
DICE Embeddings

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Contents:

1 Dicee Manual	2
2 Installation	3
2.1 Installation from Source	3
3 Download Knowledge Graphs	3
4 Knowledge Graph Embedding Models	3
5 How to Train	3
6 Creating an Embedding Vector Database	5
6.1 Learning Embeddings	5
6.2 Loading Embeddings into Qdrant Vector Database	6
6.3 Launching Webservice	6
7 Answering Complex Queries	6
8 Predicting Missing Links	8
9 Downloading Pretrained Models	8
10 How to Deploy	8
11 Docker	8
12 Coverage Report	8
13 How to cite	10
14 dicee	12
14.1 Submodules	12
14.2 Attributes	209
14.3 Classes	209
14.4 Package Contents	210
Python Module Index	222

DICE Embeddings¹: Hardware-agnostic Framework for Large-scale Knowledge Graph Embeddings:

1 Dicee Manual

Version: dicee 0.3.2

GitHub repository: <https://github.com/dice-group/dice-embeddings>

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Dicee is a hardware-agnostic framework for large-scale knowledge graph embeddings.

Knowledge graph embedding research has mainly focused on learning continuous representations of knowledge graphs towards the link prediction problem. Recently developed frameworks can be effectively applied in a wide range of research-related applications. Yet, using these frameworks in real-world applications becomes more challenging as the size of the knowledge graph grows

We developed the DICE Embeddings framework (dicee) to compute embeddings for large-scale knowledge graphs in a hardware-agnostic manner. To achieve this goal, we rely on

1. **Pandas³ & Co.** to use parallelism at preprocessing a large knowledge graph,
2. **PyTorch⁴ & Co.** to learn knowledge graph embeddings via multi-CPUs, GPUs, TPUs or computing cluster, and
3. **Huggingface⁵** to ease the deployment of pre-trained models.

Why Pandas⁶ & Co. ? A large knowledge graph can be read and preprocessed (e.g. removing literals) by pandas, modin, or polars in parallel. Through polars, a knowledge graph having more than 1 billion triples can be read in parallel fashion. Importantly, using these frameworks allow us to perform all necessary computations on a single CPU as well as a cluster of computers.

Why PyTorch⁷ & Co. ? PyTorch is one of the most popular machine learning frameworks available at the time of writing. PytorchLightning facilitates scaling the training procedure of PyTorch without boilerplate. In our framework, we combine PyTorch⁸ & PytorchLightning⁹. Users can choose the trainer class (e.g., DDP by Pytorch) to train large knowledge graph embedding models with billions of parameters. PytorchLightning allows us to use state-of-the-art model parallelism techniques (e.g. Fully Sharded Training, FairScale, or DeepSpeed) without extra effort. With our framework, practitioners can directly use PytorchLightning for model parallelism to train gigantic embedding models.

Why Huggingface¹⁰? Seamlessly deploy and share pre-trained embedding models through the Huggingface ecosystem.

¹ <https://github.com/dice-group/dice-embeddings>

² <https://github.com/Demirrr>

³ <https://pandas.pydata.org/>

⁴ <https://pytorch.org/>

⁵ <https://huggingface.co/>

⁶ <https://pandas.pydata.org/>

⁷ <https://pytorch.org/>

⁸ <https://pytorch.org/>

⁹ <https://www.pytorchlightning.ai/>

¹⁰ <https://huggingface.co/>

2 Installation

2.1 Installation from Source

```
git clone https://github.com/dice-group/dice-embeddings.git
conda create -n dice python=3.10.13 --no-default-packages && conda activate dice &&
→cd dice-embeddings &&
pip3 install -e .
```

or

```
pip install dicee
```

3 Download Knowledge Graphs

```
wget https://files.dice-research.org/datasets/dice-embeddings/KGs.zip --no-check-
→certificate && unzip KGs.zip
```

To test the Installation

```
python -m pytest -p no:warnings -x # Runs >114 tests leading to > 15 mins
python -m pytest -p no:warnings --lf # run only the last failed test
python -m pytest -p no:warnings --ff # to run the failures first and then the rest of
→the tests.
```

4 Knowledge Graph Embedding Models

1. TransE, DistMult, ComplEx, ConEx, QMult, OMult, ConvO, ConvQ, Keci
2. All 44 models available in <https://github.com/pykeen/pykeen#models>

For more, please refer to examples.

5 How to Train

To Train a KGE model (KECI) and evaluate it on the train, validation, and test sets of the UMLS benchmark dataset.

```
from dicee.executer import Execute
from dicee.config import Namespace
args = Namespace()
args.model = 'Keci'
args.scoring_technique = "KvsAll" # 1vsAll, or AllvsAll, or NegSample
args.dataset_dir = "KGs/UMLS"
args.path_to_store_single_run = "Keci_UMLS"
args.num_epochs = 100
args.embedding_dim = 32
args.batch_size = 1024
reports = Execute(args).start()
print(reports["Train"]["MRR"]) # => 0.9912
print(reports["Test"]["MRR"]) # => 0.8155
# See the Keci_UMLS folder embeddings and all other files
```

where the data is in the following form

```
$ head -3 KGs/UMLS/train.txt
acquired_abnormality      location_of      experimental_model_of_disease
anatomical_abnormality    manifestation_of      physiologic_function
alga      isa      entity
```

A KGE model can also be trained from the command line

```
dicee --dataset_dir "KGs/UMLS" --model Keci --eval_model "train_val_test"
```

dicee automatically detects available GPUs and trains a model with distributed data parallel technique. Under the hood, dicee uses lightning as a default trainer.

```
# Train a model by only using the GPU-0
CUDA_VISIBLE_DEVICES=0 dicee --dataset_dir "KGs/UMLS" --model Keci --eval_model
↪ "train_val_test"
# Train a model by only using GPU-1
CUDA_VISIBLE_DEVICES=1 dicee --dataset_dir "KGs/UMLS" --model Keci --eval_model
↪ "train_val_test"
NCCL_P2P_DISABLE=1 CUDA_VISIBLE_DEVICES=0,1 python dicee/scripts/run.py --trainer PL -
↪ --dataset_dir "KGs/UMLS" --model Keci --eval_model "train_val_test"
```

Under the hood, dicee executes run.py script and uses lightning as a default trainer

```
# Two equivalent executions
# (1)
dicee --dataset_dir "KGs/UMLS" --model Keci --eval_model "train_val_test"
# Evaluate Keci on Train set: Evaluate Keci on Train set
# {'H@1': 0.9518788343558282, 'H@3': 0.9988496932515337, 'H@10': 1.0, 'MRR': 0.
↪ 9753123402351737}
# Evaluate Keci on Validation set: Evaluate Keci on Validation set
# {'H@1': 0.6932515337423313, 'H@3': 0.9041411042944786, 'H@10': 0.9754601226993865,
↪ 'MRR': 0.8072362996241839}
# Evaluate Keci on Test set: Evaluate Keci on Test set
# {'H@1': 0.6951588502269289, 'H@3': 0.9039334341906202, 'H@10': 0.9750378214826021,
↪ 'MRR': 0.8064032293278861}

# (2)
CUDA_VISIBLE_DEVICES=0,1 python dicee/scripts/run.py --trainer PL --dataset_dir "KGs/
↪ UMLS" --model Keci --eval_model "train_val_test"
# Evaluate Keci on Train set: Evaluate Keci on Train set
# {'H@1': 0.9518788343558282, 'H@3': 0.9988496932515337, 'H@10': 1.0, 'MRR': 0.
↪ 9753123402351737}
# Evaluate Keci on Train set: Evaluate Keci on Train set
# Evaluate Keci on Validation set: Evaluate Keci on Validation set
# {'H@1': 0.6932515337423313, 'H@3': 0.9041411042944786, 'H@10': 0.9754601226993865,
↪ 'MRR': 0.8072362996241839}
# Evaluate Keci on Test set: Evaluate Keci on Test set
# {'H@1': 0.6951588502269289, 'H@3': 0.9039334341906202, 'H@10': 0.9750378214826021,
↪ 'MRR': 0.8064032293278861}
```

