

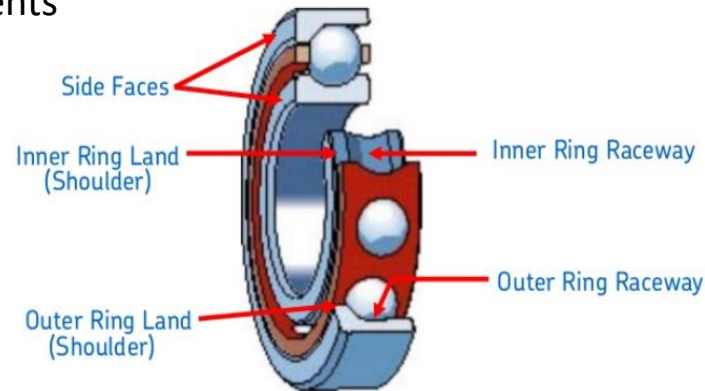
# Summary of Project

- Accelerometer Sensor Data (Case Western Reserve University)

- 12,000 samples per second
- Inner raceway bearing sensor – drive end
- Data segmented into fixed sizes of 256 samples
- 14,234 segments total
- 6,633 Baseline (normal) segments
- 7,601 Faulty segments

- Classification Problem

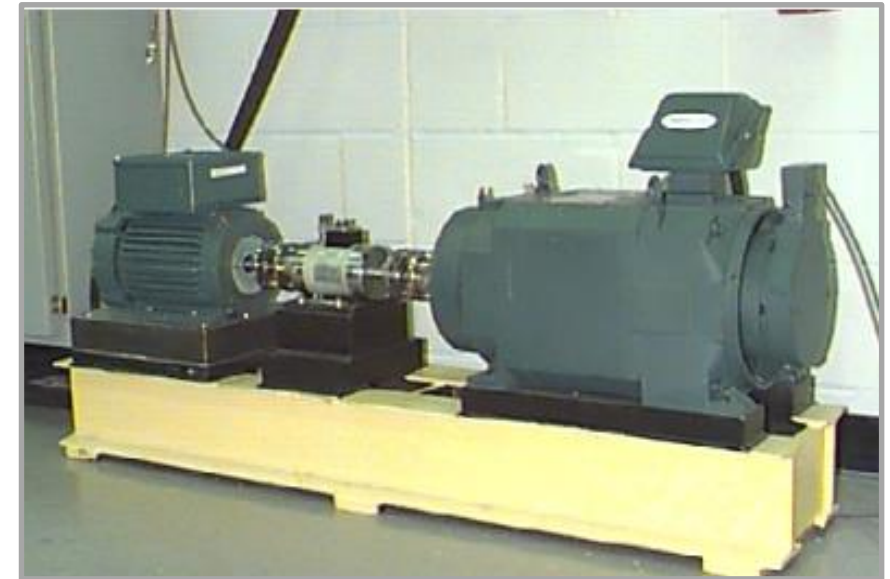
- 4 Baseline (normal) classes
- 16 Faulty classes
- 20 Total classes



- Contemporary Approach : 1D CNN

- Classic Approach : Engineered Features

- Fast Fourier Transform
- Discrete Wavelet Transform
- Fast Fourier Transform + Discrete Wavelet Transform
- Fast Fourier Transform + Discrete Wavelet Transform + 1D CNN
- SVM, XGBoost, Gradient Boosting, Random Forests

