A Neural Framework for Learning DAG to DAG Translation
M. Clara De Paolis Kaluza¹, Saeed Amizadeh², Rose Yu¹
¹ Northeastern University, ² Microsoft Inc.

Problem
Learn function mappings that translate one DAG to another while preserving syntactic and semantic similarities, e.g., query optimization, circuit simplification, code translation, etc.

Our Solution
DAG-to-DAG Recursive Neural Network (D2DRNN):
A novel neural encoder-decoder framework for learning functions from one graph space onto another graph space - aka DAG-to-DAG translation.

DAG-to-DAG RNN model
We generalize the Seq2Seq architecture to the graph space where the input DAGs are mapped into a real vector space via a graph encoder and the output graphs are synthesized from the same vector space into DAGs via a graph decoder.

Graph Encoder: Analyzing Input Graph
Deep-Gated DAG Recursive Neural Network (DG-DAGRNN)

Graph Decoder: Synthesizing Output Graph

Supervised Loss Function: \( L = L_{\text{length}} + L_{\text{nodes}} + L_{\text{structure}} \)
\( L_{\text{length}} \) = Poisson-NLL-Loss(\( |H|_{\text{in}} \), \( |V_{\text{target}}| \)) \( \approx |V_{\text{out}}| - |V_{\text{target}}| \log(|V_{\text{out}}|) \)
\( L_{\text{nodes}} \) = Cross-Entropy(\( V_{\text{out}} \), \( V_{\text{target}} \))
\( L_{\text{structure}} \) = Diffusion(\( A_{\text{out}} \), \( A_{\text{target}} \)) = MSE(\( A_{\text{out}} \), \( A_{\text{target}} \))

Logical Circuit Simplification
Given an input logical circuit, the goal is to output an equivalent and syntactically-correct circuit with smaller number of gates.

Each circuit is represented as a DAG where nodes represent the variables and gates and the node feature vectors encode the gate type.

Experiments

Baselines
Seq2Seq[2]: DAGs as sequences of nodes
Seq2DAG: sequence of nodes to DAG decoder
DAG2Seq: DAG encoder to sequence decoder

Errors (lower is better):

Valid Syntax (higher is better):

Open Problems
- Supervised Learning is not always the best approach to address graph-to-graph translation, especially when labeled data is not available or the desired output DAGs are not unique.
- Unlike syntactical constraints, enforcing semantic constraints is very challenging in the encoder-decoder design.

References