ECG_XAI_Project – Complete Technical Explanation

1. PROJECT OBJECTIVE

The ECG_XAI_Project is designed to classify ECG heartbeats into Normal and Abnormal categories
and provide explainable AI insights into the model's decision-making process.

The system consists of:
• ECG signal preprocessing
• Beat segmentation around R-peaks
• CNN-based classification
• Integrated Gradients explainability
• Visualization of explanation results

2. DATA PROCESSING PIPELINE

A. Signal Loading
The project loads ECG records from dataset files containing raw ECG signals and annotation files.

B. Preprocessing
• Mean normalization
• Standard deviation scaling
• Fixed-length beat extraction (216 samples per beat)

C. Beat Segmentation
Each beat is centered around detected R-peaks:
Start = R_peak - 72
End = R_peak + 144

This ensures consistent alignment across beats.

D. Labeling Rule
Normal beats: N, L, R → Label 0
All other beat types → Label 1 (Abnormal)

3. MODEL ARCHITECTURE

The model used is a 1D Convolutional Neural Network (CNN):

Layer 1:
• Conv1D (1 → 16 channels)
• ReLU activation
• MaxPool

Layer 2:
• Conv1D (16 → 32 channels)
• ReLU activation
• MaxPool

Fully Connected:
• Linear layer
• ReLU
• Output layer (2 classes)

Loss Function:
CrossEntropyLoss

Optimizer:
Adam optimizer (learning rate = 0.001)

4. TRAINING WORKFLOW

For each epoch:
• Forward pass
• Compute loss
• Backpropagation
• Parameter update

Loss is tracked and plotted to ensure convergence.

5. EXPLAINABLE AI MODULE

Integrated Gradients algorithm is used for interpretability.

Steps:
1. Define baseline (zero signal)
2. Generate interpolated inputs
3. Compute gradients for each step
4. Average gradients
5. Multiply by input difference

This produces attribution scores for each ECG sample point.

These attributions show which waveform regions influenced prediction most.

6. VISUALIZATION OUTPUT

The final visualization includes:
• ECG waveform
• Integrated gradients overlay
• Shaded QRS region
• Prediction label
• Confidence score

This allows human interpretability of model decisions.

7. KEY MODULES USED

• torch – Deep learning framework
• numpy – Numerical computation
• pandas – Data handling

• matplotlib – Visualization
• reportlab – PDF generation
• pathlib – File path handling

8. WORKING PRINCIPLE SUMMARY

Raw ECG → Preprocessing → Beat Segmentation → CNN Classification → Integrated Gradients → Visualization

This completes an end-to-end explainable ECG classification system.