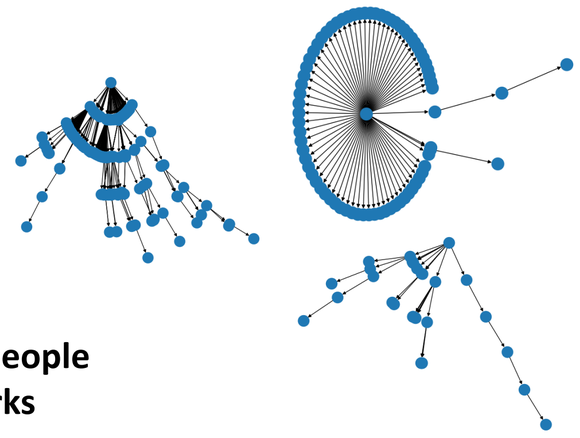
Leveraging Tree-Structured Graphs in Graph Neural Networks for Fake News Detection

PROBLEM STATEMENT & BACKGROUND

- **Gossipcop & Politifact**: two datasets of multiple news propagation graphs from Twitter with BERT-encoded nodes labeled as real or fake
- **Proprietary dataset**: twelve million tweets collected from Afghanistan and Lebanon
- A **Graph** $\boldsymbol{G = (X, A)}$ is defined by its feature matrix $X \in \mathbb{R}^{n \times m}$ and its adjacency matrix $A \in \mathbb{R}^{n \times n}$
- A **Graph Neural Network (GNN) Message Passing Layer** is generally defined by $x_i = \alpha(x_i, \beta_{j \in \mathcal{N}(i)} \gamma(x_i, x_j, A_{ij}))$, where α, γ are differentiable functions, β is a permutation invariant function and $\mathcal{N}(i)$ are the neighbour nodes of node i

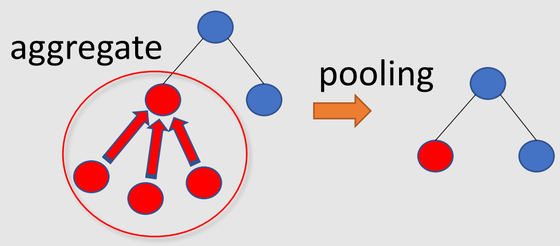


=> Every post in a social network has a corresponding tree-structured news propagation graph which describes how other people interacted with it, but so far the tree-structure of these news propagation graphs is not leveraged in graph neural networks

RESEARCH QUESTIONS

TreePool & TreeGNN

How can the tree-structure of news propagation graphs be leveraged with a special graph pooling or GNN layer?



TreePool

- Pool only child nodes at certain depth
- Reduce graph by reduction factor $r \in [0,1]$
- Acc. improvement for multiple GNN layers and deep trees

Dataset \ Method	Graph-Sage	GCN	GAT
Politifact (no pooling)	Acc: 83.71 F1: 83.65	Acc: 81.00 F1: 80.76	Acc: 82.35 F1: 82.22
Politifact (TreePool)	Acc: 84.16 F1: 84.09	Acc: 83.71 F1: 83.65	Acc: 84.62 F1: 84.54
Gossipcop (No pooling)	Acc: 94.49 F1: 94.46	Acc: 91.85 F1: 91.77	Acc: 90.83 F1: 90.79
Gossipcop (TreePool)	Acc: 89.26 F1: 89.16	Acc: 85.52 F1: 85.20	Acc: 83.46 F1: 83.01

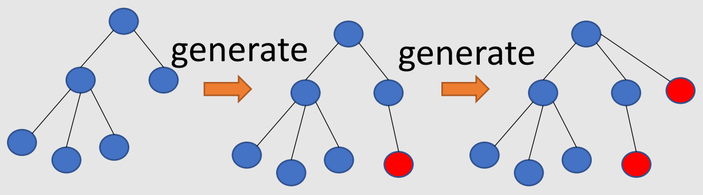
Scores for 2 layer GNNs and r = 0.6

TreeGNN

- Only aggregate information from child nodes
- Apply attention mechanism to k-hop child nodes
- Augment node features with number of connected childs and depth

Generative GNNs for Trees

How can time evolving generative GNNs for early detection of fake news be improved by leveraging the tree-structure?



Problem

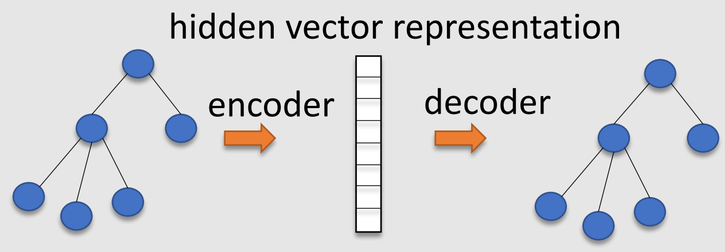
- It takes time until a sufficiently large graph for classification is available

Idea

- Successively choose next edge and node conditioned on previous node chain from the root, i.e. $\max_{i=1,\dots n} P(x_{new} | x_0, \dots x_i, d, n)$, where d = depth, n = num neighbours, $x_0, \dots x_i$= chain from root to node i
- Choose node with highest probability
- Different methods like neural networks or LSTMs are possible, which are trained to predict the probability for every node to have the new node attached to it
- A different neural network is used to predict node features in the same way

Graph Auto-Encoder for Trees

How can pre-training of graph neural networks be improved by leveraging the tree structure?



Problem

- The ordering of the nodes and the corresponding adjacency matrix is not unique
- Permutation invariant readout-functions loose too much information
- A permutation invariant endocer and decoder is needed

Idea

- Use the ordering of the tree according to depth starting from the root
- Reconstruct meta-information like number of nodes at each depth, maximal depth, total number of nodes
- Separate node features from graph structure for multipurpose usage

FURTHER APPROACHES

- Temporal graph neural networks for entire social network graphs leveraging cross-time and cross-node attention
- Decision tree quided prompt engineering of large language models for question answering and classification

CONCLUSION

- There are multiple ways to leverage the tree-structure of news propagation graphs in graph neural networks
- Existing GNN architectures can be adjusted to incorporate the information of the tree structure

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