Graph4NLP

Graph4NLP: A Library for Deep Learning on Graphs for NLP

Yu (Hugo) Chen

Research Scientist at Meta AI

DLG4NLP@ICLR'22

April 29th, 2022

Graph4NLP: A Brief History and Future

Year June/2021

Graph4NLP v0.4.1 Released, first library for promoting easy use of GNN for NLP.

Year September/2021

Our **DLG4NLP website** launched: survey, library, tutorial, workshop and many more.

Year September/2021

Graph4NLP v0.5.1 released, Lint the codes, support testing with users' own data, and fix many reported bugs.

Year 01/20/2022

Graph4NLP v0.5.5 released, Support model.predict API by introducing wrapper functions, separate graph topology and graph embedding and many more…

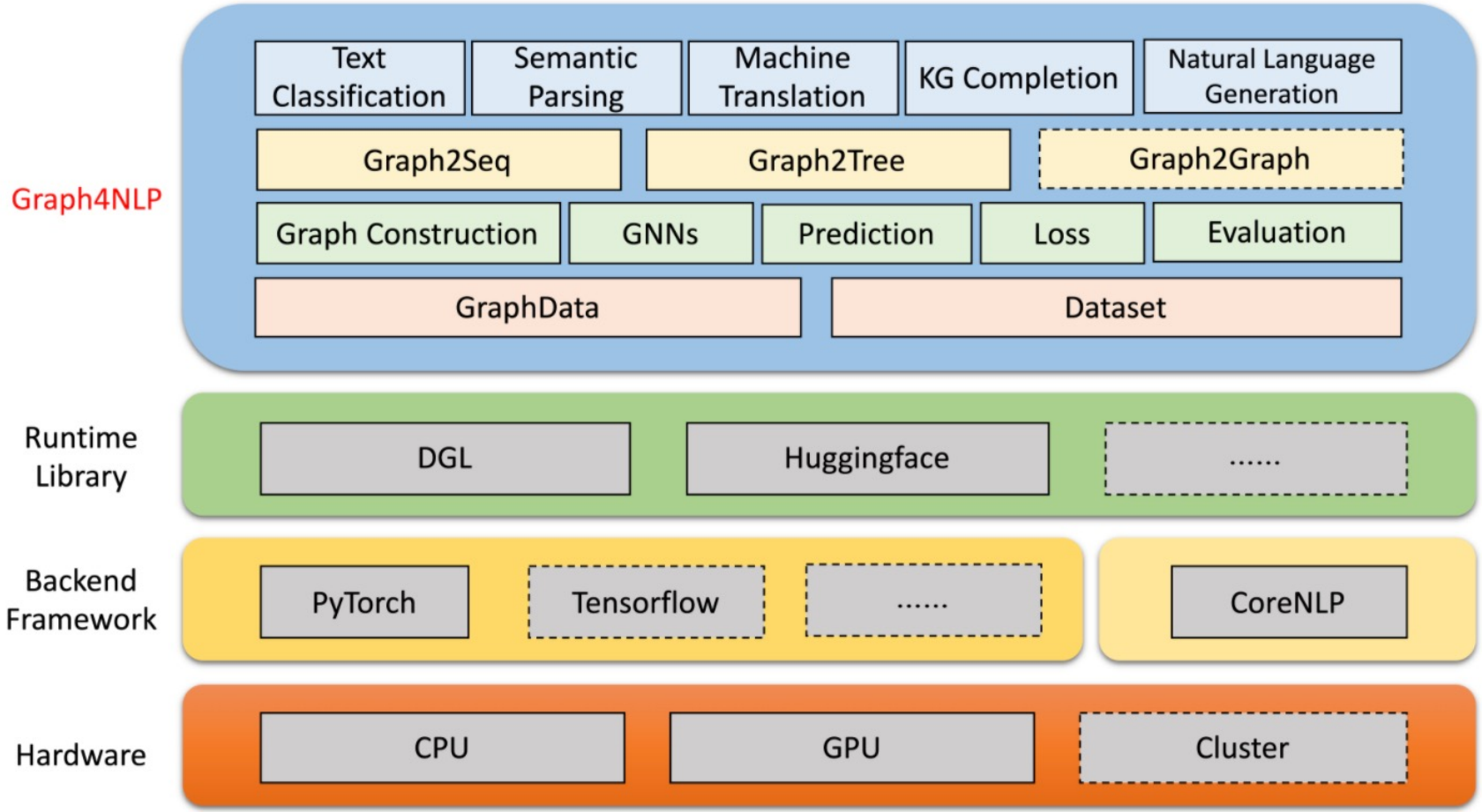
Year May/2022 (planning)

- Graph4NLP v0.6 will be released, new configuration system, relational GNN, AMR graph construction support.