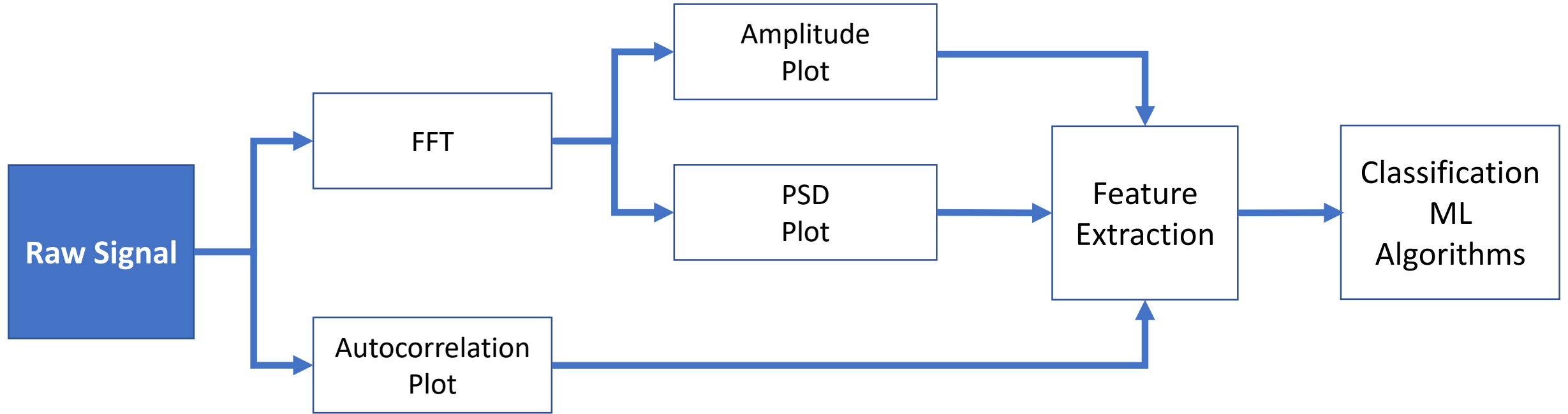


# Summary of Project – Data Class Descriptions

| Label | Segments | Data Type     | Data Description              | File Name |
|-------|----------|---------------|-------------------------------|-----------|
| 0     | 952      | Baseline Data | 0 HP workload normal          | 97.mat    |
| 1     | 1890     | Baseline Data | 1 HP workload normal          | 98.mat    |
| 2     | 1894     | Baseline Data | 2 HP workload normal          | 99.mat    |
| 3     | 1897     | Baseline Data | 3 HP workload normal          | 100.mat   |
| 4     | 473      | Faulty Data   | 0 HP workload .007 inches EDM | 105.mat   |
| 5     | 475      | Faulty Data   | 0 HP workload .014 inches EDM | 169.mat   |
| 6     | 477      | Faulty Data   | 0 HP workload .021 inches EDM | 209.mat   |
| 7     | 471      | Faulty Data   | 0 HP workload .028 inches EDM | 3001.mat  |
| 8     | 476      | Faulty Data   | 1 HP workload .007 inches EDM | 106.mat   |
| 9     | 475      | Faulty Data   | 1 HP workload .014 inches EDM | 170.mat   |
| 10    | 474      | Faulty Data   | 1 HP workload .021 inches EDM | 210.mat   |
| 11    | 474      | Faulty Data   | 1 HP workload .028 inches EDM | 3002.mat  |
| 12    | 477      | Faulty Data   | 2 HP workload .007 inches EDM | 107.mat   |
| 13    | 475      | Faulty Data   | 2 HP workload .014 inches EDM | 171.mat   |
| 14    | 475      | Faulty Data   | 2 HP workload .021 inches EDM | 211.mat   |
| 15    | 474      | Faulty Data   | 2 HP workload .028 inches EDM | 3003.mat  |
| 16    | 480      | Faulty Data   | 3 HP workload .007 inches EDM | 108.mat   |
| 17    | 475      | Faulty Data   | 3 HP workload .014 inches EDM | 172.mat   |
| 18    | 476      | Faulty Data   | 3 HP workload .021 inches EDM | 212.mat   |
| 19    | 474      | Faulty Data   | 3 HP workload .028 inches EDM | 3004.mat  |

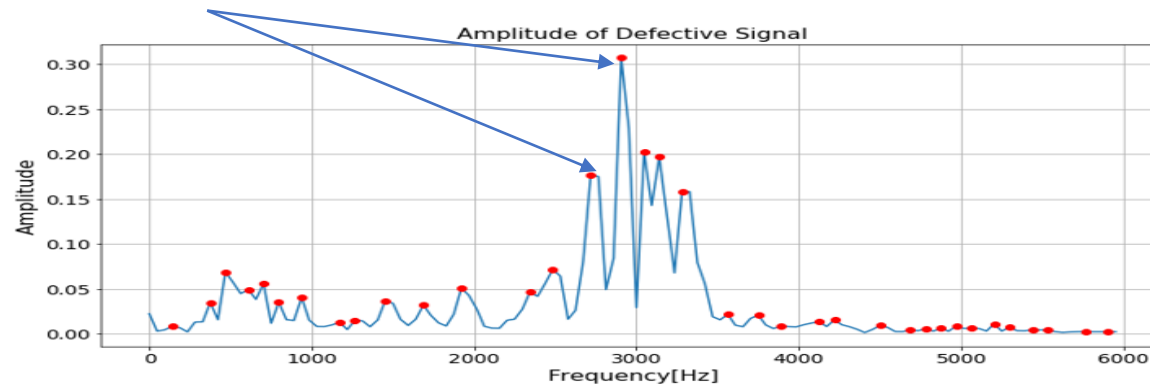
EDM - electro-discharge machining was used to create faulty bearings

