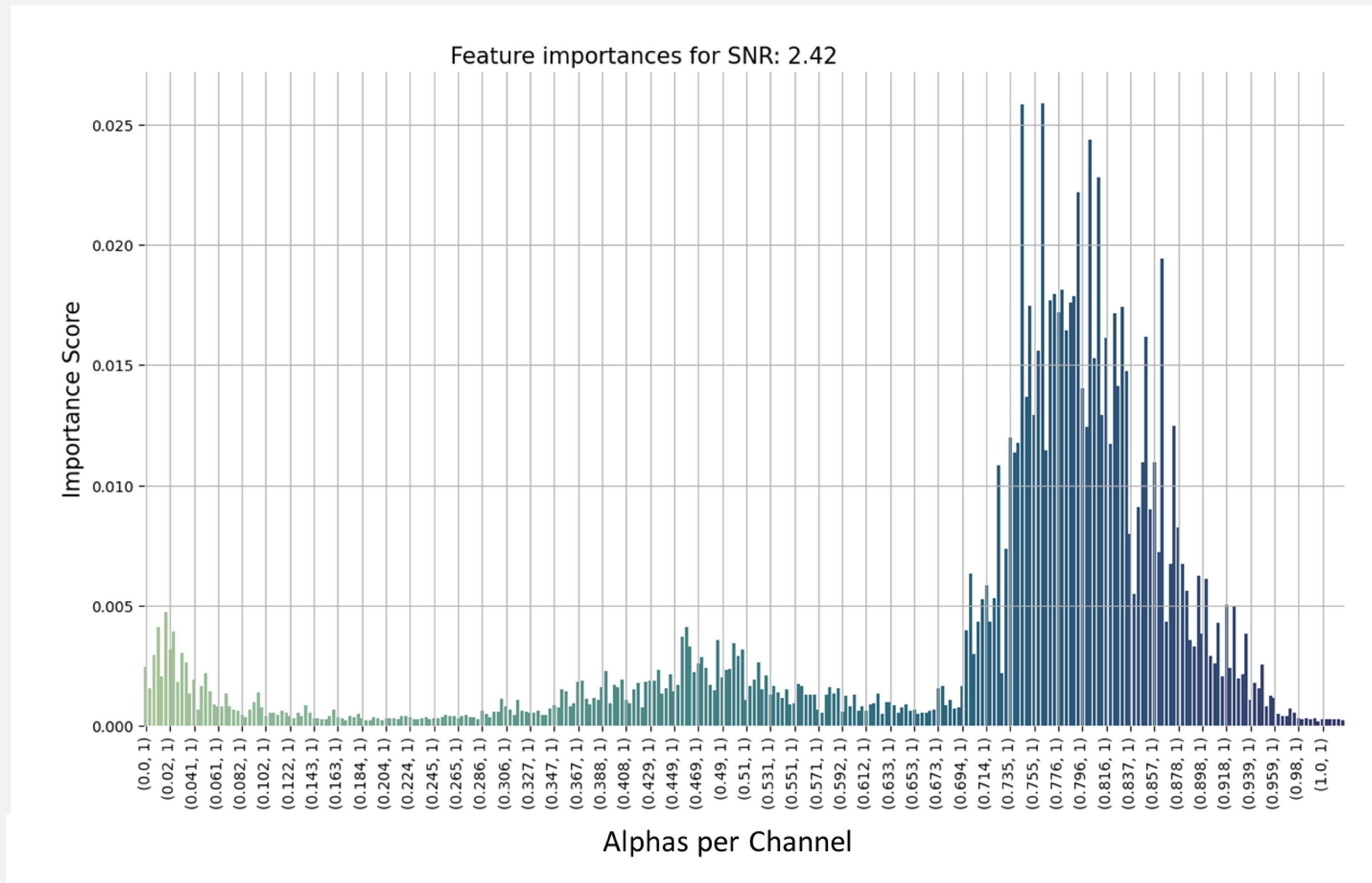

Figure 3: Feature importance distribution for the random forest algorithm with 50 values for alpha and 6 different channels.

