1 How Gaussian Noise Was Added to ECG Signals

1.1 Overview

During training, Additive White Gaussian Noise (AWGN) was dynamically added to ECG signals to improve model robustness. This on-the-fly augmentation approach exposes the model to various noise conditions without requiring pre-generated noisy datasets.

1.2 Step-by-Step Process

1.2.1 Select Training Sample

During each training epoch, randomly select an ECG beat from the training dataset. Each beat is a 216-dimensional feature vector centered on the R-peak.

1.2.2 Determine Noise Augmentation

With 70% probability: Apply noise augmentation and with 30% probability: Keep the signal clean (unmodified)

This split ensures the model learns to handle both noisy and clean signals effectively.

1.2.3 Randomly Select SNR Level

For samples selected for augmentation, randomly choose an SNR (Signal-to-Noise Ratio) value from:

$$SNRlevels = \{0, 3, 6, 9, 12, 15, 18, 20\}dB$$

- Lower SNR (0-6 dB) = extremely noisy conditions
- Higher SNR (15-20 dB) = relatively clean signals

1.2.4 Calculate Signal Power

Compute the power of the clean ECG signal:

$$P_{signal} = \frac{1}{N}\sum_{i=1}^{N} x_i^2$$

Where:

- - x_i = individual signal samples
- - $N = 216$ = length of ECG beat

1.2.5 Calculate Required Noise Power

Based on the selected SNR level, calculate the required noise power using the SNR formula:

$$SNR_{dB} = 10 \times \log_{10}\left(\frac{P_{signal}}{P_{noise}}\right)$$

Rearranging to solve for noise power:

$$P_{noise} = \frac{P_{signal}}{10^{SNR_{dB}/10}}$$

1.2.6 Determine Noise Standard Deviation

Calculate the standard deviation σ for the Gaussian noise:

$$\sigma_{noise} = \sqrt{P_{noise}}$$

1.2.7 Generate Additive White Gaussian Noise (AWGN)

Generate random noise samples from a Gaussian (normal) distribution:

$$n(t) \sim \mathcal{N}(0, \sigma_{noise}^2)$$

Where:

1. Mean: $\mu = 0$
2. Standard Deviation: $\sigma = \sigma_{noise}$
3. Length: 216 samples (matching ECG beat length)