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Use of Time or Frequency Domain in ECG Analysis

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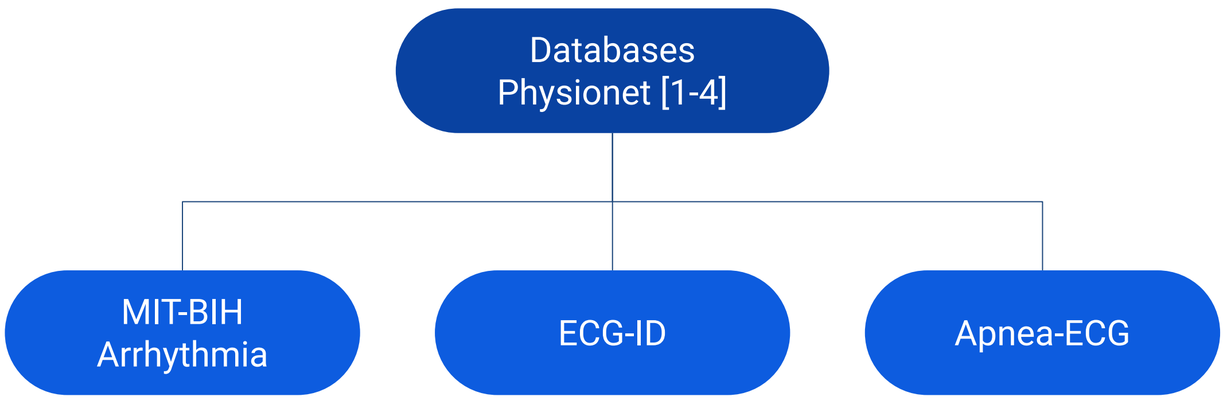
INTRODUCTION & AIM

Machine learning techniques have been widely applied in the medical field, with electrocardiogram (ECG) signals being pivotal for detecting arrhythmias and other applications such as sleep analysis and biometric identity recognition. Traditionally, selecting the right features was essential for achieving good performance in classification. However, with the advent of deep learning, particularly convolutional neural networks (CNNs), the classifier itself extracts and selects the relevant features. This development raises the question of whether it is necessary to represent ECG data in different domains, such as the frequency domain, for optimal performance.

This study aims to evaluate the performance of CNNs in three tasks: classification of arrhythmia, apnea detection and identity recognition, using three input formats: time sequence, Fourier frequency components and spectrogram.

