A Neural Framework for Learning DAG to DAG Translation

M. Clara De Paolis Kaluza[1], Saeed Amizadeh[2], Rose Yu[1]

[1] Northeastern University, [2] Microsoft Inc.

Problem

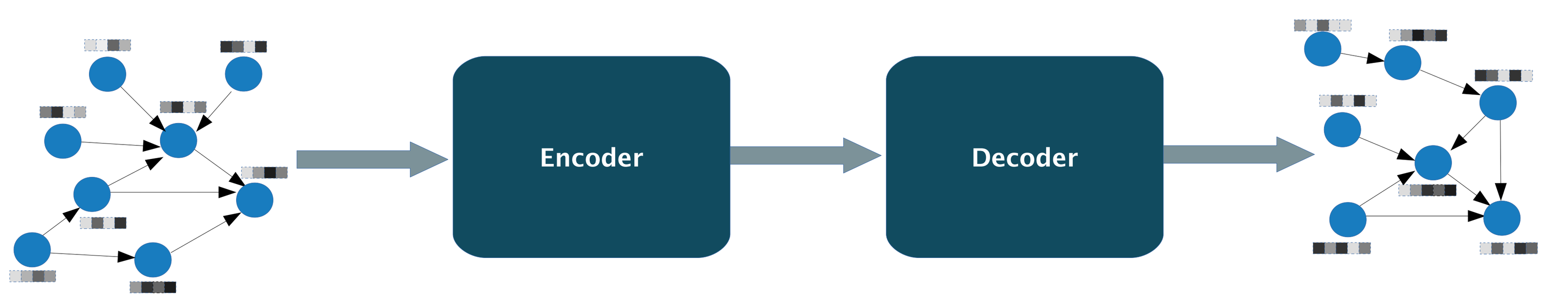
Learn function mappings that translate a DAG to another DAG while preserving syntactic and semantic similarities, applications in e.g. query optimization, circuit simplification, code translation, etc.

Our Solution

DAG-to-DAG Recursive Neural Network (`D2DRNN`):
A novel neural encoder-decoder framework for learning functions from a graph space onto another graph space - aka *DAG-to-DAG translation*.
Full paper: `https://claradepaolis.github.io/D2DRNN/`

DAG-to-DAG RNN model

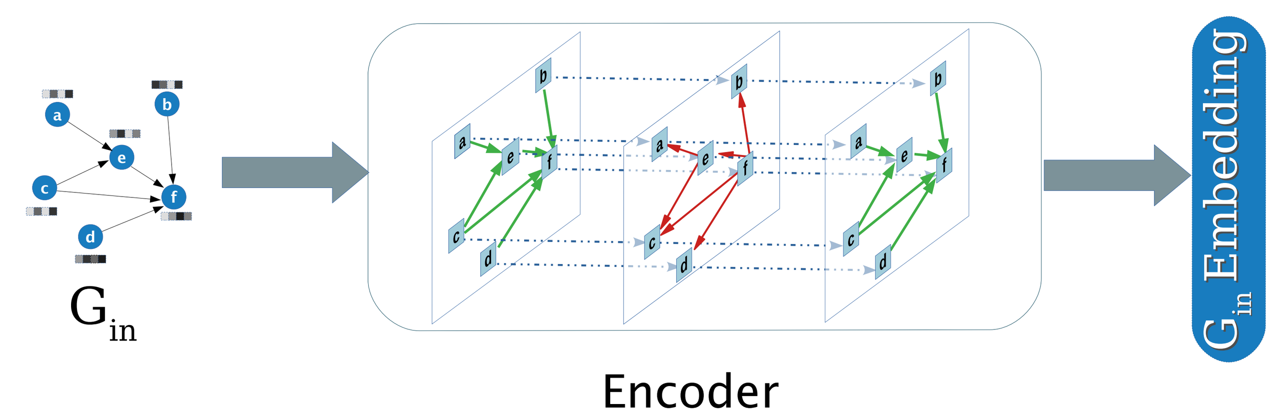
We generalize the **Seq2Seq** architecture to the graph space where the input DAGs are mapped into a real vector space via a *graph encoder* and the output graphs are synthesized from the same vector space into DAGs via a *graph decoder*.



