Recent Advances in ECG Arrhythmia Detection: A Review with 2D Convolutional Neural Networks and Contemporary Deep Learning Approaches

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Abstract

Electrocardiogram (ECG)-based arrhythmia detection is a critical task in modern healthcare, enabling early diagnosis of life threatening cardiac conditions. In recent years, deep learning models—particularly convolutional neural networks (CNNs) - have shown remarkable performance in automatically identifying abnormal heart rhythms. This paper presents a review of ECG arrhythmia detection methods with a primary focus on 2D CNN architectures applied to time frequency representations of ECG signals. We detail our implementation of a 2D CNN-based classification model, trained and evaluated on the MIT-BIH Arrhythmia Database, achieving classification accuracy of 86.12%, along with robust sensitivity and specificity metrics.

While 2D CNNs effectively capture spatial patterns in ECG transformations such as spectrograms or Gramian angular fields, recent advancements offer promising alternatives. We review emerging techniques including transformer-based architectures (e.g., ECG-BERT), representation learning, approaches self-supervised and that generalization, data scarcity, and privacy concerns. By integrating our findings with a discussion of methods, this current paper state-of-the-art provides comprehensive perspective on the evolving landscape of deep learning-based ECG arrhythmia detection. Future work aims to hybridize 2D CNNs with transformer models for improved temporal modelling and real time deployment on wearable devices.