Year 2022+

- More **Graph4NLP** releases
- More workshops
- Release a new Graph4NLP book by Cambridge Press.

Overall Architecture of Graph4NLP Library



DGL: https://github.com/dmlc/dgl, DIG: https://github.com/divelab/DIG, Huggingface: https://github.com/huggingface/transformers

Graph4NLP

Key Features

Easy-to-use and Flexible

Provides both full implementations of state-of-the-art models and also flexible interfaces to build customized models with whole-pipeline support

Rich Set of Learning Resources

Provide a variety of learning materials including code demos, code documentations, research tutorials and videos, and paper survey

High Running Efficiency and Extensibility

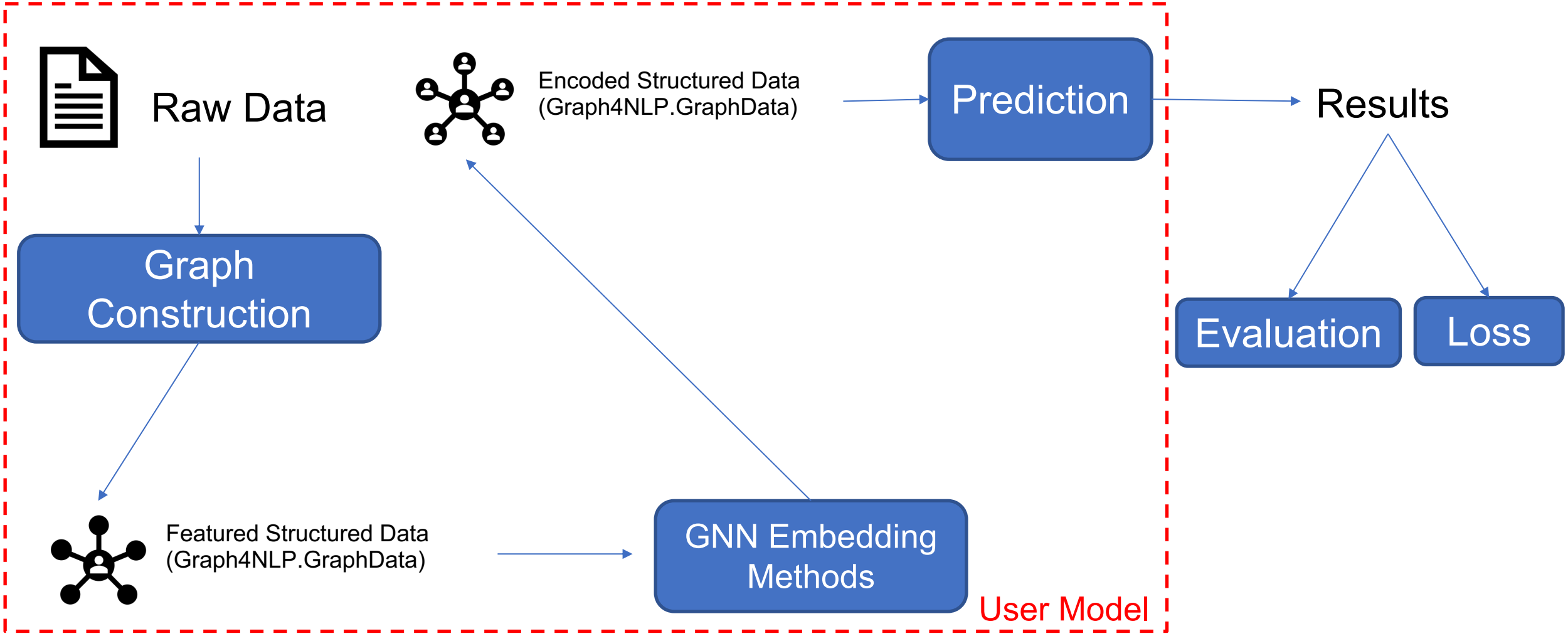
Build upon highly-optimized runtime libraries including DGL and provide highly modulization blocks

Comprehensive Code Examples

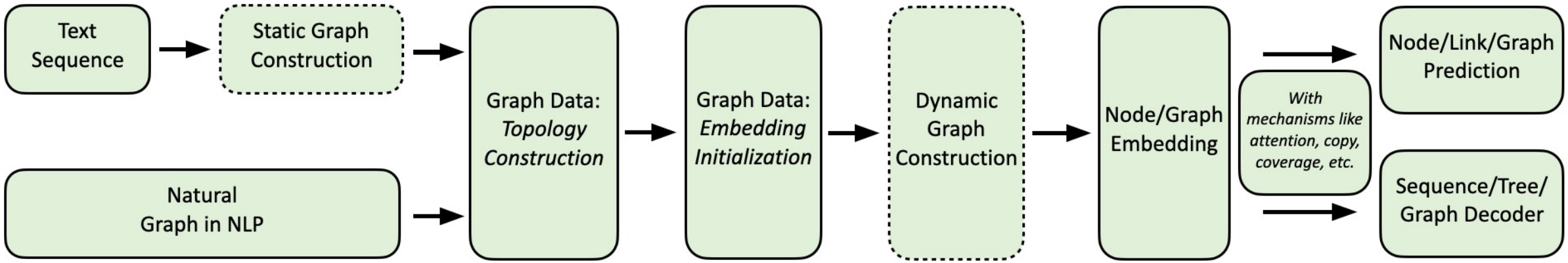
Provide a comprehensive collection of NLP applications and the corresponding code examples for quick-start

