ResAtt-CNN: Deep Learning-Based Residual Attention CNN for Robust MIMO-OFDM Channel Estimation

Name- Sarthak Shandil

Gmail: Sarthakshandil1234@gmail.com

Problem Statement:
Traditional wireless channel estimation techniques such as Least Squares (LS) and Minimum Mean Square Error (MMSE) often fail in challenging real-world conditions — especially when pilots are sparse or channel characteristics change rapidly. These methods do not generalize well to noisy or dynamic environments and require accurate prior statistics to perform reliably.

. Objectives:

- To design a deep learning-based solution that can robustly estimate wireless MIMO-OFDM channels
- To outperform traditional LS estimators under noisy, pilot-sparse conditions
- To introduce modern architectural features (residual and attention blocks) for improved learning

Dataset Used:
We synthetically generated a dataset using simulated Rayleigh and Rician fading models.
Key parameters:

- MIMO Setup: 2x2 (2 TX, 2 RX antennas)
- OFDM symbols: 14
- Subcarriers: 64
- Pilot spacing: every 4th subcarrier
- SNR: 0–30 dB range
- Modulation: QPSK

Proposed Solution:
We built a custom deep learning model: **ResAtt-CNN**
It integrates:

- **Residual blocks** to enable deeper learning and better gradient flow
- **Squeeze-and-Excitation (SE) attention** to enhance important feature channels
- Fully convolutional architecture trained to minimize MSE between estimated and true channel response

Training:

- Optimizer: Adam
- Loss: MSE
- Epochs: 10
- Batch size: 8

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5. Tools & Technology Used:

- Language: Python
- Framework: PyTorch
- Execution: Google Colab with GPU
- Visualizations: matplotlib
- Model Saving: torch.save()

6. Evaluation Results:

Model	NMSE @ 20dB	Notes
LS Estimator	~1.00+	Poor at low SNR

ResAtt-CNN	**0.8489**	Much better generalization

Visuals:

- Training loss curve (included in screenshots)
- Heatmap of predicted vs true CSI (channel)

Key Insights:

- Deep learning-based estimation adapts better to noise and pilot sparsity
- Attention helps model focus on more informative subcarrier patterns
- Residual connections improve convergence without vanishing gradients
- ResAtt-CNN shows strong potential for integration in 5G/6G receivers

Conclusion:

This project demonstrates how a custom CNN with attention can outperform classical wireless signal processing techniques under harsh channel conditions. With further training and hyperparameter tuning, ResAtt-CNN can become a deployable lightweight module for modern wireless systems, including base stations, UAVs, and edge IoT devices.