# Engineered Features using FFT

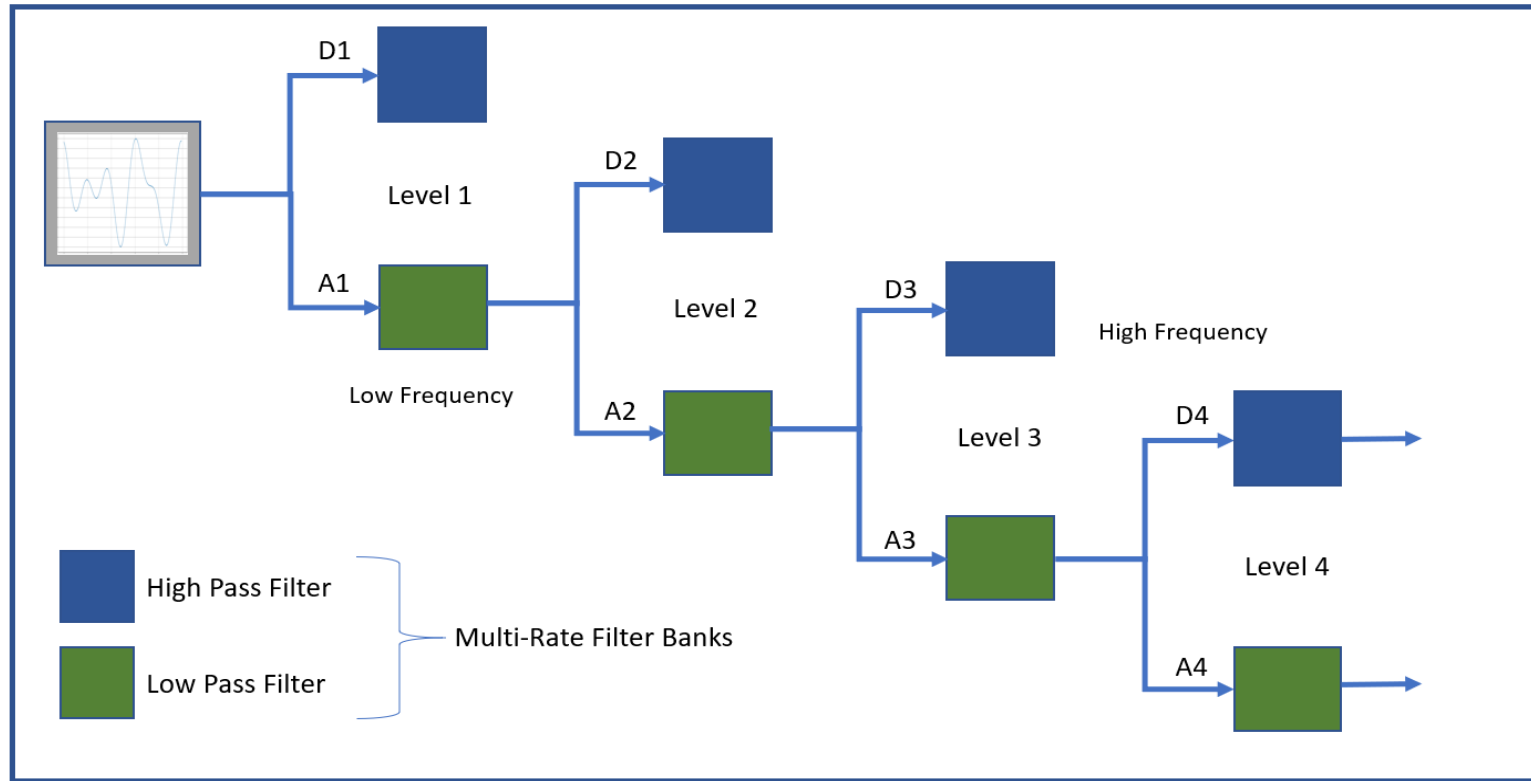


PSD – Power Spectral Density

Feature Extraction selects top n peaks of each plot

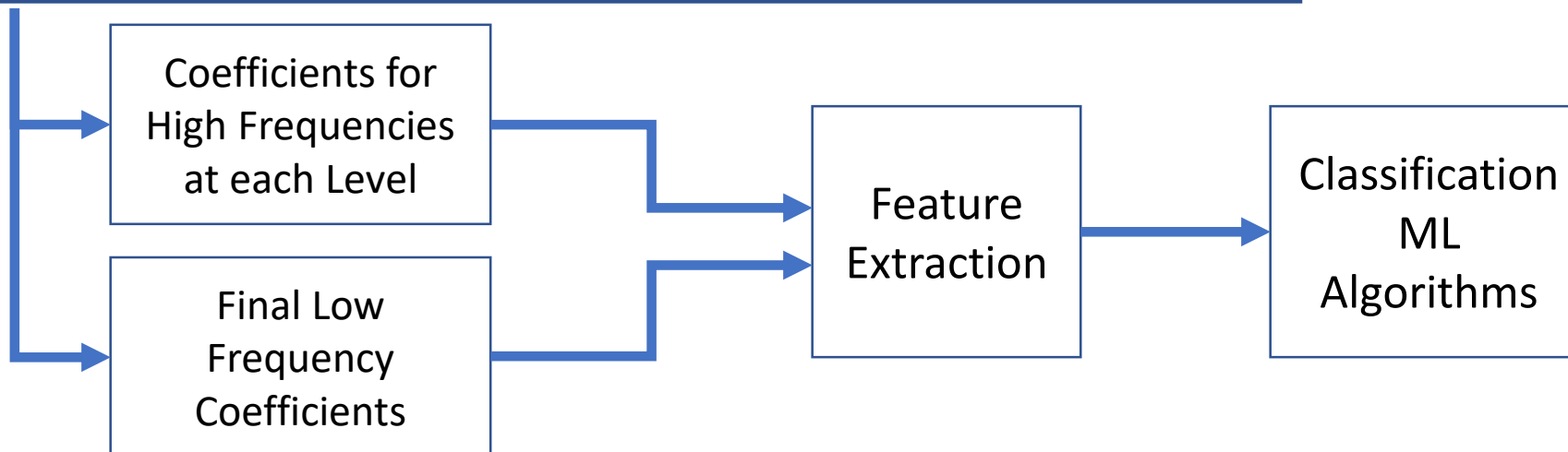