Documentation website: https://graph4ai.github.io/graph4nlp/index.html

Data Flow of Graph4NLP



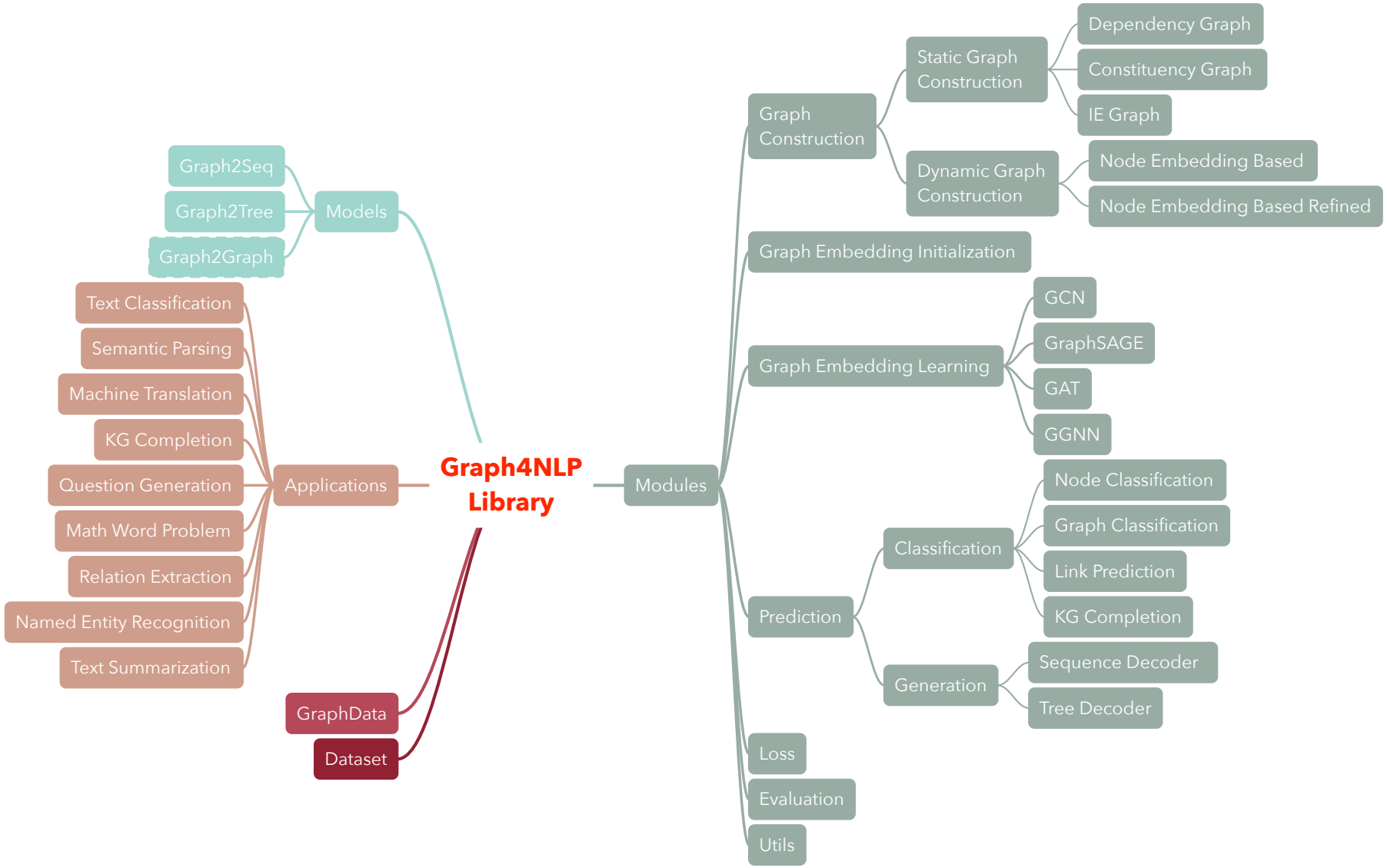
Computing Flow of Graph4NLP



Performance of Built-in NLP Tasks

Task	Dataset	GNN Model	Graph construction	Evaluation	Performance
Text classification	TRECT CAirline CNSST	GAT	Dependency	Accuracy	0.948 0.769 0.538
Semantic Parsing	JOBS	SAGE	Constituency	Execution accuracy	0.936
Question generation	SQuAD	GGNN	Dependency	BLEU-4	0.15175
Machine translation	IWSLT14	GCN	Dynamic	BLEU-4	0.3212
Summarization	CNN(30k)	GCN	Dependency	ROUGE-1	26.4
Knowledge graph completion	Kinship	GCN	Dependency	MRR	82.4
Math word problem	MAWPS MATHQA	SAGE	Dynamic	Solution accuracy Exact match	76.4 61.07

