# Graph Neural Networks on the Cora Dataset

**Name:** Shegitu Shukuri

**Objective:** Implement and benchmark multiple neural network models (MLP, GCN, GraphSAGE, GAT) on a citation network (Cora dataset), explicitly formulating each model in terms of encoder (Enc), decoder (Dec), graph structure (Gt), and loss function (L). Compare performance across architectures and provide analysis.

## 1, Dataset

**=>Cora**: A citation network dataset consisting of 2,708 nodes (papers), 5,429 edges (citations), 1,433 features per node, and 7 classes.

**=>Train/Test Split:** Standard masks from PyTorch Geometric Planetoid dataset.

## 2, Models Implemented

| **Model** | **Enc** | **Gt** | **Dec** | **L** |
|---|---|---|---|---|
| MLP | Linear layers | None | Linear layer + softmax | CrossEntropyLoss |
| GCN | GCNConv layers | Adjacency matrix | Linear layer + softmax | CrossEntropyLoss |
| GraphSAGE | SAGEConv layers | Edge list | Linear layer + softmax | CrossEntropyLoss |
| GAT | GATConv layers | Edge list + attention | Linear layer + softmax | CrossEntropyLoss |

## 3,Training Configurations

**-Hidden Dimensions:** 16, 32, 64

**-Number of Layers:** 2, 3

**-Optimizer:** Adam (lr=0.01, weight_decay=5e-4)

**-Dropout:** 0.5 (MLP/GCN/SAGE), 0.6 (GAT)

**-Epochs:** 200

## 4, Results

| Model | Hidden | Layers | Accuracy | F1 Score |
|---|---|---|---|---|
| MLP | 16 | 2 | 0.476 | 0.481 |
| MLP | 32 | 2 | 0.542 | 0.530 |
| MLP | 64 | 2 | 0.572 | 0.552 |
| MLP | 64 | 3 | 0.579 | 0.564 |
| GCN | 16 | 2 | 0.795 | 0.787 |
| GCN | 32 | 2 | 0.799 | 0.793 |
| GCN | 64 | 2 | 0.804 | 0.801 |
| GCN | 64 | 3 | 0.801 | 0.798 |
| GraphSAGE | 16 | 2 | 0.806 | 0.798 |
| GraphSAGE | 32 | 2 | 0.813 | 0.804 |
| GraphSAGE | 64 | 2 | 0.809 | 0.802 |
| GraphSAGE | 64 | 3 | 0.795 | 0.792 |
| **GAT** | **16** | **2** | **0.794** | **0.784** |
| **GAT** | **32** | **2** | **0.786** | **0.782** |
| **GAT** | **64** | **2** | **0.766** | **0.764** |
| **GAT** | **64** | **3** | **0.686** | **0.689** |

## 5, Analysis

**1,Performance Comparison:**

-Graph-based models (GCN, GraphSAGE, GAT) significantly outperform MLP due to utilization of graph structure.

-GraphSAGE achieves the highest Accuracy and F1 in most configurations, indicating effective neighborhood aggregation.

-GAT exhibits unstable performance with deeper layers and large hidden dimensions.

**2,Effect of Hidden Dimension and Layers:**

-Increasing hidden dimensions improves performance for all models initially.

-Adding more layers does not always improve performance, particularly for GAT, possibly due to overfitting or attention instability.

**3,Encoder/Decoder Observation:**

-MLP relies solely on node features (no graph information).

-GCN uses adjacency matrices to propagate node information.

-GraphSAGE aggregates neighbors via edges.

-GAT further incorporates attention mechanisms over neighbors.

## 6, Conclusion

-Graph Neural Networks outperform feature-only models (MLP) for node classification on citation networks.

-GraphSAGE demonstrates the most robust performance across configurations.

-Explicitly formulating Enc, Dec, Gt, and L helps in understanding model design and comparing architectures.