AI-powered seismic signal enhancement using deep ensemble learning

This project implements a complete deep-learning pipeline for seismic signal denoising and (optionally) event classification, with a focus on a novel ensemble denoiser that outperforms individual models and classical filters.

Problem Overview

Seismic signals recorded in the field are often heavily contaminated by:

- Environmental noise
- Instrument noise
- Anthropogenic activity

This noise:

- Reduces SNR (Signal-to-Noise Ratio)
- Distorts important waveform features
- Degrades downstream event detection/classification performance

The goal of this project is to build and evaluate a robust denoising pipeline that:

1. Recovers clean seismic waveforms from noisy measurements.
2. Highlights a trainable ensemble model that combines multiple denoisers.
3. Provides clean inputs for reliable event classification.

Project Objectives

1. Implement multiple 1D denoising models:
    - DnCNN (residual CNN)
    - 1D U-Net (encoder–decoder with skip connections)
    - Noise2Noise-style CNN
    - MLP-based denoiser (fully connected baseline)
    - Classical filter (Savitzky–Golay)
    - Enhanced Ensemble Denoiser (novel weighted combination)
2. Compare all denoisers using:
    - SNR (Signal-to-Noise Ratio)
    - PSNR (Peak SNR)
    - RMSE (Root Mean Square Error)
    - Residual error analysis
    - Wavelet scalograms
3. Visually and quantitatively demonstrate that the ensemble:

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- Produces higher SNR
- Shows lower residual error
- Preserves waveform structure better than single models

4. Prepare the pipeline for extension into event classification:
    - Denoised signals → features → classifiers (SVM/RF/MLP/CNN)
    - Confusion matrices and confidence (SECS) plots (to be integrated)