Dive Into Graph4NLP Library



Graph4NLP

Graph Construction Module

- Static graph construction
  - Dependency graph construction
  - Constituency graph construction
  - IE graph construction
- Dynamic graph construction
  - Node embedding based
  - Node embedding based refined (i.e., static & dynamic hybrid)

```
self.graph_topology = NodeEmbeddingBasedGraphConstruction(
    sim_metric_type=config["gl_metric_type"],
    num_heads=config["gl_num_heads"],
    top_k_neigh=config["gl_top_k"],
    epsilon_neigh=config["gl_epsilon"],
    smoothness_ratio=config["gl_smoothness_ratio"],
    connectivity_ratio=config["gl_connectivity_ratio"],
    sparsity_ratio=config["gl_sparsity_ratio"],
    input_size=config["num_hidden"],
    hidden_size=config["gl_num_hidden"],
)
```

```
self.graph_topology = NodeEmbeddingBasedRefinedGraphConstruction(
    config["init_adj_alpha"],
    sim_metric_type=config["gl_metric_type"],
    num_heads=config["gl_num_heads"],
    top_k_neigh=config["gl_top_k"],
    epsilon_neigh=config["gl_epsilon"],
    smoothness_ratio=config["gl_smoothness_ratio"],
    connectivity_ratio=config["gl_connectivity_ratio"],
    sparsity_ratio=config["gl_sparsity_ratio"],
    input_size=config["num_hidden"],
    hidden_size=config["gl_num_hidden"],
)
```

Graph Embedding Initialization Module

- Single-token & multi-token node/edge
- Various built-in strategies for node/edge embedding initialization (non-exhaustive list)
  - ‘w2v’
  - ‘w2v_bilstm’
  - 'bert'
  - 'bert_bilstm'
  - 'w2v_bert’
  - 'w2v_bert_bilstm'

```
self.graph_initializer = GraphEmbeddingInitialization(
    word_vocab=self.vocab_model.in_word_vocab,
    embedding_style=embedding_style,
    hidden_size=config["num_hidden"],
    word_dropout=config["word_dropout"],
    rnn_dropout=config["rnn_dropout"],
    fix_word_emb=not config["no_fix_word_emb"],
    fix_bert_emb=not config.get("no_fix_bert_emb", False),
)
```

```
embedding_style = {
    "single_token_item": True if self.graph_name != "ie" else False,
    "emb_strategy": config.get("emb_strategy", "w2v_bilstm"),
    "num_rnn_layers": 1,
    "bert_model_name": config.get("bert_model_name", "bert-base-uncased"),
    "bert_lower_case": True,
}
```

Graph Embedding Learning Module

- Common GNN variants
  - GCN
  - GAT
  - GraphSAGE
  - GGNN
- direction_option
  - ‘undirected’
  - ‘bi_fuse’
  - ‘bi_sep’
- use_edge_weight
  - useful for dynamic graph construction

```
self.gnn = GGNN(
    config["gnn_num_layers"],
    config["num_hidden"],
    config["num_hidden"],
    config["num_hidden"],
    feat_drop=config["gnn_dropout"],
    direction_option=config["gnn_direction_option"],
    bias=True,
    use_edge_weight=use_edge_weight,
)
```

Prediction Module

- Classification
  - Node classification
  - Graph classification
  - Link prediction
  - KG completion
  - Graph pooling: avg_pool, max_pool

```
self.seq_decoder = StdRNNDecoder(
    rnn_type=rnn_type,
    max_decoder_step=decoder_length,
    input_size=input_size,
    hidden_size=hidden_size,
    graph_pooling_strategy=graph_pooling_strategy,
    word_emb=self.dec_word_emb,
    vocab=vocab_model.out_word_vocab,
    attention_type=attention_type,
    fuse_strategy=fuse_strategy,
    node_type_num=node_type_num,
    rnn_emb_input_size=rnn_input_size,
    use_coverage=use_coverage,
    use_copy=use_copy,
    tgt_emb_as_output_layer=tgt_emb_as_output_layer,
    dropout=rnn_dropout,
)
```