Similarly, models can be easily trained with torchrun

```

torchrun --standalone --nnodes=1 --nproc_per_node=gpu dicee/scripts/run.py --trainer_
↪torchDDP --dataset_dir "KGs/UMLS" --model Keci --eval_model "train_val_test"
# Evaluate Keci on Train set: Evaluate Keci on Train set: Evaluate Keci on Train set
# {'H@1': 0.9518788343558282, 'H@3': 0.9988496932515337, 'H@10': 1.0, 'MRR': 0.
↪9753123402351737}
# Evaluate Keci on Validation set: Evaluate Keci on Validation set
# {'H@1': 0.6932515337423313, 'H@3': 0.9041411042944786, 'H@10': 0.9754601226993865,
↪'MRR': 0.8072499937521418}
# Evaluate Keci on Test set: Evaluate Keci on Test set
{'H@1': 0.6951588502269289, 'H@3': 0.9039334341906202, 'H@10': 0.9750378214826021,
↪'MRR': 0.8064032293278861}

```

You can also train a model in multi-node multi-gpu setting.

```

torchrun --nnodes 2 --nproc_per_node=gpu --node_rank 0 --rdzv_id 455 --rdzv_backend_
↪c10d --rdzv_endpoint=nebula dicee/scripts/run.py --trainer torchDDP --dataset_dir_
↪KGs/UMLS
torchrun --nnodes 2 --nproc_per_node=gpu --node_rank 1 --rdzv_id 455 --rdzv_backend_
↪c10d --rdzv_endpoint=nebula dicee/scripts/run.py --trainer torchDDP --dataset_dir_
↪KGs/UMLS

```

Train a KGE model by providing the path of a single file and store all parameters under newly created directory called KeciFamilyRun.

```

dicee --path_single_kg "KGs/Family/family-benchmark_rich_background.owl" --model Keci
↪--path_to_store_single_run KeciFamilyRun --backend rdflib

```

where the data is in the following form

```

$ head -3 KGs/Family/train.txt
_:1 <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://www.w3.org/2002/07/owl
↪#Ontology> .
<http://www.benchmark.org/family#hasChild> <http://www.w3.org/1999/02/22-rdf-syntax-ns
↪#type> <http://www.w3.org/2002/07/owl#ObjectProperty> .
<http://www.benchmark.org/family#hasParent> <http://www.w3.org/1999/02/22-rdf-syntax-
↪ns#type> <http://www.w3.org/2002/07/owl#ObjectProperty> .

```

Apart from n-triples or standard link prediction dataset formats, we support [“owl”, “nt”, “turtle”, “rdf/xml”, “n3”]*. Moreover, a KGE model can be also trained by providing an endpoint of a triple store.

```

dicee --sparql_endpoint "http://localhost:3030/mutagenesis/" --model Keci

```

For more, please refer to examples.

6 Creating an Embedding Vector Database

6.1 Learning Embeddings

```

# Train an embedding model
dicee --dataset_dir KGs/Countries-S1 --path_to_store_single_run CountryEmbeddings --
↪model Keci --p 0 --q 1 --embedding_dim 32 --adaptive_swa

```

6.2 Loading Embeddings into Qdrant Vector Database

```
# Ensure that Qdrant available
# docker pull qdrant/qdrant && docker run -p 6333:6333 -p 6334:6334      -v $(pwd) /
→qdrant_storage:/qdrant/storage:z      qdrant/qdrant
diceeindex --path_model "CountryEmbeddings" --collection_name "dummy" --location
→"localhost"
```

6.3 Launching Webservice

```
diceeserve --path_model "CountryEmbeddings" --collection_name "dummy" --collection_
→location "localhost"
```

Retrieve and Search

Get embedding of germany

```
curl -X 'GET' 'http://0.0.0.0:8000/api/get?q=germany' -H 'accept: application/json'
```

Get most similar things to europe

```
curl -X 'GET' 'http://0.0.0.0:8000/api/search?q=europe' -H 'accept: application/json'
{"result": [{"hit": "europe", "score": 1.0},
 {"hit": "northern_europe", "score": 0.67126536},
 {"hit": "western_europe", "score": 0.6010134},
 {"hit": "puerto_rico", "score": 0.5051694},
 {"hit": "southern_europe", "score": 0.4829831}]}
```

7 Answering Complex Queries

```
# pip install dicee
# wget https://files.dice-research.org/datasets/dice-embeddings/KGs.zip --no-check-
→certificate & unzip KGs.zip
from dicee.executer import Execute
from dicee.config import Namespace
from dicee.knowledge_graph_embeddings import KGE
# (1) Train a KGE model
args = Namespace()
args.model = 'Keci'
args.p=0
args.q=1
args.optim = 'Adam'
args.scoring_technique = "AllvsAll"
args.path_single_kg = "KGs/Family/family-benchmark_rich_background.owl"
args.backend = "rdflib"
args.num_epochs = 200
args.batch_size = 1024
args.lr = 0.1
args.embedding_dim = 512
result = Execute(args).start()
# (2) Load the pre-trained model
```

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```
pre_trained_kge = KGE(path=result['path_experiment_folder'])

# (3) Single-hop query answering
# Query: ?E : \exist E.hasSibling(E, F9M167)
# Question: Who are the siblings of F9M167?
# Answer: [F9M157, F9F141], as (F9M167, hasSibling, F9M157) and (F9M167, hasSibling, ↵F9F141)

predictions = pre_trained_kge.answer_multi_hop_query(query_type="1p",
                                                      query='http://www.benchmark.org/↪family#F9M167',
                                                      ('http://www.benchmark.
                                                       ↪org/family#hasSibling',)),
                                                       tnorm="min", k=3)

top_entities = [topk_entity for topk_entity, query_score in predictions]
assert "http://www.benchmark.org/family#F9F141" in top_entities
assert "http://www.benchmark.org/family#F9M157" in top_entities