Model overview

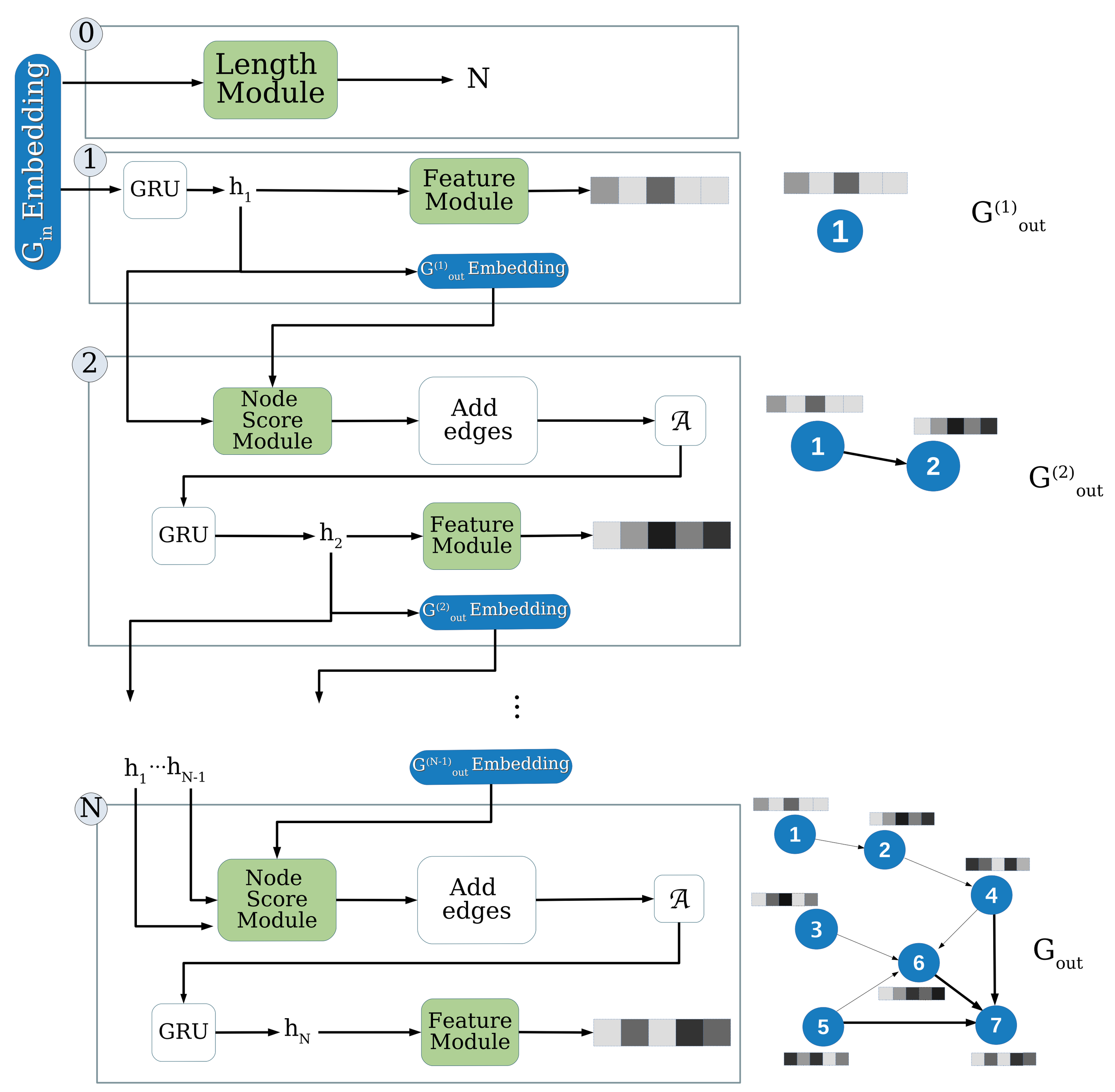
Graph Encoder: Analyzing Input Graph

Deep-Gated DAG Recursive Neural Network (DG-DAGRNN)[1]