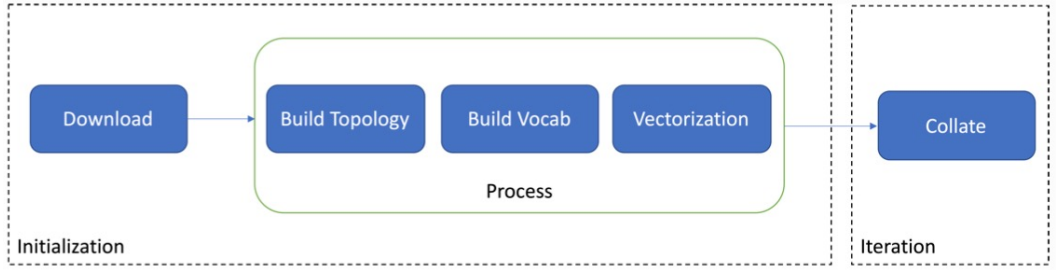
- Generation
  - Sequence decoder
  - Tree decoder
  - Attention, copy, coverage mechanisms

```
self.decoder = StdTreeDecoder(
    attn_type=dec_attention_type,
    embeddings=self.enc_word_emb.word_emb_layer
    if self.use_share_vocab
    else self.tgt_word_embedding,
    enc_hidden_size=gnn_hidden_size,
    dec_emb_size=self.tgt_vocab.embedding_dims,
    dec_hidden_size=dec_hidden_size,
    output_size=self.output_size,
    criterion=self.criterion,
    teacher_force_ratio=dec_teacher_forcing_rate,
    use_sibling=dec_use_sibling,
    use_copy=self.use_copy,
    dropout_for_decoder=dec_dropout,
    max_dec_seq_length=dec_max_decoder_step,
    max_dec_tree_depth=dec_max_tree_depth,
    tgt_vocab=self.tgt_vocab,
)
```

Built-in high-level Graph2Seq, Graph2Tree APIs. Config in, model out.

Dataset

- Built-in dataset types
  - Text2TextDataset
  - TextToTreeDataset
  - Text2LabelDataset
  - SequenceLabelingDataset
  - DoubleText2TextDataset



Dataset Workflow

```python
class TrecDataset(Text2LabelDataset):
    @property
    def raw_file_names(self):
        """3 reserved keys: 'train', 'val' (optional), 'test'. Represent the split of dataset."""
        return {"train": "train.txt", "test": "test.txt"}

    @property
    def processed_file_names(self):
        """At least 3 reserved keys should be fiiled: 'vocab', 'data' and 'label'."""
        return {"vocab": "vocab.pt", "data": "data.pt", "label": "label.pt"}

    def __init__(
```

```python
dataset = TrecDataset(
    root_dir=self.config["graph_construction_args"]["graph_construction_share"]["root_dir"],
    topology_subdir=topology_subdir,
    graph_name=self.graph_name,
    dynamic_init_graph_name=self.config["graph_construction_args"][
        "graph_construction_private"
    ]["dynamic_init_graph_name"],
    dynamic_init_topology_aux_args={"dummy_param": 0},
    pretrained_word_emb_name=self.config["pretrained_word_emb_name"],
    merge_strategy=self.config["graph_construction_args"]["graph_construction_private"][
        "merge_strategy"
    ],
    edge_strategy=self.config["graph_construction_args"]["graph_construction_private"][
        "edge_strategy"
    ],
    min_word_vocab_freq=self.config.get("min_word_freq", 1),
    word_emb_size=self.config.get("word_emb_size", 300),
    seed=self.config["seed"],
    thread_number=self.config["graph_construction_args"]["graph_construction_share"][
        "thread_number"
    ],
    port=self.config["graph_construction_args"]["graph_construction_share"]["port"],
    timeout=self.config["graph_construction_args"]["graph_construction_share"]["timeout"],
    reused_label_model=None,
)
```

Inference

- Inference wrapper
  - classifier_inference_wrapper
  - generator_inference_wrapper
  - generator_inference_wrapper_for_tree