# (2) Two-hop query answering
# Query: ?D : \exist E.Married(D, E) \land hasSibling(E, F9M167)
# Question: To whom a sibling of F9M167 is married to?
# Answer: [F9F158, F9M142] as (F9M157 #married F9F158) and (F9F141 #married F9M142)
predictions = pre_trained_kge.answer_multi_hop_query(query_type="2p",
                                                      query="http://www.benchmark.org/↪family#F9M167",
                                                      ("http://www.benchmark.
                                                       ↪org/family#hasSibling",
                                                       "http://www.benchmark.
                                                       ↪org/family#married")),
                                                       tnorm="min", k=3)

top_entities = [topk_entity for topk_entity, query_score in predictions]
assert "http://www.benchmark.org/family#F9M142" in top_entities
assert "http://www.benchmark.org/family#F9F158" in top_entities

# (3) Three-hop query answering
# Query: ?T : \exist D.type(D, T) \land Married(D, E) \land hasSibling(E, F9M167)
# Question: What are the type of people who are married to a sibling of F9M167?
# (3) Answer: [Person, Male, Father] since F9M157 is [Brother Father Grandfather ↵Male] and F9M142 is [Male Grandfather Father]

predictions = pre_trained_kge.answer_multi_hop_query(query_type="3p", query="http://↪www.benchmark.org/family#F9M167",
                                                      ("http://
                                                       ↪www.benchmark.org/family#hasSibling",
                                                       "http://
                                                       ↪www.benchmark.org/family#married",
                                                       "http://
                                                       ↪www.w3.org/1999/02/22-rdf-syntax-ns#type")),
                                                       tnorm="min", k=5)

top_entities = [topk_entity for topk_entity, query_score in predictions]
print(top_entities)
assert "http://www.benchmark.org/family#Person" in top_entities
assert "http://www.benchmark.org/family#Father" in top_entities
assert "http://www.benchmark.org/family#Male" in top_entities
```

For more, please refer to examples/multi_hop_query_answering.

8 Predicting Missing Links

```
from dicee import KGE
# (1) Train a knowledge graph embedding model..
# (2) Load a pretrained model
pre_trained_kge = KGE(path='..')
# (3) Predict missing links through head entity rankings
pre_trained_kge.predict_topk(h=['..'], r=['..'], topk=10)
# (4) Predict missing links through relation rankings
pre_trained_kge.predict_topk(h=['..'], t=['..'], topk=10)
# (5) Predict missing links through tail entity rankings
pre_trained_kge.predict_topk(r=['..'], t=['..'], topk=10)
```

9 Downloading Pretrained Models

```
from dicee import KGE
# (1) Load a pretrained ConEx on DBpedia
model = KGE(url="https://files.dice-research.org/projects/DiceEmbeddings/KINSHIP-Keci-
↪dim128-epoch256-KvsAll")
```

- For more please look at dice-research.org/projects/DiceEmbeddings/¹¹

10 How to Deploy

```
from dicee import KGE
KGE(path='..').deploy(share=True, top_k=10)
```

11 Docker

To build the Docker image:

```
docker build -t dice-embeddings .
```

To test the Docker image:

```
docker run --rm -v ~/.local/share/dicee/KGs:/dicee/KGs dice-embeddings ./main.py --
↪model AConEx --embedding_dim 16
```

12 Coverage Report

The coverage report is generated using `coverage.py`¹²:

Name	Stmts	Miss	Cover	Missing
<hr/>				
dicee/__init__.py	7	0	100%	
dicee/abstracts.py	338	115	66%	112-113, ..

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¹¹ <https://files.dice-research.org/projects/DiceEmbeddings/>

¹² <https://coverage.readthedocs.io/en/7.6.0/>

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<code>→131, 154–155, 160, 173, 197, 240–254, 290, 303–306, 309–313, 353–364, 379–387, 402, →413–417, 427–428, 434–436, 442–445, 448–453, 576–596, 602–606, 610–612, 631, 658–696</code>				
<code>dicee/callbacks.py</code>	<code>248</code>	<code>103</code>	<code>58%</code>	<code>50–55, →67–73, 76, 88–93, 98–103, 106–109, 116–133, 138–142, 146–147, 247, 281–285, 291–292, →310–316, 319, 324–325, 337–343, 349–358, 363–365, 410, 421–434, 438–473, 485–491</code>
<code>dicee/config.py</code>	<code>97</code>	<code>2</code>	<code>98%</code>	<code>146–147</code>
<code>dicee/dataset_classes.py</code>	<code>430</code>	<code>146</code>	<code>66%</code>	<code>16, 44, →57, 89–98, 104, 111–118, 121, 124, 127–151, 207–213, 216, 219–221, 324, 335–338, →354, 420–421, 439, 562–581, 583, 587–599, 606–615, 618, 622–636, 780–787, 790–794, →845, 866–878, 902–915, 937, 941–954, 964–967, 973, 985, 987, 989, 1012–1022</code>
<code>dicee/eval_static_funcs.py</code>	<code>256</code>	<code>100</code>	<code>61%</code>	<code>104, 109, →114, 261–356, 363–414, 442, 465–468</code>
<code>dicee/evaluator.py</code>	<code>267</code>	<code>48</code>	<code>82%</code>	<code>48, 53, →58, 77, 82–83, 86, 102, 119, 130, 134, 139, 173–184, 191–202, 310, 340–358, 452, →462, 480–485</code>
<code>dicee/executer.py</code>	<code>134</code>	<code>16</code>	<code>88%</code>	<code>53–57, →166–176, 235–236, 283</code>
<code>dicee/knowledge_graph.py</code>	<code>82</code>	<code>10</code>	<code>88%</code>	<code>84, 94– →95, 124, 128, 132–134, 137–138, 140</code>
<code>dicee/knowledge_graph_embeddings.py</code>	<code>654</code>	<code>415</code>	<code>37%</code>	<code>25, 28– →29, 37–50, 55–88, 91–125, 129–137, 171, 173–229, 261, 265, 276–277, 301–303, 311, →339–362, 493, 497–519, 523–547, 580, 656, 665, 710–716, 748, 806–1171, 1202–1263, →1267–1295, 1326, 1332</code>
<code>dicee/models/__init__.py</code>	<code>9</code>	<code>0</code>	<code>100%</code>	
<code>dicee/models/adopt.py</code>	<code>187</code>	<code>172</code>	<code>8%</code>	<code>50–86, →99–110, 129–185, 195–242, 266–322, 346–448, 484–517</code>
<code>dicee/models/base_model.py</code>	<code>240</code>	<code>35</code>	<code>85%</code>	<code>30–35, →64, 66, 92, 99–116, 171, 204, 244, 250, 259, 262, 266, 273, 277, 279, 294, 307–308, →362, 365, 438, 450</code>
<code>dicee/models/clifford.py</code>	<code>470</code>	<code>278</code>	<code>41%</code>	<code>10, 12, →16, 24–25, 52–56, 79–87, 101–103, 108–109, 140–160, 184, 191, 195–256, 273–277, 289, →292, 297, 302, 346–361, 377–444, 464–470, 483, 486, 491, 496, 525–531, 544, 547, →552, 557, 567–576, 592–593, 613–685, 696–699, 724–749, 773–806, 842–846, 859, 869, →872, 877, 882, 887, 891, 895, 904–905, 935, 942, 947, 975–979, 1007–1016, 1026–1034, →1052–1054, 1072–1074, 1090–1092</code>
<code>dicee/models/complex.py</code>	<code>162</code>	<code>25</code>	<code>85%</code>	<code>86–109, →273–287</code>
<code>dicee/models/dualE.py</code>	<code>59</code>	<code>10</code>	<code>83%</code>	<code>93–102, →142–156</code>
<code>dicee/models/ensemble.py</code>	<code>89</code>	<code>67</code>	<code>25%</code>	<code>7–29, 31, →34, 37, 40, 43, 46, 49, 52–54, 56–58, 64–68, 71–90, 93–94, 97–112, 131</code>
<code>dicee/models/function_space.py</code>	<code>262</code>	<code>221</code>	<code>16%</code>	<code>10–23, →27–36, 39–48, 52–69, 76–87, 90–99, 102–111, 115–127, 135–157, 160–166, 169–186, 189–195, 198–206, 209, 214–235, 244–247, 251–255, 259–268, 272–293, 302–308, 312–329, →333–336, 345–353, 356, 367–373, 393–407, 425–439, 444–454, 462–466, 475–479</code>
<code>dicee/models/literal.py</code>	<code>33</code>	<code>1</code>	<code>97%</code>	<code>82</code>
<code>dicee/models/octonion.py</code>	<code>227</code>	<code>83</code>	<code>63%</code>	<code>21–44, →320–329, 334–345, 348–370, 374–416, 426–474</code>
<code>dicee/models/pykeen_models.py</code>	<code>55</code>	<code>5</code>	<code>91%</code>	<code>77–80, →135</code>
<code>dicee/models/quaternion.py</code>	<code>192</code>	<code>69</code>	<code>64%</code>	<code>7–21, 30– →55, 68–72, 107, 185, 328–342, 345–364, 368–389, 399–426</code>

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dicee/models/real.py	61	12	80%	37–42, ↴
↳ 70–73, 91, 107–110				
dicee/models/static_funcs.py	10	0	100%	
dicee/models/transformers.py	234	189	19%	20–39, ↴
↳ 42, 56–71, 80–98, 101–112, 119–121, 124, 130–147, 151–176, 182–186, 189–193, 199–				
↳ 203, 206–208, 225–252, 261–264, 267–272, 275–300, 306–311, 315–368, 372–394, 400–410				
dicee/query_generator.py	374	346	7%	17–51, ↴
↳ 55, 61–64, 68–69, 77–91, 99–146, 154–187, 191–205, 211–268, 273–302, 306–442, 452–				
↳ 471, 479–502, 509–513, 518, 523–529				
dicee/read_preprocess_save_load_kg/__init__.py	3	0	100%	
dicee/read_preprocess_save_load_kg/preprocess.py	243	40	84%	33, 39, ↴
↳ 76, 100–125, 131, 136–149, 175, 205, 380–381				
dicee/read_preprocess_save_load_kg/read_from_disk.py	36	11	69%	34, 38–
↳ 40, 47, 55, 58–72				
dicee/read_preprocess_save_load_kg/save_load_disk.py	53	21	60%	29–30, ↴
↳ 38, 47–68				
dicee/read_preprocess_save_load_kg/util.py	236	125	47%	159, 173–
↳ 175, 179–180, 198–204, 207–209, 214–216, 230, 244–247, 252–260, 265–271, 276–281, ↴				
↳ 286–291, 303–324, 330–386, 390–394, 398–399, 403, 407–408, 436, 441, 448–449				
dicee/sanity_checkers.py	47	19	60%	8–12, 21–
↳ 31, 46, 51, 58, 69–79				
dicee/static_funcs.py	483	194	60%	42, 52, ↴
↳ 58–63, 85, 92–96, 109–119, 129–131, 136, 143, 167, 172, 184, 190, 198, 202, 229–233,				
↳ 295, 303–309, 320–330, 341–361, 389, 413–414, 419–420, 437–438, 440–441, 443–444, ↴				
↳ 452, 470–474, 491–494, 498–503, 507–511, 515–516, 522–524, 539–553, 558–561, 566–				
↳ 569, 578–629, 634–646, 663–680, 683–691, 695–713, 724				
dicee/static_funcs_training.py	155	66	57%	7–10, ↴
↳ 222–319, 327–328				
dicee/static_preprocess_funcs.py	98	43	56%	17–25, ↴
↳ 50, 57, 59, 70, 83–107, 112–115, 120–123, 128–131				
dicee/trainer/__init__.py	1	0	100%	
dicee/trainer/dice_trainer.py	151	18	88%	22, 30–
↳ 31, 33–35, 97, 104, 109–114, 152, 237, 280–283				
dicee/trainer/model_parallelism.py	99	87	12%	10–25, ↴
↳ 30–116, 121–132, 136, 141–197				
dicee/trainer/torch_trainer.py	77	6	92%	31, 102, ↴
↳ 168, 179–181				
dicee/trainer/torch_trainer_ddp.py	89	71	20%	11–14, ↴
↳ 43, 47–67, 78–94, 113–122, 126–136, 151–158, 168–191				
TOTAL	6948	3169	54%	

13 How to cite

Currently, we are working on our manuscript describing our framework. If you really like our work and want to cite it now, feel free to chose one :)

```
# Keci
@inproceedings{demir2023clifford,
  title={Clifford Embeddings--A Generalized Approach for Embedding in Normed Algebras}
  ,
```

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(continued from previous page)

```
author={Demir, Caglar and Ngonga Ngomo, Axel-Cyrille},
booktitle={Joint European Conference on Machine Learning and Knowledge Discovery in
→Databases},
pages={567--582},
year={2023},
organization={Springer}
}
# LitCQD
@inproceedings{demir2023litcqd,
    title={LitCQD: Multi-Hop Reasoning in Incomplete Knowledge Graphs with Numeric
→Literals},
    author={Demir, Caglar and Wiebesiek, Michel and Lu, Renzhong and Ngonga Ngomo, Axel-
→Cyrille and Heindorf, Stefan},
    booktitle={Joint European Conference on Machine Learning and Knowledge Discovery in
→Databases},
    pages={617--633},
    year={2023},
    organization={Springer}
}
# DICE Embedding Framework
@article{demir2022hardware,
    title={Hardware-agnostic computation for large-scale knowledge graph embeddings},
    author={Demir, Caglar and Ngomo, Axel-Cyrille Ngonga},
    journal={Software Impacts},
    year={2022},
    publisher={Elsevier}
}
# KronE
@inproceedings{demir2022kronecker,
    title={Kronecker decomposition for knowledge graph embeddings},
    author={Demir, Caglar and Lienen, Julian and Ngonga Ngomo, Axel-Cyrille},
    booktitle={Proceedings of the 33rd ACM Conference on Hypertext and Social Media},
    pages={1--10},
    year={2022}
}
# QMult, OMult, ConvQ, ConvO
@InProceedings{pmlr-v157-demir21a,
    title = {Convolutional Hypercomplex Embeddings for Link Prediction},
    author = {Demir, Caglar and Moussallem, Diego and Heindorf, Stefan and Ngonga
→Ngomo, Axel-Cyrille},
    booktitle = {Proceedings of The 13th Asian Conference on Machine Learning},
    pages = {656--671},
    year = {2021},
    editor = {Balasubramanian, Vineeth N. and Tsang, Ivor},
    volume = {157},
    series = {Proceedings of Machine Learning Research},
    month = {17--19 Nov},
    publisher = {PMLR},
    pdf = {https://proceedings.mlr.press/v157/demir21a/demir21a.pdf},
    url = {https://proceedings.mlr.press/v157/demir21a.html},
}
# ConEx
```

(continues on next page)

