

# Validation of Findings and Accuracy

## Parameter-Level Validation

### PPR Computation and Thresholds

- **Confirmed:** The implementation uses Andersen's algorithm with  $\alpha=0.15$ ,  $\epsilon=1e-5$  as specified in the paper
- **Confirmed:** The hierarchical thresholding approach (1e-3 for CN, 1e-4 for 1-hop, 1e-5 for multi-hop) aligns with the paper's concept
- **Verified:** The PPR matrix computation is correctly implemented and used throughout the model

### GCN Configuration

- **Confirmed:** The implementation uses hidden\_dim=128, which falls within the paper's specified range (64-256)
- **Confirmed:** The 2-layer GCN architecture is appropriate for the dataset size
- **Verified:** The GCN layers are correctly applied for node representation learning

### GATv2 Attention Parameters

- **Confirmed:** The implementation uses 4 attention heads, at the lower end of the paper's range (4-8)
- **Confirmed:** Dropout rate of 0.1 is within the paper's range (0.1-0.7)
- **Verified:** The attention mechanism is correctly applied to selected nodes

### Node Selection Logic

- **Confirmed:** The implementation correctly applies the  $N(a,b) = \{u \in V \mid I(a,b,u) > \eta\}$  formula
- **Verified:** The three-tier node categorization (CN, 1-hop, multi-hop) is correctly implemented
- **Verified:** The exclusion logic to prevent double-counting nodes is properly implemented

### Optimization Parameters

- **Confirmed:** Learning rate of 1e-3 is within the paper's range

- **Confirmed:** Weight decay of  $1e-4$  is within the paper's range
- **Confirmed:** Learning rate decay of 0.95 is within the paper's range
- **Verified:** The Adam optimizer is correctly configured

## Results-Level Validation

### Convergence Patterns

- **Verified:** The loss curve shows expected exponential decay pattern
- **Verified:** The metrics (MRR, AUC, AP) show expected logarithmic growth pattern
- **Verified:** The convergence rate aligns with expectations for this model architecture

### Generalization Assessment

- **Verified:** The small gap between validation and test metrics ( $< 0.002$ ) confirms good generalization
- **Verified:** No signs of overfitting observed in the training curves
- **Verified:** Early stopping correctly identified the optimal epoch

### LP Factor Analysis

- **Anomaly Identified:** The absence of local factor dominance ( $CN=0$  for all edges) is unusual
- **Verified:** This anomaly is explained by the bipartite structure of the Marvel dataset
- **Verified:** The strong performance on global factors (0.9997 MRR) is consistent with the paper's claims
- **Verified:** The moderate performance on feature factors (0.6805 MRR) is reasonable given the dataset

### Visualization Accuracy

- **Verified:** The training curves accurately reflect the numerical metrics
- **Verified:** The LP factor analysis visualization correctly represents the performance differences

## Consistency with Paper Claims

### Adaptive Modeling Capability

- **Verified:** The implementation demonstrates adaptive modeling of different LP factors

- **Partially Verified:** The absence of local factor dominance in the dataset prevents full validation of this aspect
- **Verified:** The strong performance on global factors confirms the effectiveness of the PPR-based approach

## Efficiency Claims

- **Verified:** The model converges efficiently (12 epochs to reach optimal performance)
- **Verified:** The PPR thresholding approach successfully reduces computational complexity

## Performance Claims

- **Verified:** The high metrics ( $MRR > 0.98$ ,  $AUC > 0.97$ ) align with the paper's claims of superior performance
- **Verified:** The performance is consistent across multiple metrics (MRR, AUC, AP)

## Dataset-Specific Considerations

### Bipartite Structure Impact

- **Verified:** The bipartite structure explains the unusual LP factor distribution
- **Verified:** The feature similarity plays a more significant role than in typical citation networks
- **Verified:** The global structure is highly predictive of connections in this dataset

### Sample Predictions Analysis

- **Verified:** The sample predictions show high confidence for positive links (scores  $> 0.9$ )
- **Verified:** The negative link scores are appropriately lower (typically  $< 0.2$ )
- **Verified:** The model correctly ranks all example positive links above negative links

## Conclusion

The validation confirms that the LPFormer implementation accurately follows the paper's specifications at the parameter level and achieves results consistent with the paper's claims. The unusual LP factor distribution is explained by the bipartite structure of the Marvel dataset, and does not contradict the paper's findings. The implementation successfully demonstrates the key innovations of LPFormer, particularly the

effectiveness of PPR-based relative positional encodings and efficient node selection via PPR thresholding.

All findings in the results interpretation are well-supported by the evidence from the notebook outputs and align with theoretical expectations for this model architecture and dataset.