$$\boldsymbol{h}_v = GRU(\boldsymbol{x}_v, \boldsymbol{h}'_v), \quad \text{where } \boldsymbol{h}'_v = \mathcal{A}(\{\boldsymbol{h}_u | u \in \pi(v)\})$$

Graph Decoder: Synthesizing Output Graph



Supervised Loss Function: $\mathcal{L} = \mathcal{L}_{length} + \mathcal{L}_{nodes} + \mathcal{L}_{structure}$

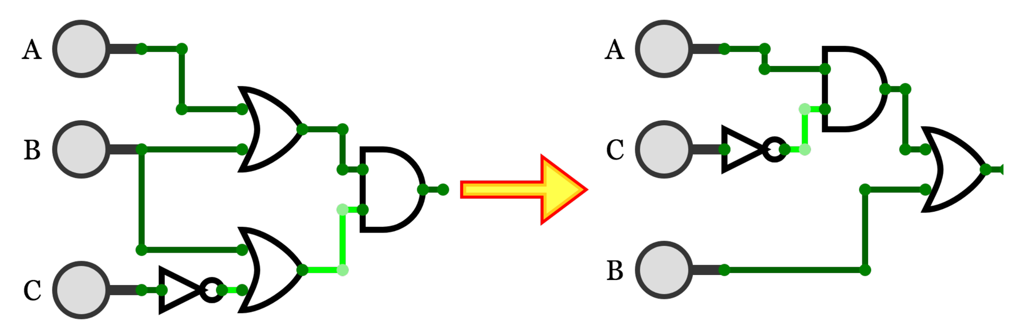
$\mathcal{L}_{length} = \text{Poisson-NLL-Loss}(f_{Length}(\boldsymbol{H}_{in}), |V_{target}|) \approx |V_{out}| - |V_{target}| \log(|V_{out}|)$

$\mathcal{L}_{nodes} = \text{Cross-Entropy}(V_{out}, V_{target})$

$\mathcal{L}_{structure} = \text{Diffusion}(\boldsymbol{A}_{out}, \boldsymbol{A}_{target}) = \text{MSE}(\boldsymbol{A}_{out}\boldsymbol{r}, \boldsymbol{A}_{target}\boldsymbol{r})$