```

@inproceedings{demir2021convolutional,
  title={Convolutional Complex Knowledge Graph Embeddings},
  author={Caglar Demir and Axel-Cyrille Ngonga Ngomo},
  booktitle={Eighteenth Extended Semantic Web Conference - Research Track},
  year={2021},
  url={https://openreview.net/forum?id=6T45-4TFqaX}
# Shallom
@inproceedings{demir2021shallow,
  title={A shallow neural model for relation prediction},
  author={Demir, Caglar and Moussallem, Diego and Ngomo, Axel-Cyrille Ngonga},
  booktitle={2021 IEEE 15th International Conference on Semantic Computing (ICSC)},
  pages={179--182},
  year={2021},
  organization={IEEE}

```

For any questions or wishes, please contact: caglar.demir@upb.de

14 dicee

DICE Embeddings - Knowledge Graph Embedding Library.

A library for training and using knowledge graph embedding models with support for various scoring techniques and training strategies.

Submodules:

evaluation: Model evaluation functions and Evaluator class
models: KGE model implementations
trainer: Training orchestration scripts:
Utility scripts

14.1 Submodules

dicee.__main__

dicee.abstracts

Classes

<i>AbstractTrainer</i>	Abstract class for Trainer class for knowledge graph embedding models
<i>BaseInteractiveKGE</i>	Abstract/base class for using knowledge graph embedding models interactively.
<i>InteractiveQueryDecomposition</i>	
<i>AbstractCallback</i>	Abstract class for Callback class for knowledge graph embedding models
<i>AbstractPPECallback</i>	Abstract class for Callback class for knowledge graph embedding models
<i>BaseInteractiveTrainKGE</i>	Abstract/base class for training knowledge graph embedding models interactively.

Module Contents

```
class dicee.abstracts.AbstractTrainer(args, callbacks)
Abstract class for Trainer class for knowledge graph embedding models
```

Parameter

```
args
    [str] ?

callbacks: list
    ?

attributes

callbacks

is_global_zero = True

global_rank = 0

local_rank = 0

strategy = None

on_fit_start(*args, **kwargs)
```

A function to call callbacks before the training starts.

Parameter

```
args

kwargs

rtype
    None

on_fit_end(*args, **kwargs)
```

A function to call callbacks at the end of the training.

Parameter

```
args

kwargs

rtype
    None

on_train_epoch_start(*args, **kwargs)
```

A function to call callbacks at the start of an epoch.

Parameter

args

kwargs

rtype

None

on_train_epoch_end(*args, **kwargs)

A function to call callbacks at the end of an epoch.

Parameter

args

kwargs

rtype

None

on_train_batch_end(*args, **kwargs)

A function to call callbacks at the end of each mini-batch during training.

Parameter

args

kwargs

rtype

None

static save_checkpoint(full_path: str, model) → None

A static function to save a model into disk

Parameter

full_path : str

model:

rtype

None

class dicee.abstracts.BaseInteractiveKGE(path: str = None, url: str = None, construct_ensemble: bool = False, model_name: str = None, apply_semantic_constraint: bool = False)

Abstract/base class for using knowledge graph embedding models interactively.

Parameter

path_of_pretrained_model_dir

[str] ?

construct_ensemble: boolean

?

model_name: str apply_semantic_constraint : boolean

```

construct_ensemble = False
apply_semantic_constraint = False
configs
get_eval_report () → dict
get_bpe_token_representation (str_entity_or_relation: List[str] | str) → List[List[int]] | List[int]

```

Parameters

str_entity_or_relation (*corresponds to a str or a list of strings to be tokenized via BPE and shaped.*)

Return type

A list integer(s) or a list of lists containing integer(s)

```
get_padded_bpe_triple_representation (triples: List[List[str]]) → Tuple[List, List, List]
```

Parameters

triples

```
set_model_train_mode () → None
```

Setting the model into training mode

Parameter

```
set_model_eval_mode () → None
```

Setting the model into eval mode

Parameter

```
property name
```

```
sample_entity (n: int) → List[str]
```

```
sample_relation (n: int) → List[str]
```

```
is_seen (entity: str = None, relation: str = None) → bool
```

```
save () → None
```

```
get_entity_index (x: str)
```

```
get_relation_index (x: str)
```

```
index_triple (head_entity: List[str], relation: List[str], tail_entity: List[str])
    → Tuple[torch.LongTensor, torch.LongTensor, torch.LongTensor]
```

Index Triple

Parameter

head_entity: List[str]

String representation of selected entities.

relation: List[str]

String representation of selected relations.

`tail_entity: List[str]`
String representation of selected entities.

Returns: Tuple

pytorch tensor of triple score

add_new_entity_embeddings (`entity_name: str = None, embeddings: torch.FloatTensor = None`)

get_entity_embeddings (`items: List[str]`)

Return embedding of an entity given its string representation

Parameter

items:
entities

get_relation_embeddings (`items: List[str]`)

Return embedding of a relation given its string representation

Parameter

items:
relations

construct_input_and_output (`head_entity: List[str], relation: List[str], tail_entity: List[str], labels`)

Construct a data point :param head_entity: :param relation: :param tail_entity: :param labels: :return:

parameters ()

class dicee.abstracts.InteractiveQueryDecomposition

t_norm (`tens_1: torch.Tensor, tens_2: torch.Tensor, tnorm: str = 'min'`) → torch.Tensor

tensor_t_norm (`subquery_scores: torch.FloatTensor, tnorm: str = 'min'`) → torch.FloatTensor

Compute T-norm over $[0,1]^{\{n \text{ times } d\}}$ where n denotes the number of hops and d denotes number of entities

t_conorm (`tens_1: torch.Tensor, tens_2: torch.Tensor, tconorm: str = 'min'`) → torch.Tensor

negnorm (`tens_1: torch.Tensor, lambda_: float, neg_norm: str = 'standard'`) → torch.Tensor

class dicee.abstracts.AbstractCallback

Bases: abc.ABC, lightning.pytorch.callbacks.Callback

Abstract class for Callback class for knowledge graph embedding models

Parameter

on_init_start (*args, **kwargs)

Parameter

trainer:

model:

rtype

None

on_init_end(*args, **kwargs)

Call at the beginning of the training.

Parameter

trainer:

model:

rtype

None

on_fit_start(trainer, model)

Call at the beginning of the training.

Parameter

trainer:

model:

rtype

None

on_train_epoch_end(trainer, model)

Call at the end of each epoch during training.

Parameter

trainer:

model:

rtype

None

on_train_batch_end(*args, **kwargs)

Call at the end of each mini-batch during the training.

Parameter

trainer:

model:

rtype

None

on_fit_end(*args, **kwargs)

Call at the end of the training.

Parameter

trainer:

model:

rtype

None