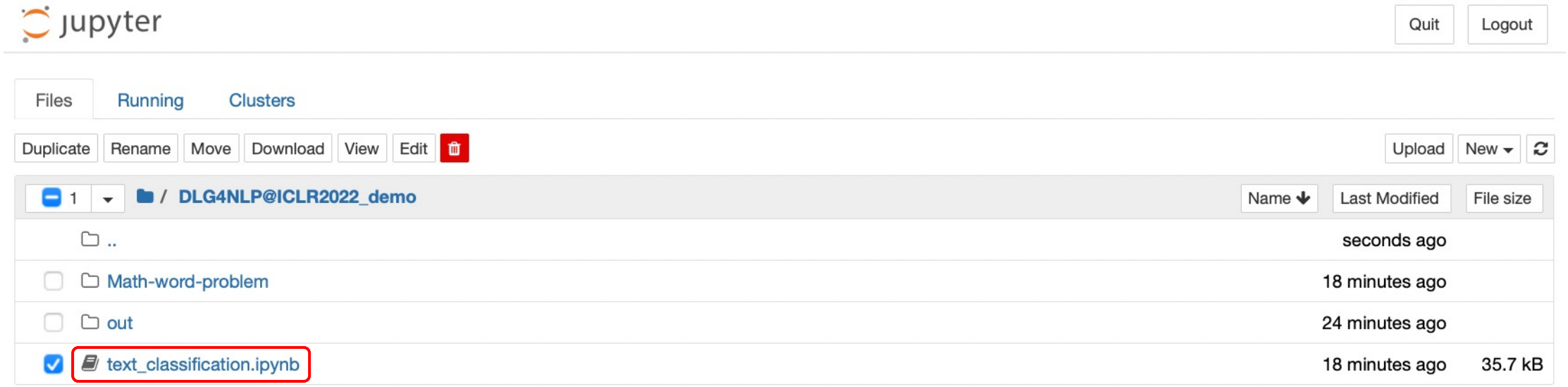
```
self.inference_tool = GeneratorInferenceWrapper(
    cfg=self.config, model=self.model,
    dataset=DoubleText2TextDataset,
    data_item=DoubleText2TextDataItem,
    beam_size=self.config["beam_size"],
    topk=1, lower_case=True,
    tokenizer=word_tokenize,
    share_vocab=True,
)
```

```
self.inference_tool = ClassifierInferenceWrapper(
    cfg=self.config,
    model=self.model,
    label_names=self.model.label_model.le.classes_.tolist(),
    dataset=Text2LabelDataset,
    data_item=Text2LabelDataItem,
    lower_case=True,
    tokenizer=word_tokenize,
)
```

Ref: https://mentorphile.com/2018/09/14/demo-or-die/

Demo 1: Text Classification Application

1) git clone https://github.com/graph4ai/graph4nlp_demo
2) follow Get Started instructions in README



Demo 1: Building a Text Classification Application

```python
def forward(self, graph_list, tgt=None, require_loss=True):
    # graph embedding initialization
    batch_gd = self.graph_initializer(graph_list)

    # run dynamic graph construction if turned on
    if hasattr(self, "graph_topology") and hasattr(self.graph_topology, "dynamic_topology"):
        batch_gd = self.graph_topology.dynamic_topology(batch_gd)

    # run GNN
    self.gnn(batch_gd)

    # run graph classifier
    self.clf(batch_gd)
    logits = batch_gd.graph_attributes["logits"]

    if require_loss:
        loss = self.loss(logits, tgt)
        return logits, loss
    else:
        return logits
```

https://github.com/graph4ai/graph4nlp_demo/tree/main/DLG4NLP%40ICLR2022_demo

Graph4NLP

Demo 1: Building a Text Classification Application

Graph embedding initialization API, various built-in options, can be customized

```
embedding_style = {
    "single_token_item": True if self.graph_name != "ie" else False,
    "emb_strategy": config.get("emb_strategy", "w2v_bilstm"),
    "num_rnn_layers": 1,
    "bert_model_name": config.get("bert_model_name", "bert-base-uncased"),
    "bert_lower_case": True,
}

self.graph_initializer = GraphEmbeddingInitialization(
    word_vocab=self.vocab_model.in_word_vocab,
    embedding_style=embedding_style,
    hidden_size=config["num_hidden"],
    word_dropout=config["word_dropout"],
    rnn_dropout=config["rnn_dropout"],
    fix_word_emb=not config["no_fix_word_emb"],
    fix_bert_emb=not config.get("no_fix_bert_emb", False),
)
```

https://github.com/graph4ai/graph4nlp_demo/tree/main/DLG4NLP%40ICLR2022_demo

Demo 1: Building a Text Classification Application

Graph construction API, various built-in options, can be customized

```
self.graph_topology = NodeEmbeddingBasedGraphConstruction(
    sim_metric_type=config["gl_metric_type"],
    num_heads=config["gl_num_heads"],
    top_k_neigh=config["gl_top_k"],
    epsilon_neigh=config["gl_epsilon"],
    smoothness_ratio=config["gl_smoothness_ratio"],
    connectivity_ratio=config["gl_connectivity_ratio"],
    sparsity_ratio=config["gl_sparsity_ratio"],
    input_size=config["num_hidden"],
    hidden_size=config["gl_num_hidden"],
)
```