# Engineered Features using DWT

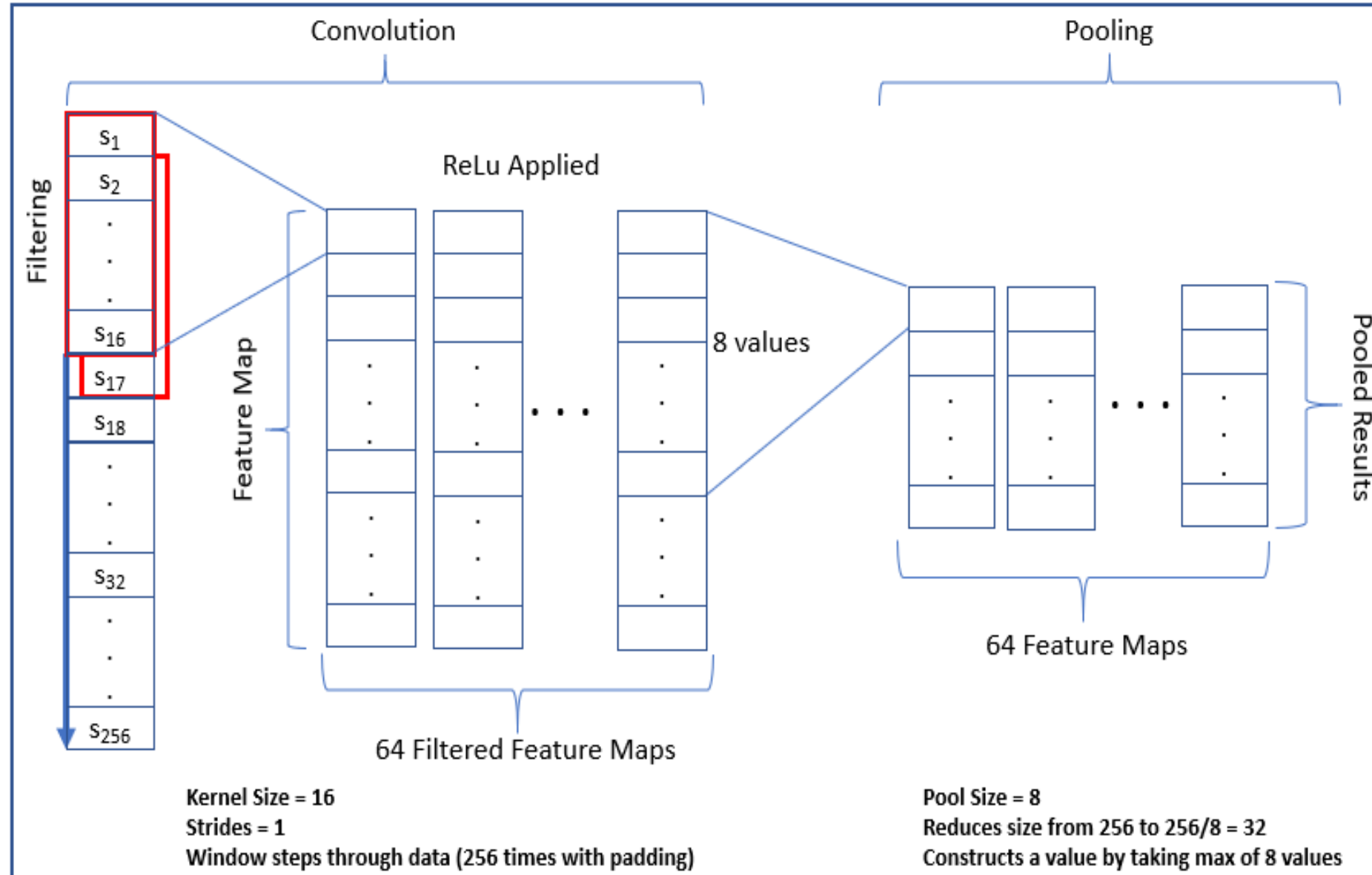


## Feature Extraction

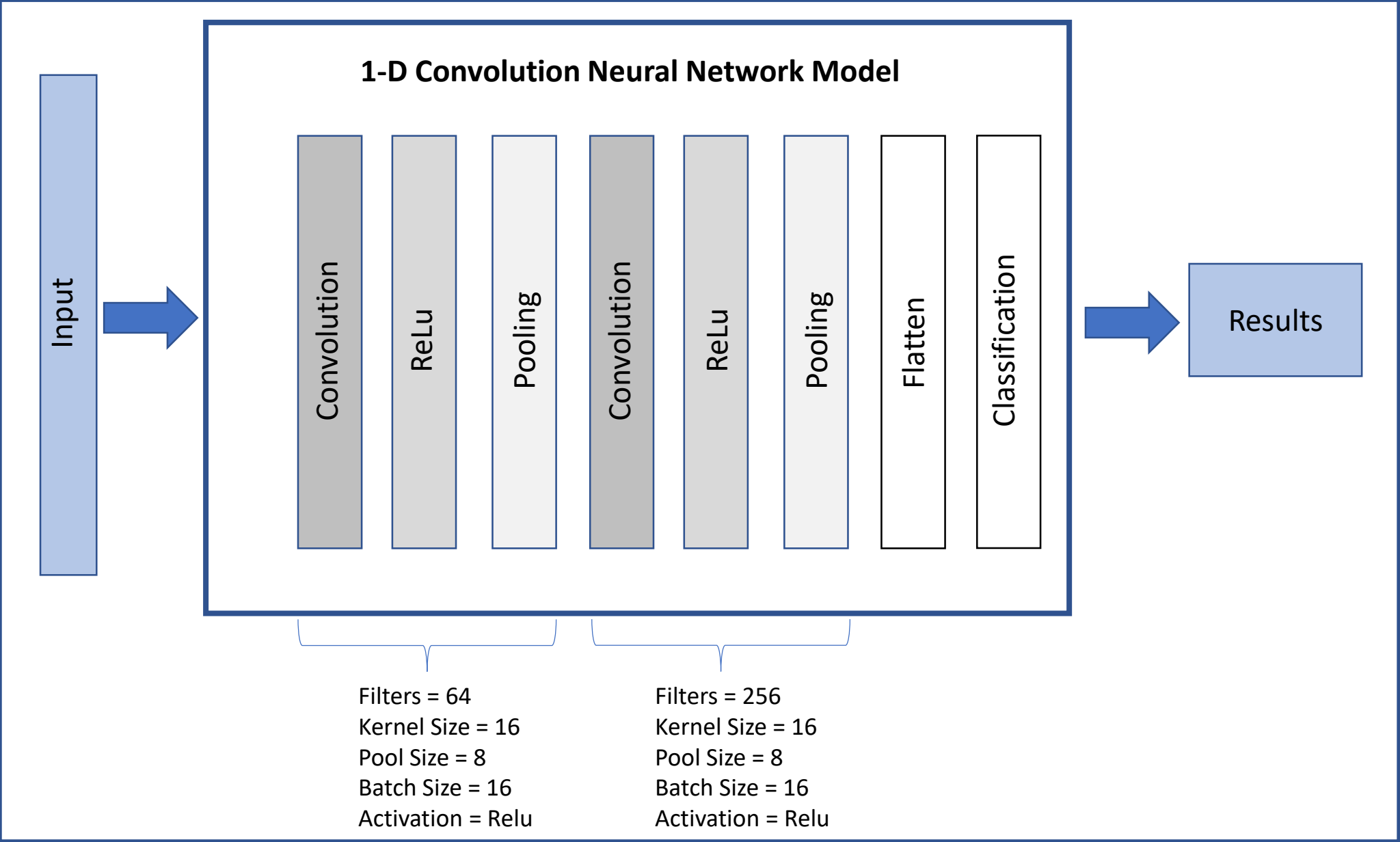
- Entropy
- Statistics
- Crossings