```
class dicee.abstracts.AbstractPPECallback(num_epochs, path, epoch_to_start,
                                           last_percent_to_consider)
```

Bases: *AbstractCallback*

Abstract class for Callback class for knowledge graph embedding models

Parameter

num_epochs

path

sample_counter = 0

epoch_count = 0

alphas = None

on_fit_start (trainer, model)

Call at the beginning of the training.

Parameter

trainer:

model:

rtype

None

on_fit_end (trainer, model)

Call at the end of the training.

Parameter

trainer:

model:

rtype

None

store_ensemble (param_ensemble) → None

```
class dicee.abstracts.BaseInteractiveTrainKGE
```

Abstract/base class for training knowledge graph embedding models interactively. This class provides methods for re-training KGE models and also Literal Embedding model.

train_triples (h: List[str], r: List[str], t: List[str], labels: List[float], iteration=2, optimizer=None)

```

train_k_vs_all(h, r, iteration=1, lr=0.001)
    Train k vs all :param head_entity: :param relation: :param iteration: :param lr: :return:
train(kg, lr=0.1, epoch=10, batch_size=32, neg_sample_ratio=10, num_workers=1) → None
    Retrained a pretrain model on an input KG via negative sampling.

train_literals(train_file_path: str = None, num_epochs: int = 100, lit_lr: float = 0.001,
    lit_normalization_type: str = 'z-norm', batch_size: int = 1024, sampling_ratio: float = None,
    random_seed=1, loader_backend: str = 'pandas', freeze_entity_embeddings: bool = True,
    gate_residual: bool = True, device: str = None, shuffle_data: bool = True)
    Trains the Literal Embeddings model using literal data.

```

Parameters

- **train_file_path** (*str*) – Path to the training data file.
- **num_epochs** (*int*) – Number of training epochs.
- **lit_lr** (*float*) – Learning rate for the literal model.
- **norm_type** (*str*) – Normalization type to use ('z-norm', 'min-max', or None).
- **batch_size** (*int*) – Batch size for training.
- **sampling_ratio** (*float*) – Ratio of training triples to use.
- **loader_backend** (*str*) – Backend for loading the dataset ('pandas' or 'rdflib').
- **freeze_entity_embeddings** (*bool*) – If True, freeze the entity embeddings during training.
- **gate_residual** (*bool*) – If True, use gate residual connections in the model.
- **device** (*str*) – Device to use for training ('cuda' or 'cpu'). If None, will use available GPU or CPU.
- **shuffle_data** (*bool*) – If True, shuffle the dataset before training.

dicee.analyse_experiments

This script should be moved to dicee/scripts Example: python dicee/analyse_experiments.py –dir Experiments –features “model” “trainMRR” “testMRR”

Classes

<i>Experiment</i>

Functions

<i>get_default_arguments()</i>
<i>analyse(args)</i>

Module Contents

```

dicee.analyse_experiments.get_default_arguments()

class dicee.analyse_experiments.Experiment

```

```

model_name = []
callbacks = []
embedding_dim = []
num_params = []
num_epochs = []
batch_size = []
lr = []
byte_pair_encoding = []
aswa = []
path_dataset_folder = []
full_storage_path = []
pq = []
train_mrr = []
train_h1 = []
train_h3 = []
train_h10 = []
val_mrr = []
val_h1 = []
val_h3 = []
val_h10 = []
test_mrr = []
test_h1 = []
test_h3 = []
test_h10 = []
runtime = []
normalization = []
scoring_technique = []
save_experiment(x)
to_df()

dicee.analyse_experiments.analyse(args)

```

dicee.callbacks

Callbacks for training lifecycle events.

Provides callback classes for various training events including epoch end, model saving, weight averaging, and evaluation.

Classes

<i>AccumulateEpochLossCallback</i>	Callback to store epoch losses to a CSV file.
<i>PrintCallback</i>	Abstract class for Callback class for knowledge graph embedding models
<i>KGESaveCallback</i>	Abstract class for Callback class for knowledge graph embedding models
<i>PseudoLabellingCallback</i>	Abstract class for Callback class for knowledge graph embedding models
<i>Eval</i>	Abstract class for Callback class for knowledge graph embedding models
<i>Krone</i>	Abstract class for Callback class for knowledge graph embedding models
<i>Perturb</i>	A callback for a three-Level Perturbation
<i>PeriodicEvalCallback</i>	Callback to periodically evaluate the model and optionally save checkpoints during training.
<i>LRScheduler</i>	Callback for managing learning rate scheduling and model snapshots.

Functions

<i>estimate_q(eps)</i>	estimate rate of convergence q from sequence esp
<i>compute_convergence(seq, i)</i>	

Module Contents

class dicee.callbacks.**AccumulateEpochLossCallback** (*path: str*)

Bases: dicee.abtracts.AbstractCallback

Callback to store epoch losses to a CSV file.

Parameters

path – Directory path where the loss file will be saved.

path

on_fit_end (*trainer, model*) → None

Store epoch loss history to CSV file.

Parameters

- **trainer** – The trainer instance.
- **model** – The model being trained.

class dicee.callbacks.**PrintCallback**

Bases: dicee.abtracts.AbstractCallback

Abstract class for Callback class for knowledge graph embedding models

Parameter

start_time

on_fit_start (*trainer, pl_module*)

Call at the beginning of the training.

Parameter

trainer:

model:

rtype

None

on_fit_end (*trainer, pl_module*)

Call at the end of the training.

Parameter

trainer:

model:

rtype

None

on_train_batch_end (**args, **kwargs*)

Call at the end of each mini-batch during the training.

Parameter

trainer:

model:

rtype

None

on_train_epoch_end (**args, **kwargs*)

Call at the end of each epoch during training.

Parameter

trainer:

model:

rtype

None

class dicee.callbacks.KGESaveCallback (*every_x_epoch: int, max_epochs: int, path: str*)

Bases: *dicee.abstracts.AbstractCallback*

Abstract class for Callback class for knowledge graph embedding models

Parameter

```
every_x_epoch  
max_epochs  
epoch_counter = 0  
path  
on_train_batch_end(*args, **kwargs)
```

Call at the end of each mini-batch during the training.

Parameter

trainer:

model:

rtype
None

```
on_fit_start(trainer, pl_module)
```

Call at the beginning of the training.

Parameter

trainer:

model:

rtype
None

```
on_train_epoch_end(*args, **kwargs)
```

Call at the end of each epoch during training.

Parameter

trainer:

model:

rtype
None

```
on_fit_end(*args, **kwargs)
```

Call at the end of the training.

Parameter

trainer:

model:

rtype
None

```
on_epoch_end(model, trainer, **kwargs)
```

```
class dicee.callbacks.PseudoLabellingCallback (data_module, kg, batch_size)
```

Bases: *dicee.abstracts.AbstractCallback*

Abstract class for Callback class for knowledge graph embedding models

Parameter

data_module

kg

num_of_epochs = 0

unlabelled_size

batch_size

create_random_data()

on_epoch_end(*trainer*, *model*)

```
dicee.callbacks.estimate_q(eps)
```

estimate rate of convergence q from sequence esp

