RABBIT TO HUMAN: TRANSFER LEARNING FOR ECG DELINEATION

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Introduction

Accurate identification of the P-wave, QRS complex, and T-wave of the electrocardiogram (ECG) is important for diagnosing cardiac disorders. Previous work has demonstrated the superiority of deep neural networks (DNNs) over traditional algorithms in ECG delineation [1,2]. Furthermore, transfer learning (TL) has been shown to enhance the performance of DNNs and to decrease the training time needed for the target dataset [3]. In the context of ECGs, TL has already been applied within the same species for arrhythmia classification, but a cross-species approach has not yet been explored. Here, for the first time, we propose using TL from animal to human data for ECG delineation.

Methods

Two datasets were utilized: (1) 9 hours of ECG recordings from 7 rabbits sampled at 1000 Hz [4] with ~ 85 thousand beats, and (2) an 18-hour Holter ECG of one heart failure patient sampled at 250 Hz [5] with ~ 120 thousand beats. The study protocol was approved by the Institutional Review Board (ClinicalTrials.gov Identifier: NCT04641416). All participants provided written informed consent. Datasets were manually annotated for one of four classes: P-wave, T-wave, QRS Complex, or No wave. The models underwent pre-training on the rabbit dataset (80/20 train-test split) to evaluate various architectures. A hyperparameter grid optimization via 5-fold cross-validation was performed. Model performance was assessed on unseen rabbit data. The best-performing model was additionally tested on the human dataset. The final DNN architecture included one 1D convolutional neural network (CNN) layer, three bidirectional long short-term memory (BiLSTM) layers, and a dense output layer. Subsequently, TL was applied to fine-tune the best-performing model on the human dataset. Fine-tuning was performed by freezing specific network layers (e.g., the CNN and first BiLSTM layer) while only retraining the active layers. The efficacy of the TL approach was assessed by accuracy and F1-Score for the human ECGs. All computations were performed using an NVIDIA A100 40 GB GPU.

Results

Pretraining required 5 hours, while the TL approach averaged just 1 hour. The best-performing pretrained network achieved an accuracy of 95.7% and an F1-Score of 95.8% on unseen rabbit data, and notably lower performance on human data, with an accuracy of only 57.5% and an F1-Score of 53.0%. Employing TL significantly enhanced the delineation performance with an accuracy of 95.9% and an F1-Score of 95.6%.

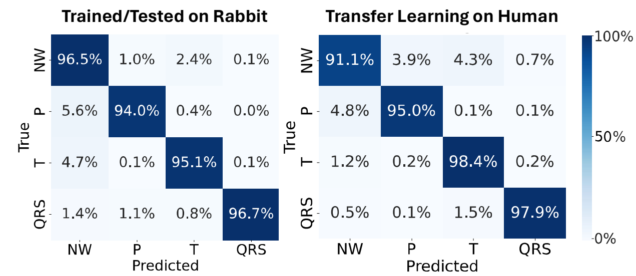

Figure 1: Confusion matrices of the network trained and tested on the rabbit dataset (left) and the transfer learning approach on the human dataset (right). QRS: QRS-complex, T: T-wave, P: P-wave, NW: no wave.

Discussion

TL was successfully employed for ECG delineation across species going from rabbit to human, while significantly reducing computational training time without sacrificing performance. The current study was focused on a patient-specific approach; however, future work aims at scaling this approach to a larger patient population, thereby enhancing its generalizability.

References

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