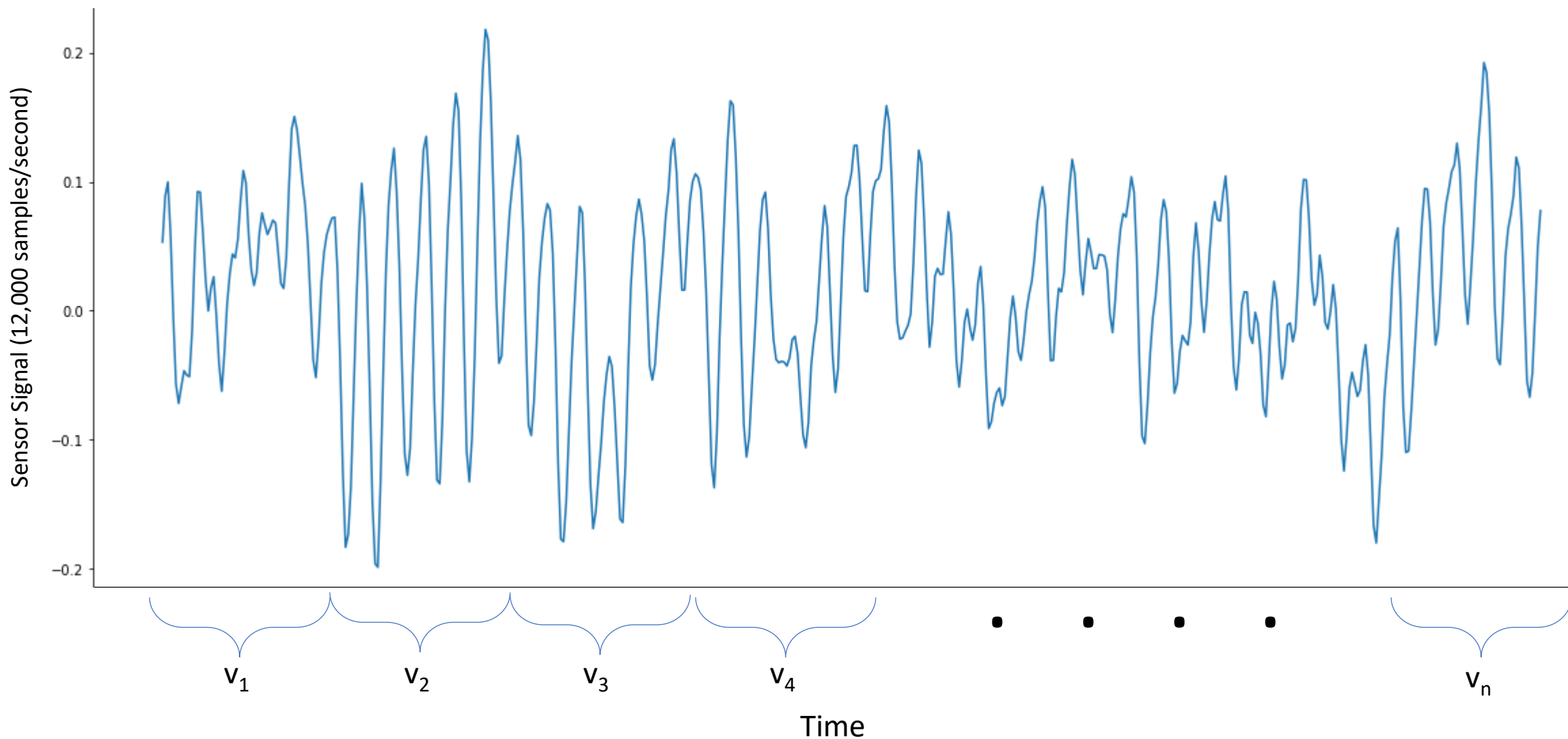
# CNN 1D Architecture



# CNN 1D Architecture – Sensor Data



# Data Preparation: Training Set

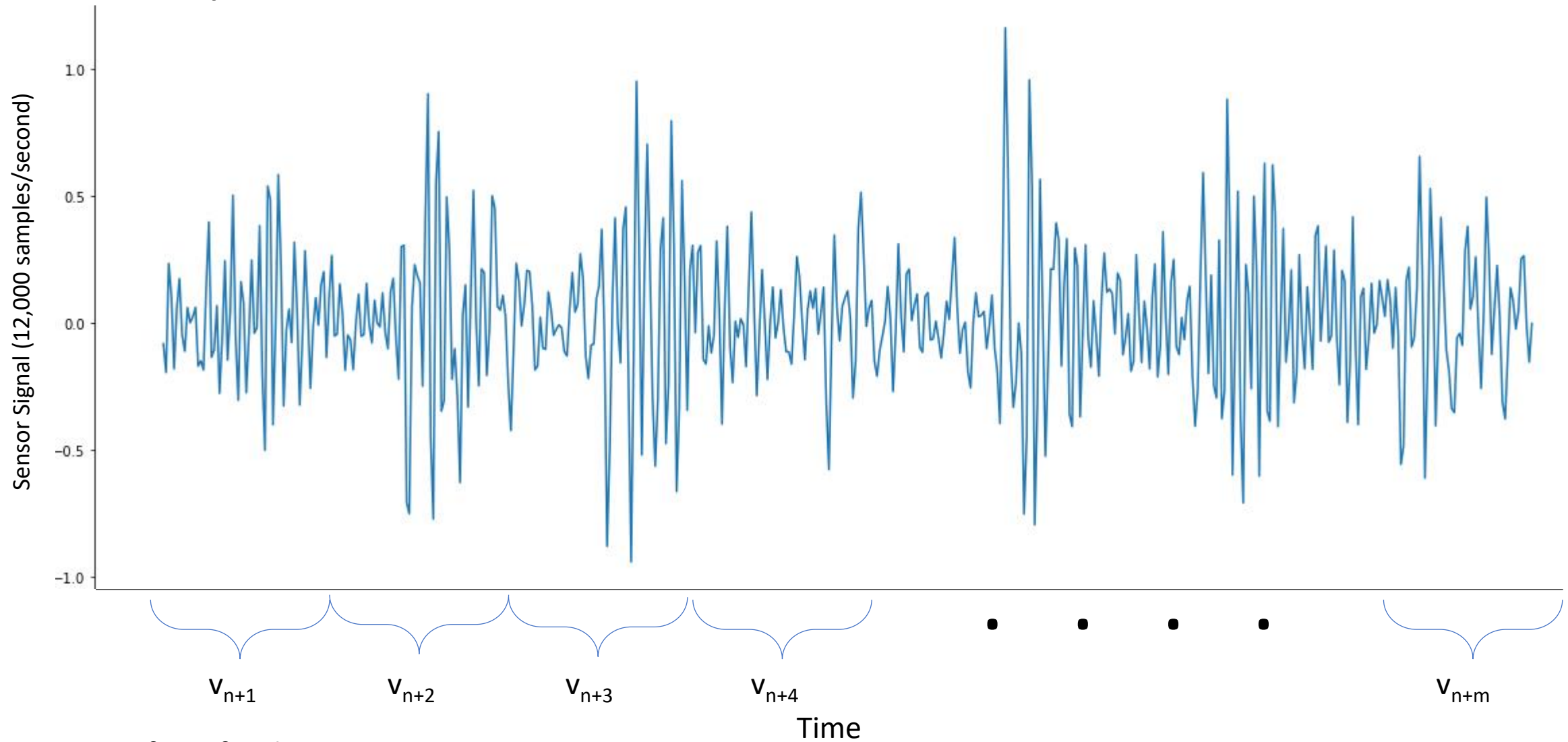


Size of  $v_i$  is fixed at 256.