METHOD



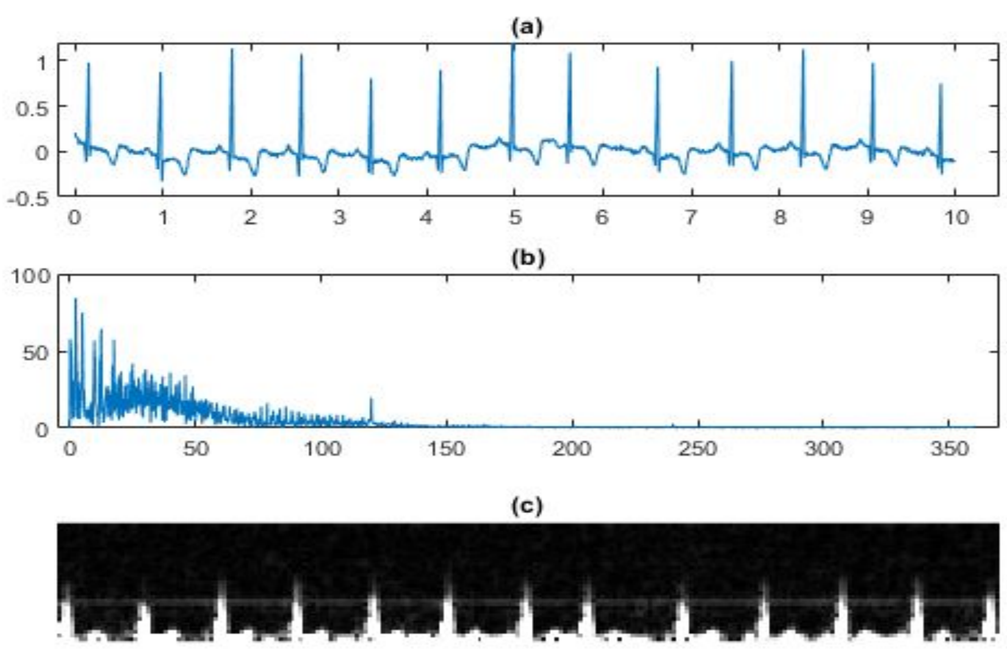


Figure 1. Illustration of segment of ECG from MIT-BIH Arrhythmia database represented using: (a) time series; (b) Fourier frequency components; (c) spectrogram

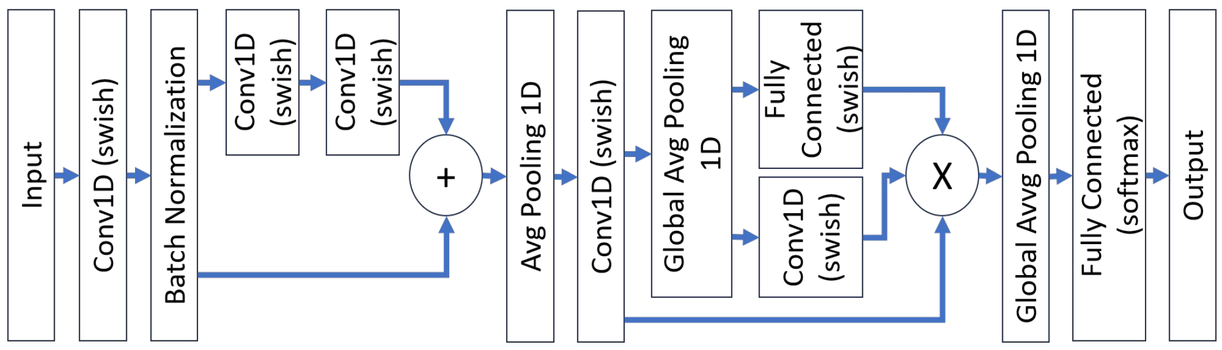


Figure 2. Architecture of the network used for time series and Fourier frequency components as inputs

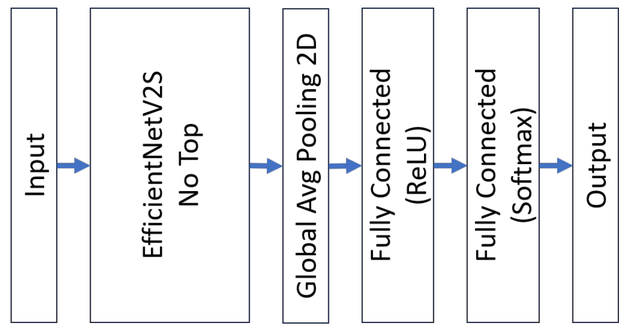


Figure 3. Architecture of the network used for spectrogram as inputs

Table I. Number of folds for cross-validation

Database	Numbers of folds
ECG ID	4 - fold
MIT-BIH Apnea-ECG	10 - fold

RESULTS

Table II. Mean and standard deviation values for each data representation at each database

Database	Data Representation	Accuracy (%)
ECG ID	Time	99,13 ± 0,39
ECG ID	FFT	95,77 ± 0,60
ECG ID	Spectrogram	95,97 ± 0,86
MIT-BIH	Time	99,37 ± 0,29
MIT-BIH	FFT	97,97 ± 0,86
MIT-BIH	Spectrogram	98,93 ± 0,38
Apnea-ECG	Time	94,56 ± 0,72
Apnea-ECG	FFT	89,20 ± 0,97
Apnea-ECG	Spectrogram	93,12 ± 0,52

CONCLUSION

The mean accuracy obtained for each task was consistently higher when using the time domain compared to the frequency domain, with differences ranging from 1.4% to 5.4%. Considering that obtained rates of accuracy have a normal distribution, the maximum p-value of one-tailed Student's t-test between Time network and others was 2.4e-4, showing that there are significant difference. Consequently, there is no advantage in transforming time-series data into the frequency domain for these tasks.

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