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Electrocardiogram(ECG) Based Auto-encoder Models for Cardiovascular Disease Detection

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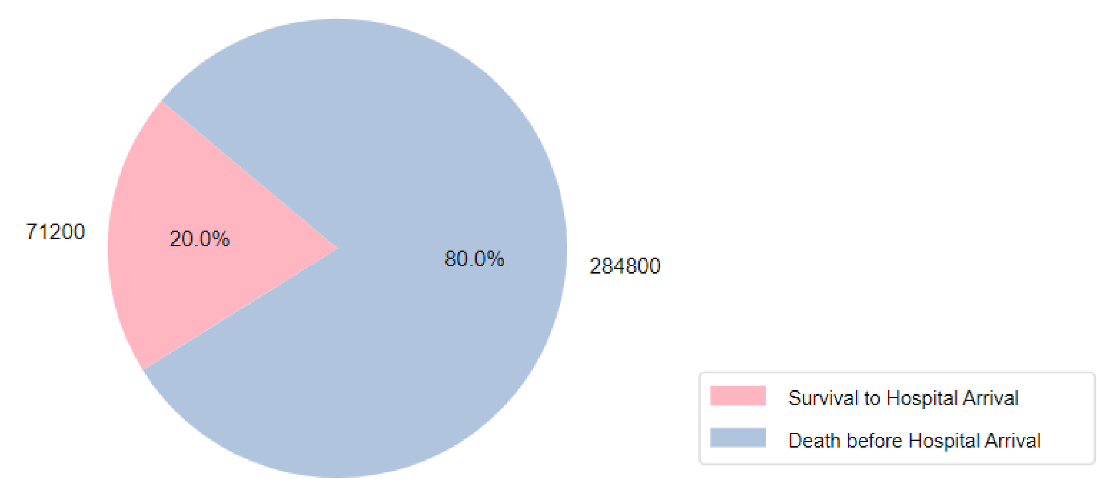
Background

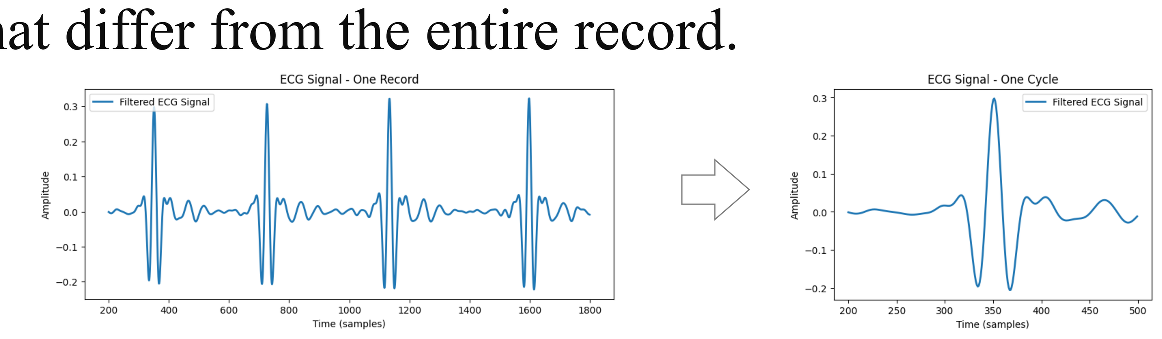
Outcomes of Out-of-Hospital Cardiac Arrests in the U.S.



- **Motivation:** Over 356,000 out-of-hospital cardiac arrests occur annually in the U.S., with up to 80% resulting in death before hospital arrival, showing the need for **an efficient solution to continuously monitor cardiovascular disease in daily life.**
- **Goal:** We aim to build unsupervised single-class auto-encoder models for anomaly detection via electrocardiogram(ECG) signal cycles.

Challenges

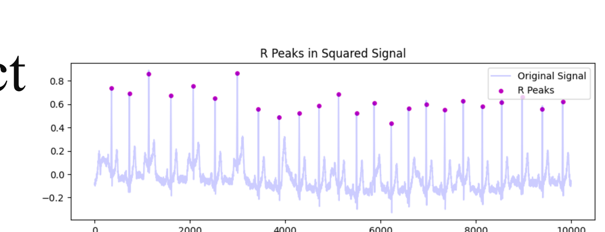
- **Using single cycle**: The label set of the ECG dataset is for the entire record. To detect immediacy, we *extract each cycle* and risk having wrong labels in single cycles that differ from the entire record.