https://github.com/graph4ai/graph4nlp_demo/tree/main/DLG4NLP%40ICLR2022_demo

Demo 1: Building a Text Classification Application

Graph embedding learning API, various built-in options, can be customized

```
self.gnn = GraphSAGE(config['gnn_num_layers'],
             config['num_hidden'],
             config['num_hidden'],
             config['num_hidden'],
             config['graphsage_aggreagte_type'],
             direction_option=config['gnn_direction_option'],
             feat_drop=config['gnn_dropout'],
             bias=True,
             norm=None,
             activation=F.relu,
             use_edge_weight=use_edge_weight)
```

https://github.com/graph4ai/graph4nlp_demo/tree/main/DLG4NLP%40ICLR2022_demo

Demo 1: Building a Text Classification Application

Prediction API, various built-in options, can be customized

```
self.clf = FeedForwardNN(2 * config['num_hidden'] \
                if config['gnn_direction_option'] == 'bi_sep' \
                else config['num_hidden'],
                config['num_classes'],
                [config['num_hidden']],
                graph_pool_type=config['graph_pooling'],
                dim=config['num_hidden'],
                use_linear_proj=config['max_pool_linear_proj'])
```

https://github.com/graph4ai/graph4nlp_demo/tree/main/DLG4NLP%40ICLR2022_demo

Demo 1: Building a Text Classification Application

```
dataset = TrecDataset(
    root_dir=self.config["graph_construction_args"]["graph_construction_share"]["root_dir"],
    topology_subdir=topology_subdir,
    graph_name=self.graph_name,
    dynamic_init_graph_name=self.config["graph_construction_args"][
        "graph_construction_private"
    ]["dynamic_init_graph_name"],
    dynamic_init_topology_aux_args={"dummy_param": 0},
    pretrained_word_emb_name=self.config["pretrained_word_emb_name"],
    merge_strategy=self.config["graph_construction_args"]["graph_construction_private"][
        "merge_strategy"
    ],
    edge_strategy=self.config["graph_construction_args"]["graph_construction_private"][
        "edge_strategy"
    ],
    min_word_vocab_freq=self.config.get("min_word_freq", 1),
    word_emb_size=self.config.get("word_emb_size", 300),
    seed=self.config["seed"],
    thread_number=self.config["graph_construction_args"]["graph_construction_share"][
        "thread_number"
    ],
    port=self.config["graph_construction_args"]["graph_construction_share"]["port"],
    timeout=self.config["graph_construction_args"]["graph_construction_share"]["timeout"],
    reused_label_model=None,
)
```

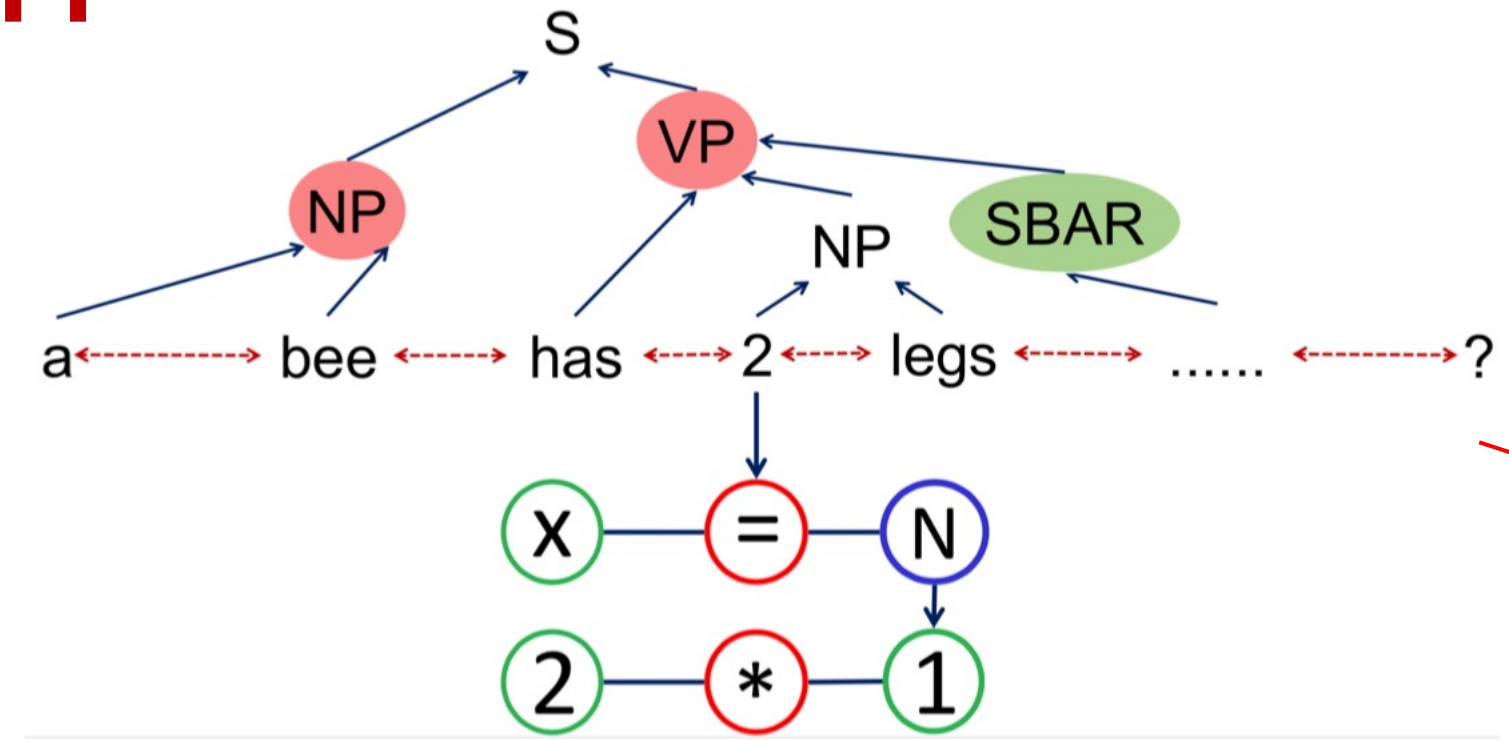
Dataset API, various built-in options, can be customized