Logical Circuit Simplification

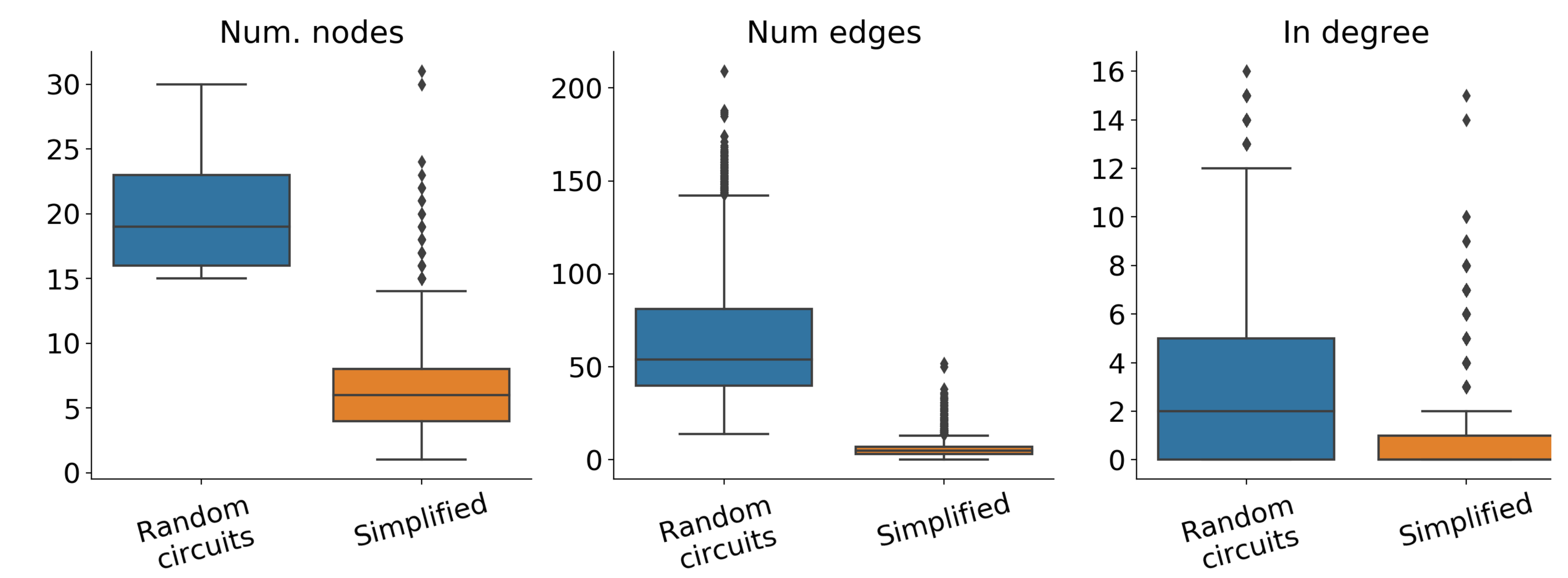
Given an input logical circuit, the goal is to output an *equivalent* and *syntactically-correct* circuit with smaller number of gates.