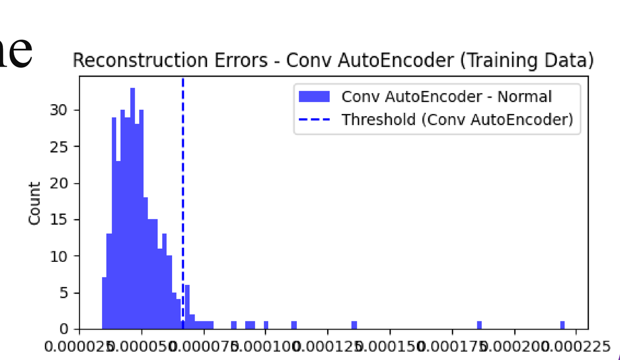
- **Computational Constraints**: Target portable devices have limited processing power. Thus, we must use only *one lead* to make predictions.
- **Disease diversity:** Some anomaly detection algorithms often only apply to a limited number of specific disease types. We try to evaluate *a variety of diseases.*

Key Concepts

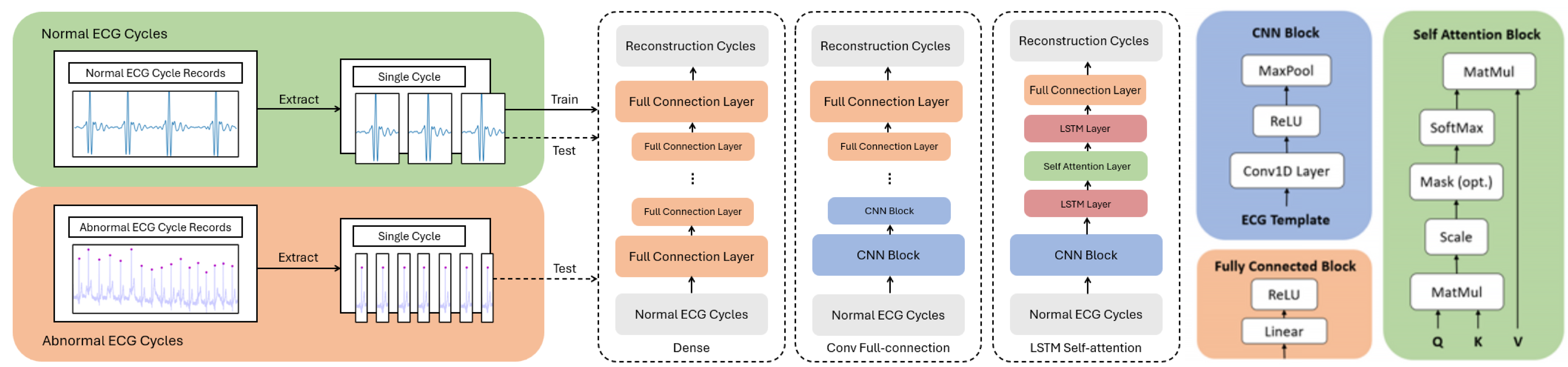
- **ECG Signal Processing:** Detect P/Q/R/S/T points in single-lead ECG signals and analyze cycles.



- **Abnormal Detection:** Using the auto-encoder model to process and reconstruct the signal. The reconstruction error of abnormal data will be larger than normal.



Framework



The framework shows the workflow of the project: 1) De-noise, extract, and sample the data, then use normal data to build a single classifier model and optimize the objective function, the MSE reconstruction error; 2) Test on normal and abnormal data to verify the effect of distinguishing the reconstruction errors of different data. The figure shows the three models built.

Results

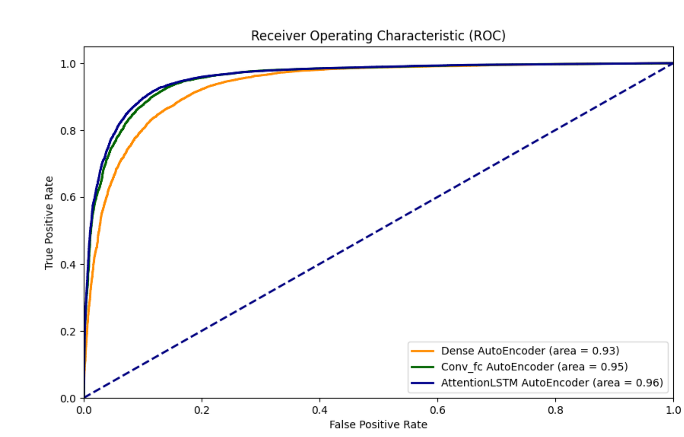
Model	Recall	Precision	F1 Score
Model A	0.9266	0.8138	0.8666
Model B	0.9148	0.8178	0.8636
Model C	0.9039	0.8469	0.8744