Where  $n$  is the number of fixed sample vectors of size 256

$y_i$  is the label for signal vector  $v_i$ .  $y_i$  in  $(0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19)$

# Data Preparation: Test Set



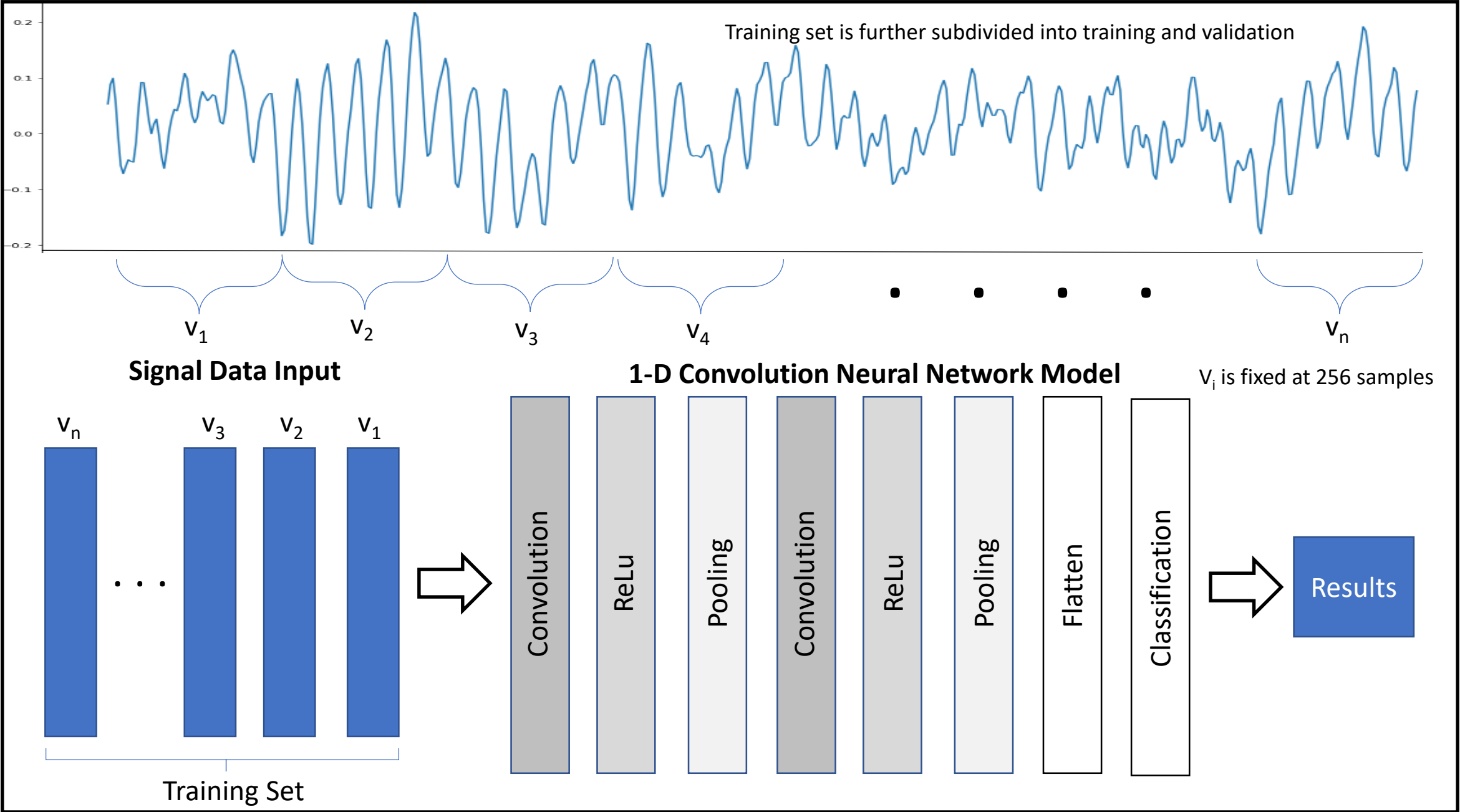
Size of  $v_i$  is fixed at 256.