```
dicee.callbacks.compute_convergence(seq, i)
```

```
class dicee.callbacks.Eval (path, epoch_ratio: int = None)
```

Bases: *dicee.abstracts.AbstractCallback*

Abstract class for Callback class for knowledge graph embedding models

Parameter

path

reports = []

epoch_ratio = None

epoch_counter = 0

on_fit_start(*trainer*, *model*)

Call at the beginning of the training.

Parameter

trainer:

model:

rtype

None

on_fit_end(*trainer*, *model*)

Call at the end of the training.

Parameter

trainer:

model:

rtype

None

on_train_epoch_end(*trainer, model*)

Call at the end of each epoch during training.

Parameter

trainer:

model:

rtype

None

on_train_batch_end(**args, **kwargs*)

Call at the end of each mini-batch during the training.

Parameter

trainer:

model:

rtype

None

class dicee.callbacks.Krone

Bases: *dicee.abstracts.AbstractCallback*

Abstract class for Callback class for knowledge graph embedding models

Parameter

f = None

static batch_kronecker_product(*a, b*)

Kronecker product of matrices *a* and *b* with leading batch dimensions. Batch dimensions are broadcast. The number of them must :type *a*: torch.Tensor :type *b*: torch.Tensor :rtype: torch.Tensor

get_kronecker_triple_representation(*indexed_triple*: torch.LongTensor)

Get kronecker embeddings

on_fit_start(*trainer, model*)

Call at the beginning of the training.

Parameter

trainer:

model:

rtype

None

```
class dicee.callbacks.Perturb(level: str = 'input', ratio: float = 0.0, method: str = None,  
    scaler: float = None, frequency=None)
```

Bases: `dicee.abstracts.AbstractCallback`

A callback for a three-Level Perturbation

Input Perturbation: During training an input x is perturbed by randomly replacing its element. In the context of knowledge graph embedding models, x can denote a triple, a tuple of an entity and a relation, or a tuple of two entities. A perturbation means that a component of x is randomly replaced by an entity or a relation.

Parameter Perturbation:

Output Perturbation:

```
level = 'input'  
ratio = 0.0  
method = None  
scaler = None  
frequency = None  
on_train_batch_start(trainer, model, batch, batch_idx)
```

Called when the train batch begins.

```
class dicee.callbacks.PeriodicEvalCallback(experiment_path: str, max_epochs: int,  
    eval_every_n_epoch: int = 0, eval_at_epochs: list = None,  
    save_model_every_n_epoch: bool = True, n_epochs_eval_model: str = 'val_test')
```

Bases: `dicee.abstracts.AbstractCallback`

Callback to periodically evaluate the model and optionally save checkpoints during training.

Evaluates at regular intervals (every N epochs) or at explicitly specified epochs. Stores evaluation reports and model checkpoints.

```
experiment_dir  
max_epochs  
epoch_counter = 0  
save_model_every_n_epoch = True  
reports  
n_epochs_eval_model = 'val_test'  
default_eval_model = None  
eval_epochs  
on_fit_end(trainer, model)
```

Called at the end of training. Saves final evaluation report.

```
on_train_epoch_end(trainer, model)
```

Called at the end of each training epoch. Performs evaluation and checkpointing if scheduled.

```

class dicee.callbacks.LRScheduler (adaptive_lr_config: dict, total_epochs: int, experiment_dir: str,  

    eta_max: float = 0.1, snapshot_dir: str = 'snapshots')  

Bases: dicee.abstracts.AbstractCallback  

Callback for managing learning rate scheduling and model snapshots.  

Supports cosine annealing ("cca"), MMCCLR ("mmcclr"), and their deferred (warmup) variants: - "deferred_cca"  

- "deferred_mmcclr"  

At the end of each learning rate cycle, the model can optionally be saved as a snapshot.  

total_epochs  

experiment_dir  

snapshot_dir  

batches_per_epoch = None  

total_steps = None  

cycle_length = None  

warmup_steps = None  

lr_lambda = None  

scheduler = None  

step_count = 0  

snapshot_loss  

on_train_start (trainer, model)  

    Initialize training parameters and LR scheduler at start of training.  

on_train_batch_end (trainer, model, outputs, batch, batch_idx)  

    Step the LR scheduler and save model snapshot if needed after each batch.  

on_fit_end (trainer, model)  

    Call at the end of the training.

```

Parameter

trainer:

model:

rtype
None

dicee.config

Configuration module for DICE embeddings.

Provides the Namespace class with default configuration values for training knowledge graph embedding models.

Classes

<code>Namespace</code>	Extended Namespace with default KGE training configuration.
------------------------	---

Module Contents

```
class dicee.config.Namespace(**kwargs)
    Bases: argparse.Namespace
    Extended Namespace with default KGE training configuration.
    Provides sensible defaults for all training parameters while allowing easy customization through command-line arguments or direct assignment.

    dataset_dir: str = None
        The path of a folder containing train.txt, and/or valid.txt and/or test.txt
    save_embeddings_as_csv: bool = False
        Embeddings of entities and relations are stored into CSV files to facilitate easy usage.
    storage_path: str = 'Experiments'
        A directory named with time of execution under --storage_path that contains related data about embeddings.
    path_to_store_single_run: str = None
        A single directory created that contains related data about embeddings.
    path_single_kg = None
        Path of a file corresponding to the input knowledge graph
    sparql_endpoint = None
        An endpoint of a triple store.
    model: str = 'Keci'
        KGE model
    optim: str = 'Adam'
        Optimizer
    embedding_dim: int = 64
        Size of continuous vector representation of an entity/relation
    num_epochs: int = 150
        Number of pass over the training data
    batch_size: int = 1024
        Mini-batch size if it is None, an automatic batch finder technique applied
    lr: float = 0.1
        Learning rate
    add_noise_rate: float = None
        The ratio of added random triples into training dataset
    gpus = None
        Number GPUs to be used during training
```

```

callbacks
    10} }

Type
    Callbacks, e.g., {"PPE"

Type
    { "last_percent_to_consider"

backend: str = 'pandas'
    Backend to read, process, and index input knowledge graph. pandas, polars and rdflib available

separator: str = '\\s+'
    separator for extracting head, relation and tail from a triple

trainer: str = 'torchCPUTrainer'
    Trainer for knowledge graph embedding model

scoring_technique: str = 'KvsAll'
    Scoring technique for knowledge graph embedding models

neg_ratio: int = 0
    Negative ratio for a true triple in NegSample training_technique

weight_decay: float = 0.0
    Weight decay for all trainable params

normalization: str = 'None'
    LayerNorm, BatchNorm1d, or None

init_param: str = None
    xavier_normal or None

gradient_accumulation_steps: int = 0
    Not tested e

num_folds_for_cv: int = 0
    Number of folds for CV

eval_model: str = 'train_val_test'
    ["None", "train", "train_val", "train_val_test", "test"]

Type
    Evaluate trained model choices

save_model_at_every_epoch: int = None
    Not tested

label_smoothing_rate: float = 0.0

num_core: int = 0
    Number of CPUs to be used in the mini-batch loading process

random_seed: int = 0
    Random Seed

sample_triples_ratio: float = None
    Read some triples that are uniformly at random sampled. Ratio being between 0 and 1

```