Table 1: Performance Metrics for Different Models

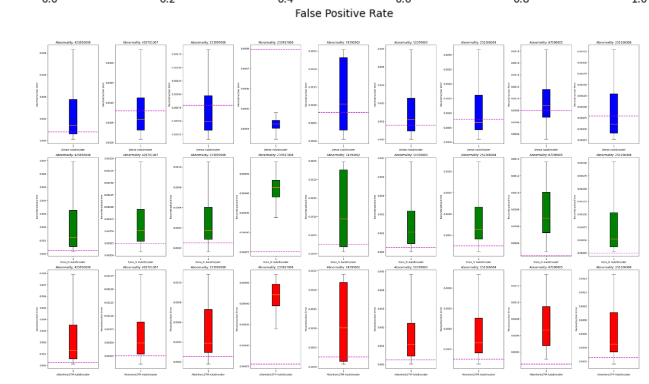
Score: While the recall rate is as high as more than 90% (which means that possible anomalies will not be missing), the F1 Score remains above 0.86.

Core Findings

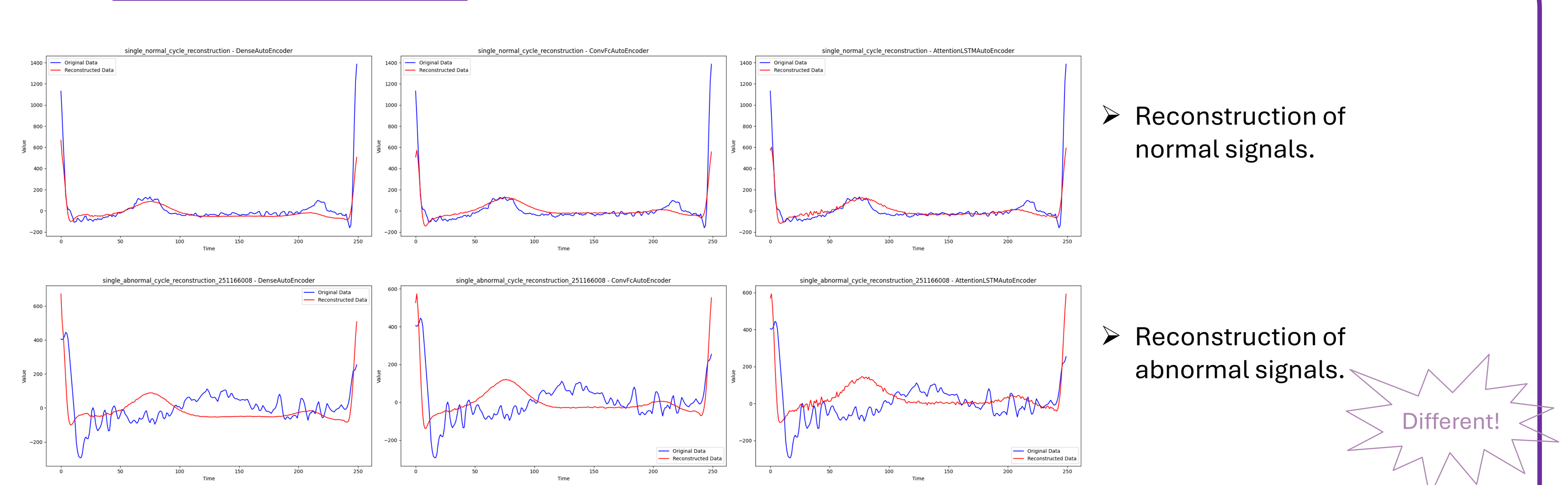
- **Great Performance:** The three models showed strong performance in detecting abnormal ECG cycles. As shown in the figure, the area of the ROC curve is close to 1, indicating good classification performance.



- **Analysis of Disease Labels:** We analyzed the reconstruction characteristics of all single disease labels. This analysis lays the groundwork for prioritizing diseases for monitoring based on reconstruction features.



Conclusion



In conclusion, this project successfully developed and evaluated single-class autoencoder models for ECG anomaly detection. The models achieved high recall rates, especially the Conv-fc and LSTM models, which ensures that most abnormal cycles can be detected.

Future plans include: 1) Optimize signal feature point detection algorithms to reduce extraction errors. 2) improve lead and segment selection methods based on guidance from cardiology experts.

Reference

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