Where  $m$  is the number of fixed sample vectors of size 256

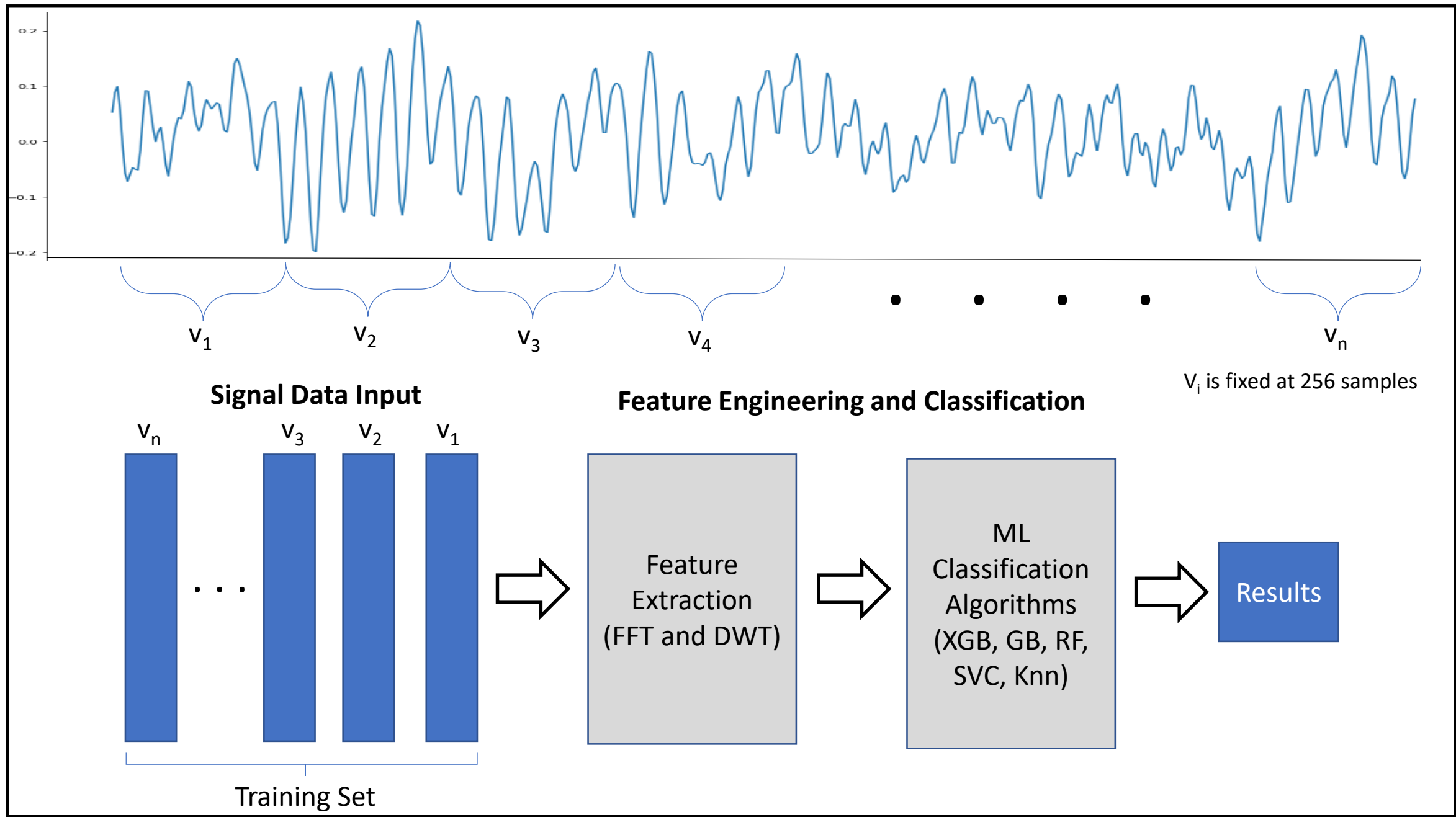
$y_i$  is the label for signal vector  $v_i$ .  $y_i$  in  $(0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19)$