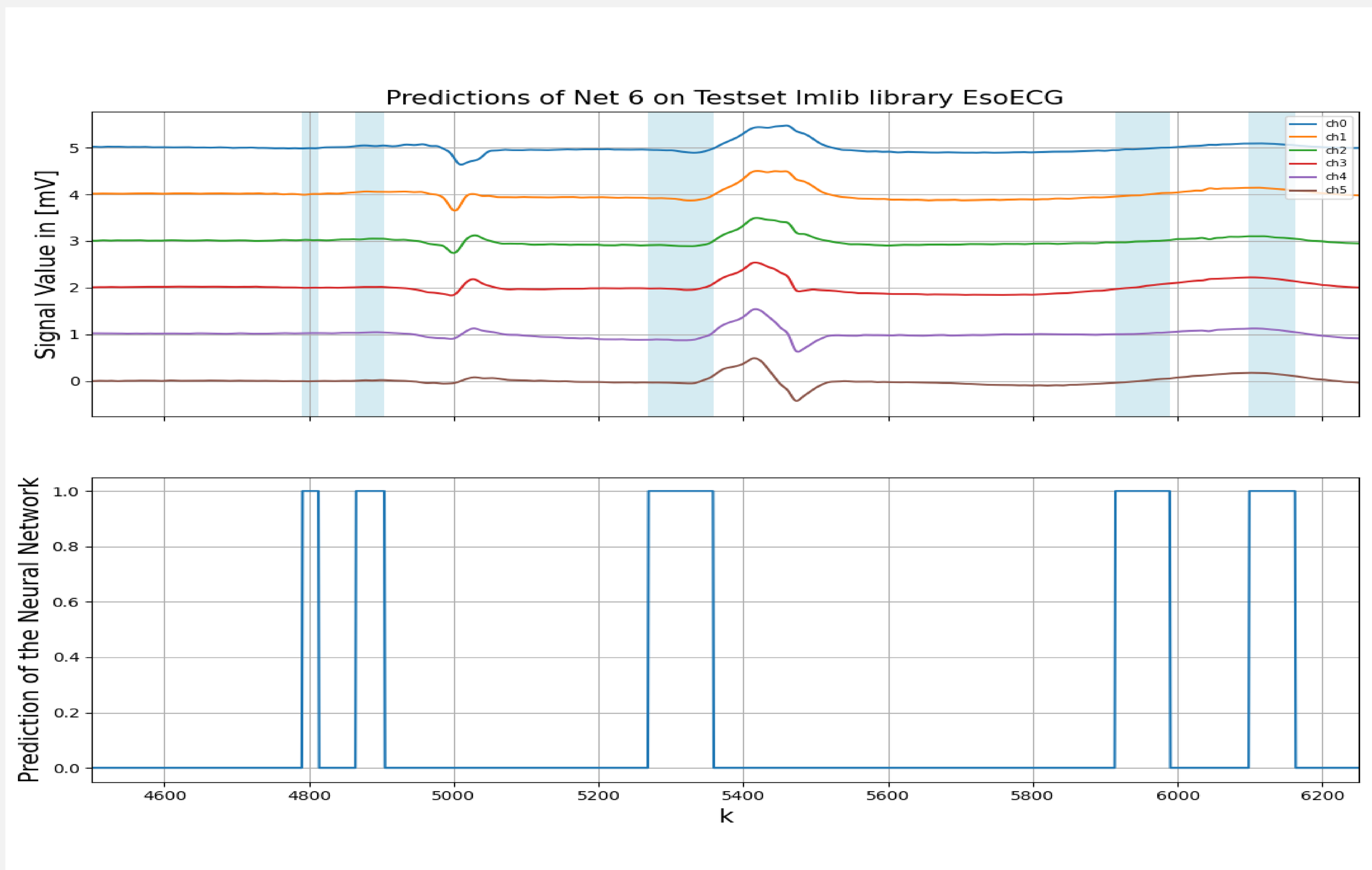

Figure 4: Application of the trained neural network with SNR = 1.04 onto a real EsoECG signal from the lmlib library.

Conclusion

Both hybrid models show high potential for further investigation. The neural network showed a slightly higher performance compared to the random forest.
Figure 3 shows that the parameters with α > 0.7 and α < 0.9 show the highest importance. the highest importance of the parameters with α > 0.7 and α < 0.9

References

[1] Lucie Saclova et al. “Reliable P wave detection in pathological ECG signals”. In: Sci Rep 12.1 (Apr. 21, 2022), p. 658
[2] Raphael Andonie. “Time-Adaptive Algorithms for Low-Power Medical Devices, 2021
[3] lmlib: Model-Based Signal Processing — lmlib 2.1.2 documentation. url: https://lmlib.ch/stable/html/ (visited on 02/14/2024)
[4] Frédéric Waldmann et al. “Onset Detection of Pulse-Shaped Bioelectrical Signals Using Linear State Space Models”. In: Current Directions in Biomedical Engineering 8.2 (Sept. 2,2022), pp. 101–104.

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