https://github.com/graph4ai/graph4nlp_demo/tree/main/DLG4NLP%40ICLR2022_demo

Demo 2: Building a Math Word Problem Application

1) git clone https://github.com/graph4ai/graph4nlp_demo
2) follow Get Started instructions in README

Demo 2: Building a Math Word Problem Application



Graph2Tree problem

Demo 2: Building a Math Word Problem Application

Graph2Tree API (with attention, copy and coverage mechanisms)

```
def _build_model(self):
    '''For encoder-decoder'''
    self.model = Graph2Tree.from_args(self.opt,
                                      vocab_model=self.vocab_model)
    self.model.init(self.opt["init_weight"])
    self.model.to(self.device)
```

https://github.com/graph4ai/graph4nlp_demo/tree/main/DLG4NLP%40ICLR2022_demo/Math-word-problem

Demo 2: Building a Math Word Problem Application

Dataset API, various built-in options, can be customized

```
para_dic = {
    "root_dir": self.data_dir,
    "word_emb_size": self.opt["graph_initialization_args"]["input_size"],
    "topology_subdir": self.opt["graph_construction_args"]["graph_construction_share"][
        "topology_subdir"
    ],
    "edge_strategy": self.opt["graph_construction_args"]["graph_construction_private"][
        "edge_strategy"
    ],
    "graph_name": self.opt["graph_construction_args"]["graph_construction_share"][
        "graph_name"
    ],
    "share_vocab": self.use_share_vocab,
    "enc_emb_size": self.opt["graph_initialization_args"]["input_size"],
    "dec_emb_size": self.opt["decoder_args"]["rnn_decoder_share"]["input_size"],
    "dynamic_init_graph_name": self.opt["graph_construction_args"][
        "graph_construction_private"
    ].get("dynamic_init_graph_name", None),
    "min_word_vocab_freq": self.opt["min_freq"],
    "pretrained_word_emb_name": self.opt["pretrained_word_emb_name"]
}

dataset = MawpsDatasetForTree(**para_dic)
```

https://github.com/graph4ai/graph4nlp_demo/tree/main/DLG4NLP%40ICLR2022_demo/Math-word-problem

Future Directions

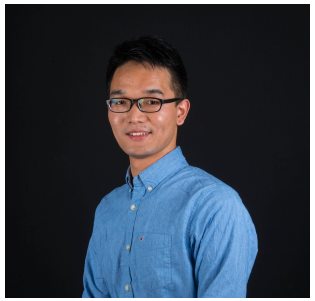
- Customization
- Scalability – native multi-GPU/node training support
- Easy deployment to production
- Benchmarking –more SOTA models and NLP tasks
- TensorFlow support
- …

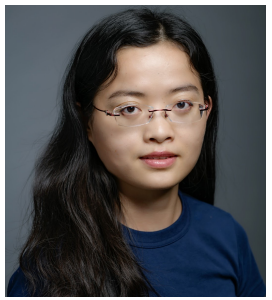
PRs and suggestions are welcome 😁

Resources

- DLG4NLP website: https://dlg4nlp.github.io/index.html
- Graph4NLP library: https://github.com/graph4ai/graph4nlp
- Graph4NLP documentation https://graph4ai.github.io/graph4nlp/
- Survey: https://arxiv.org/abs/2106.06090
- Literature list: https://github.com/graph4ai/graph4nlp_literature

Team Members





and Jing Hu

Thanks!
Q&A

Yu (Hugo) Chen
Research Scientist
Meta AI,
Email: hugochan2013@gmail.com, hugochen@fb.com
Web: http://academic.hugochan.net