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

Experiments

Data statistics



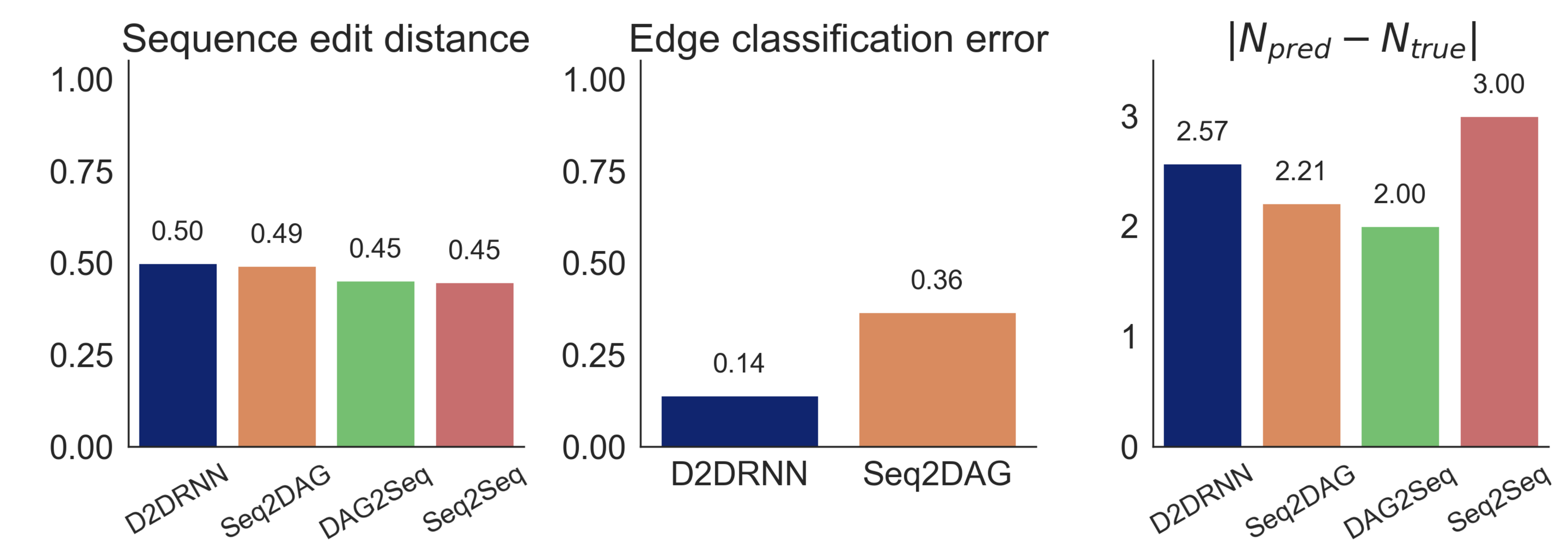
Baselines

`Seq2Seq`[2]: DAGS as sequences of nodes

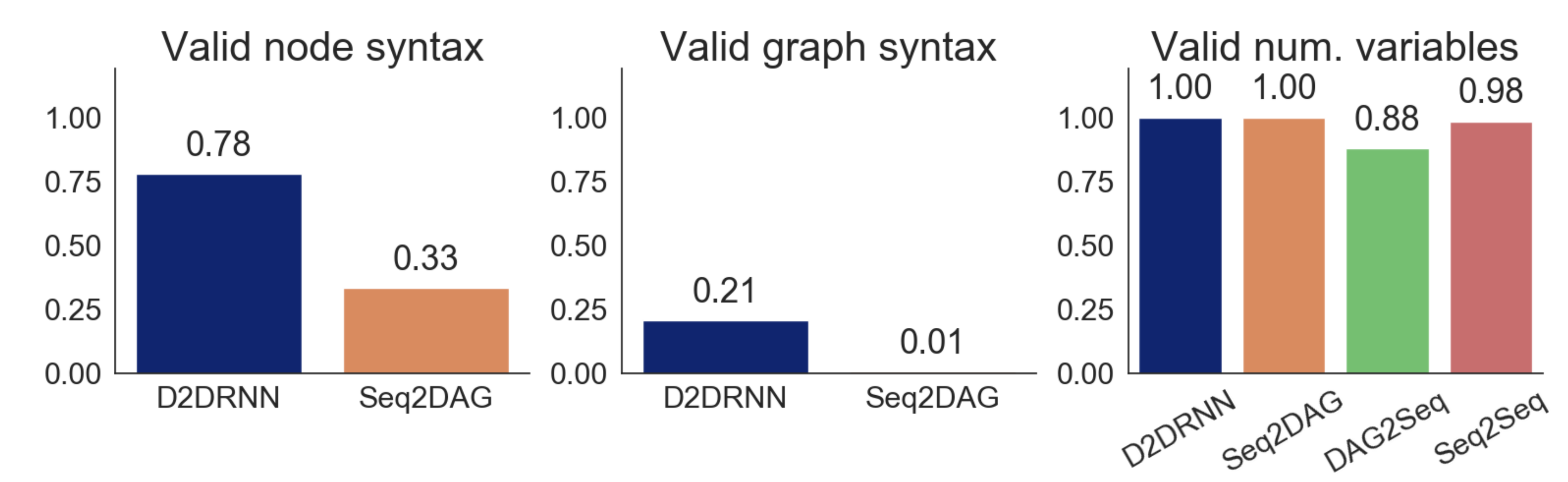
`Seq2DAG`: sequence of nodes to DAG decoder

`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

[1] Anonymous.
Learning to solve circuit-sat: An unsupervised differentiable approach.
In *Submitted to International Conference on Learning Representations*, 2019. under review.

[2] I. Sutskever, O. Vinyals, and Q. V. Le.
Sequence to sequence learning with neural networks.
In *Advances in neural information processing systems*, pages 3104–3112, 2014.