ECG Heartbeat Classification using a 1D Convolutional Neural Network

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1 Introduction

One of the most commonly used methods of assessing the functioning of the heart through the use of non-invasive means is via an electrocardiogram (ECG). An ECG is a recording of the electrical impulses generated by the heart over a set period of time in the form of characteristic waves: P-waves, QRS complexes, and T-waves. These waves provide valuable clinical information regarding the possible existence of cardiac pathology. Therefore, the accurate classification of ECG beats from the ECG is a critical component of both biomedical signal processing and computer-aided diagnosis.

Manual ECG analysis performed by healthcare professionals and physicians typically takes a considerable amount of time to complete. Additionally, because clinicians may experience fatigue or become distracted when evaluating large amounts of data over long periods of time, they may make mistakes when attempting to determine the type of ECG signal. As such, researchers have developed various machine-learning and deep-learning algorithms to expedite the process of classifying ECG beats, and to provide physicians with greater accuracy and consistency when diagnosing arrhythmias.

In this project, we will investigate the ECG classification task using the MIT-BIH arrhythmia database made available on Kaggle. Each ECG beat from the MIT-BIH database has been sampled as a one-dimensional (1D) time series of fixed length. The specific objectives of this project include conducting a basic exploratory data analysis of the MIT-BIH dataset, training a single deep-learning model to classify multiple classes of ECG beats, and evaluating the classification results using standard classification metrics.

2 Dataset Description and Exploratory Data Analysis

Kaggle provided the original dataset used for this analysis (MIT-BIH Arrhythmia), which can be downloaded with the kagglehub's command. The dataset is represented as two files: mitbih_train.csv - the training dataset, and mitbih_test.csv - the test dataset.

Each example represents an ECG heartbeat and includes 187 numbers which represent the amplitude of the ECG signal in each of its time points, and one class label, which corresponds to the class of this heartbeat. In total there are 5 classes of heartbeat. The training dataset contains 87554 examples, the test dataset contains 21892 examples.

The exploratory analyses indicate that the dataset is heavily skewed; class 0 (a normal heartbeat) has a much higher frequency than any of the other classes, due to this heavy skew class 3 has an extremely small number of examples. The class imbalance creates a problem for the classification models, because the classifiers may be biased to predicting the dominating class (class 0).

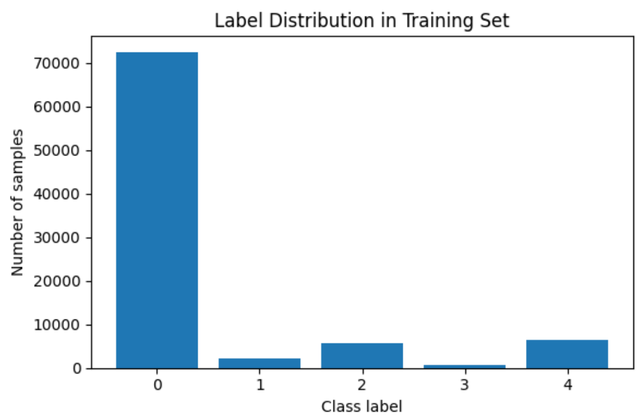

Figure 1: Label distribution of the training set.

3 Methodology

3.1 Model Selection

ECG signals are one-dimensional time series data that have local temporal patterns with a lot of meaning across time. Therefore, we decided to go with a one-dimensional Convolutional Neural Network model (CNN 1D) to perform the task. CNN 1D models are able to learn local temporal features using convolutional filters and can automatically create features from the original ECG signal; there is no need for manual feature engineering.

3.2 Model Architecture

Two convolutional layers and two max-pooling layers are included in the designed CNN 1D Architecture to provide feature extraction and dimensionality reduction capabilities. The use of dropout with a fully-connected dense layer will help minimize the risk of overfitting. The softmax activation function will be used in the output layer to classify each heartbeat into one of five possible classifications.

In training the model, the Adam optimizer will be utilized with categorical cross-entropy as the loss function.

4 Experimental Results

Following the training of the model using a stratified validation split, the following performance metrics were obtained from the test dataset.

- Test Accuracy: 97.84%
- Test Loss: 0.087

Results from the confusion matrix indicate that the model has performed relatively well in classifying objects in the majority class, while only achieving low levels of recall (i.e., false negatives) with respect to classified objects in the minority classes because there were a limited number of training examples available for each class.

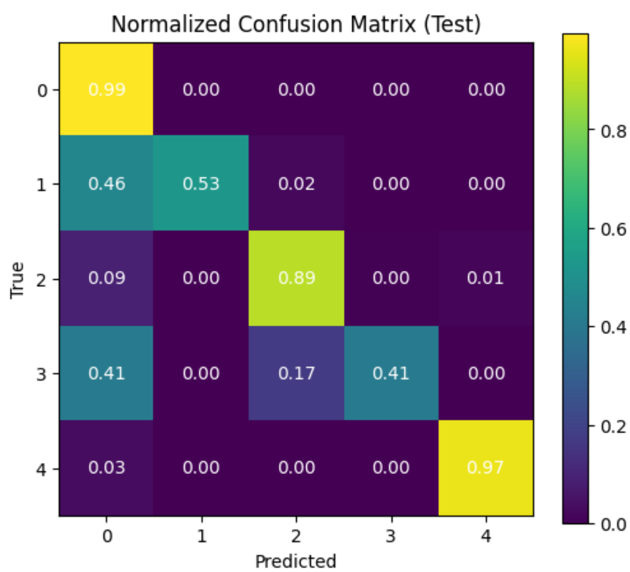

Figure 2: Normalized confusion matrix on the test set.

5 Discussion

The accuracy is generally high, though significant differences between the weighted F1 score and the macro-averaged F1 score demonstrate how class imbalances affect a classifier's performance as it performs poorly for the classes that are overrepresented(since bias is forming within the model). Studies using another dataset (MIT-BIH) support this.

6 Conclusion

In this project, a CNN 1D model was developed to classify heartbeat data recorded using an ECG recording device the MIT-BIH Arrhythmia dataset. The accuracy achieved by the model was high with good generalization performance. However, there were issues related to the class imbalance between the heartbeats especially in the more rare cases of the heartbeats. In conclusion, the CNN 1D method used to classify the ECG heartbeat data was effective and appropriate for the purpose of this laboratory exercise.