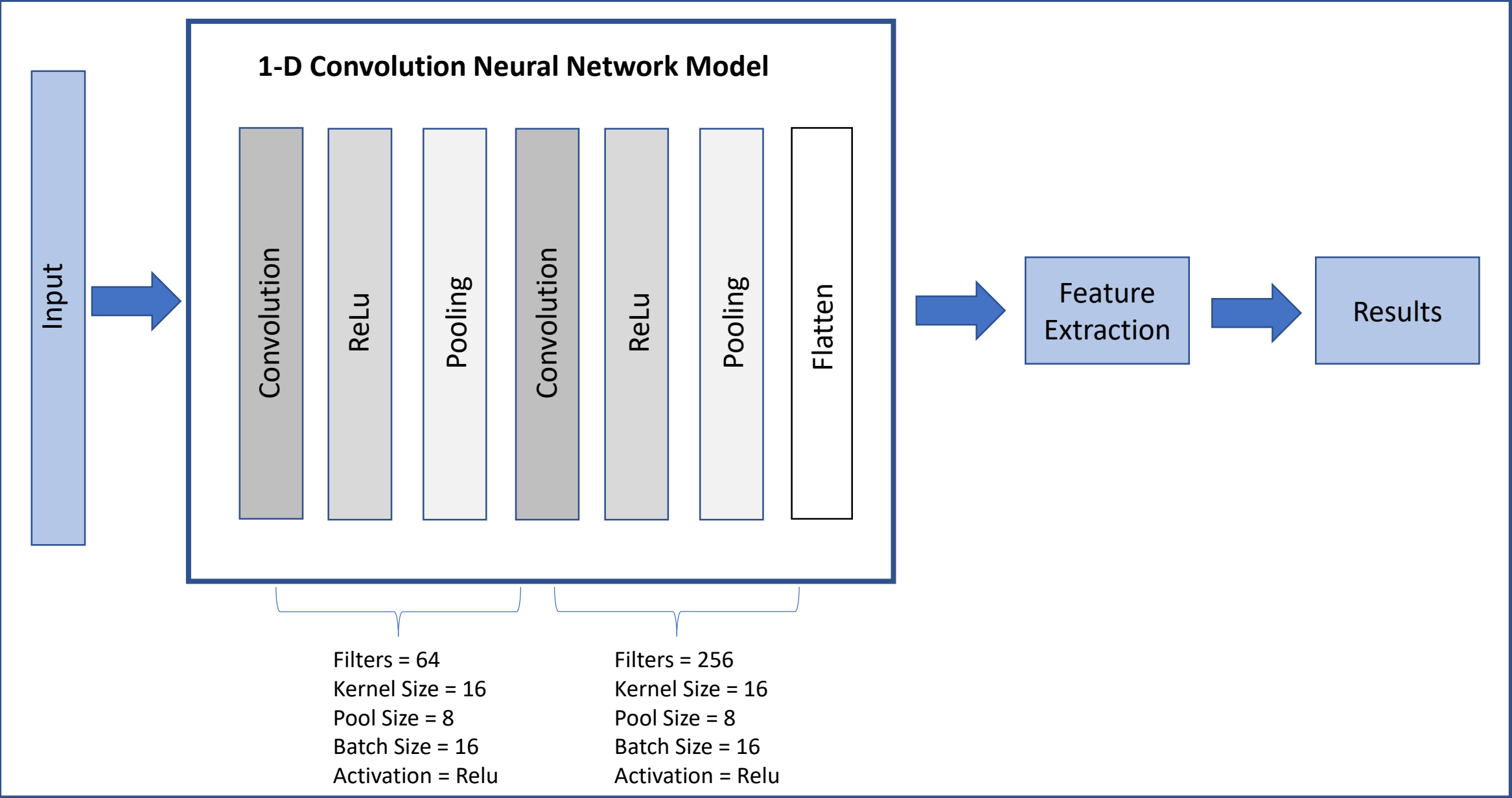
# Contemporary Approach - Training



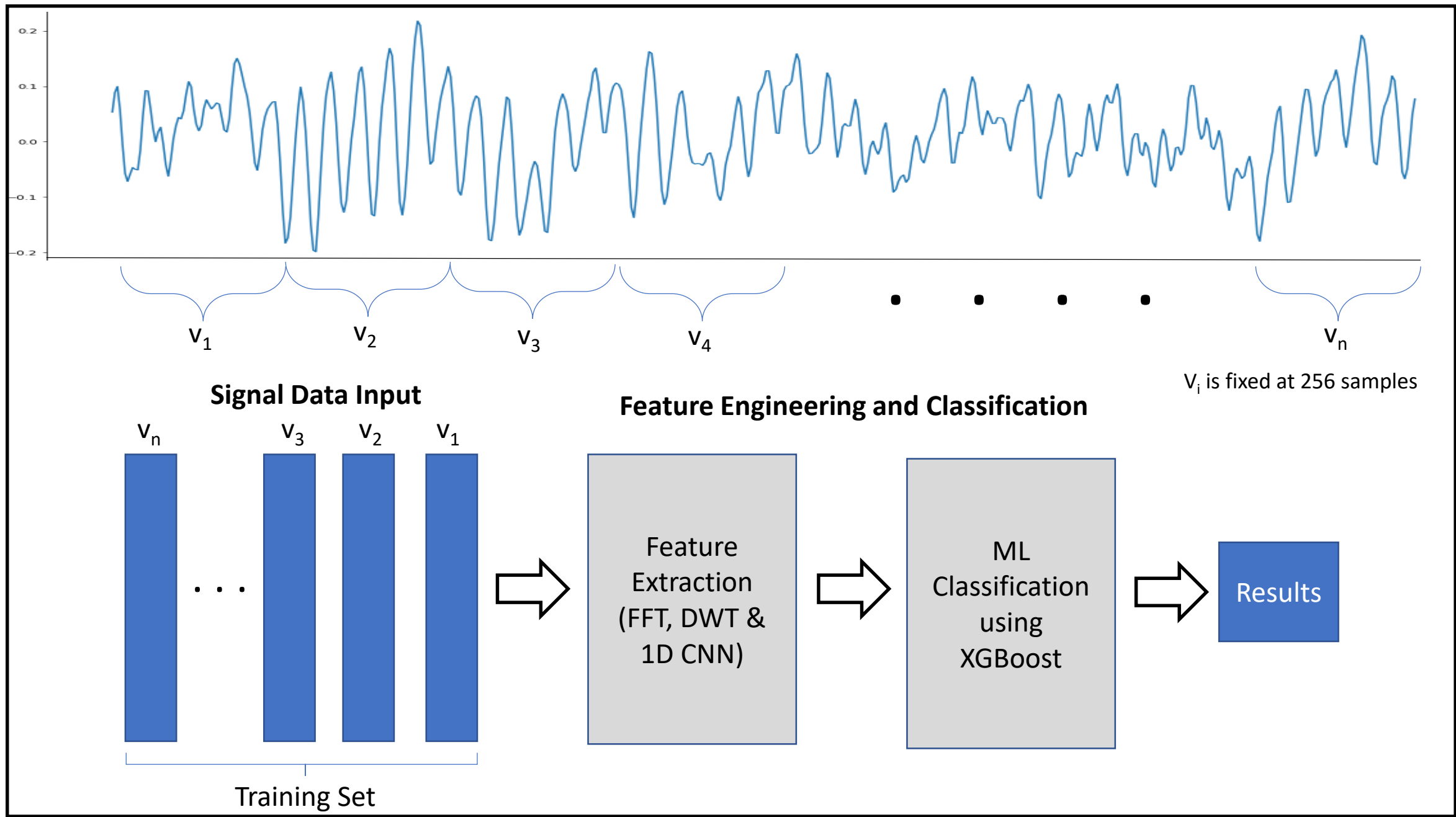
# Classic Approach- Training



# CNN 1D Feature Extraction



# Classic and Contemporary Approach Together



## Prediction and Results using Testing Data

| Approach     | Engineered Features Source | Algorithm         | Training Accuracy | Testing Accuracy | Execution Time (minutes) |
|--------------|----------------------------|-------------------|-------------------|------------------|--------------------------|
| Contemporary | N/A                        | 1D CNN            | 0.97              | 0.94             | 23                       |
| Classic      | FFT                        | XGBoost           | 1.00              | 0.87             | 8                        |
| Classic      | FFT                        | Gradient Boosting | 1.00              | 0.81             | 5                        |
| Classic      | FFT                        | Random Forests    | 1.00              | 0.81             | 6                        |
| Classic      | FFT                        | Knn               | 0.63              | 0.54             | 1                        |
| Classic      | FFT                        | SVCLinear         | 0.70              | 0.54             | 1                        |
| Classic      | DWT                        | XGBoost           | 1.00              | 0.81             | 13                       |
| Classic      | DWT                        | Gradient Boosting | 1.00              | 0.79             | 4                        |
| Classic      | DWT                        | Random Forests    | 1.00              | 0.80             | 7                        |
| Classic      | DWT                        | Knn               | 0.63              | 0.53             | 2                        |
| Classic      | DWT                        | SVCLinear         | 0.72              | 0.43             | 1                        |
| Classic      | FFT & DWT                  | XGBoost           | 1.00              | 0.90             | 17                       |
| Classic      | FFT & DWT                  | Gradient Boosting | 1.00              | 0.87             | 4                        |
| Classic      | FFT & DWT                  | Random Forests    | 1.00              | 0.86             | 10                       |
| Classic      | FFT & DWT                  | Knn               | 0.65              | 0.56             | 3                        |
| Classic      | FFT & DWT                  | SVCLinear         | 0.83              | 0.53             | 1                        |
| Both         | FFT, DWT & 1D CNN          | XGBoost           | 1.00              | 0.95             | 36                       |