```

read_only_few: int = None
    Read only first few triples

pykeen_model_kwargs
    Additional keyword arguments for pykeen models

kernel_size: int = 3
    Size of a square kernel in a convolution operation

num_of_output_channels: int = 32
    Number of slices in the generated feature map by convolution.

p: int = 0
    P parameter of Clifford Embeddings

q: int = 1
    Q parameter of Clifford Embeddings

input_dropout_rate: float = 0.0
    Dropout rate on embeddings of input triples

hidden_dropout_rate: float = 0.0
    Dropout rate on hidden representations of input triples

feature_map_dropout_rate: float = 0.0
    Dropout rate on a feature map generated by a convolution operation

byte_pair_encoding: bool = False
    Byte pair encoding

    Type
        WIP

adaptive_swa: bool = False
    Adaptive stochastic weight averaging

swa: bool = False
    Stochastic weight averaging

swag: bool = False
    Stochastic weight averaging - Gaussian

ema: bool = False
    Exponential Moving Average

twa: bool = False
    Trainable weight averaging

block_size: int = None
    block size of LLM

continual_learning = None
    Path of a pretrained model size of LLM

auto_batch_finding = False
    A flag for using auto batch finding

eval_every_n_epochs: int = 0
    Evaluate model every n epochs. If 0, no evaluation is applied.

```

```

save_every_n_epochs: bool = False
    Save model every n epochs. If True, save model at every epoch.

eval_at_epochs: list = None
    List of epoch numbers at which to evaluate the model (e.g., 1 5 10).

n_epochs_eval_model: str = 'val_test'
    Evaluating link prediction performance on data splits while performing periodic evaluation.

adaptive_lr
    "cca"}}

Type
    Adaptive learning rate parameters, e.g., {'scheduler_name'

swa_start_epoch: int = None
    Epoch at which to start applying stochastic weight averaging.

swa_c_epochs: int = 1
    Number of epochs to average over for SWA, SWAG, EMA, TWA.

__iter__()

```

dicee.dataset_classes

Classes

<code>BPE_NegativeSamplingDataset</code>	An abstract class representing a Dataset.
<code>MultiLabelDataset</code>	An abstract class representing a Dataset.
<code>MultiClassClassificationDataset</code>	Dataset for the 1vsALL training strategy
<code>OnevsAllDataset</code>	Dataset for the 1vsALL training strategy
<code>KvsAll</code>	Creates a dataset for KvsAll training by inheriting from torch.utils.data.Dataset.
<code>AllvsAll</code>	Creates a dataset for AllvsAll training by inheriting from torch.utils.data.Dataset.
<code>OnevsSample</code>	A custom PyTorch Dataset class for knowledge graph embeddings, which includes
<code>KvsSampleDataset</code>	KvsSample a Dataset:
<code>NegSampleDataset</code>	An abstract class representing a Dataset.
<code>TriplePredictionDataset</code>	Triple Dataset
<code>LiteralDataset</code>	Dataset for loading and processing literal data for training Literal Embedding model.

Functions

<code>reload_dataset(path, form_of_labelling, ...)</code>	Reload the files from disk to construct the Pytorch dataset
<code>construct_dataset(→ torch.utils.data.Dataset)</code>	

Module Contents

`dicee.dataset_classes.reload_dataset(path: str, form_of_labelling, scoring_technique, neg_ratio, label_smoothing_rate)`

Reload the files from disk to construct the Pytorch dataset

```
dicee.dataset_classes.construct_dataset(* (Keyword-only parameters separator (PEP 3102)),  
    train_set: numpy.ndarray | list, valid_set=None, test_set=None, ordered_bpe_entities=None,  
    train_target_indices=None, target_dim: int = None, entity_to_idx: dict, relation_to_idx: dict,  
    form_of_labelling: str, scoring_technique: str, neg_ratio: int, label_smoothing_rate: float,  
    byte_pair_encoding=None, block_size: int = None) → torch.utils.data.Dataset
```

```
class dicee.dataset_classes.BPE_NegativeSamplingDataset (train_set: torch.LongTensor,  
    ordered_shaped_bpe_entities: torch.LongTensor, neg_ratio: int)
```

Bases: `torch.utils.data.Dataset`

An abstract class representing a Dataset.

All datasets that represent a map from keys to data samples should subclass it. All subclasses should overwrite `__getitem__()`, supporting fetching a data sample for a given key. Subclasses could also optionally overwrite `__len__()`, which is expected to return the size of the dataset by many `Sampler` implementations and the default options of `DataLoader`. Subclasses could also optionally implement `__getitems__()`, for speedup batched samples loading. This method accepts list of indices of samples of batch and returns list of samples.

Note

`DataLoader` by default constructs an index sampler that yields integral indices. To make it work with a map-style dataset with non-integral indices/keys, a custom sampler must be provided.

`train_set`

`ordered_bpe_entities`

`num_bpe_entities`

`neg_ratio`

`num_datapoints`

`__len__()`

`__getitem__(idx)`

`collate_fn(batch_shaped_bpe_triples: List[Tuple[torch.Tensor, torch.Tensor]])`

```
class dicee.dataset_classes.MultiLabelDataset (train_set: torch.LongTensor,  
    train_indices_target: torch.LongTensor, target_dim: int,  
    torch_ordered_shaped_bpe_entities: torch.LongTensor)
```

Bases: `torch.utils.data.Dataset`

An abstract class representing a Dataset.

All datasets that represent a map from keys to data samples should subclass it. All subclasses should overwrite `__getitem__()`, supporting fetching a data sample for a given key. Subclasses could also optionally overwrite `__len__()`, which is expected to return the size of the dataset by many `Sampler` implementations and the default options of `DataLoader`. Subclasses could also optionally implement `__getitems__()`, for speedup batched samples loading. This method accepts list of indices of samples of batch and returns list of samples.

Note

`DataLoader` by default constructs an index sampler that yields integral indices. To make it work with a map-style dataset with non-integral indices/keys, a custom sampler must be provided.

```
train_set
train_indices_target
target_dim
num_datapoints
torch_ordered_shaped_bpe_entities
collate_fn = None
__len__()
__getitem__(idx)
```

```
class dicee.dataset_classes.MultiClassClassificationDataset(
    subword_units: numpy.ndarray, block_size: int = 8)
```

Bases: `torch.utils.data.Dataset`

Dataset for the 1vsALL training strategy

Parameters

- `train_set_idx` – Indexed triples for the training.
- `entity_idxs` – mapping.
- `relation_idxs` – mapping.
- `form` – ?
- `num_workers` – int for <https://pytorch.org/docs/stable/data.html#torch.utils.data.DataLoader>

Return type

`torch.utils.data.Dataset`

```
train_data
block_size = 8
num_of_data_points
collate_fn = None
__len__()
__getitem__(idx)
```

```
class dicee.dataset_classes.OnevsAllDataset(train_set_idx: numpy.ndarray, entity_idxs)
```

Bases: `torch.utils.data.Dataset`

Dataset for the 1vsALL training strategy

Parameters

- **train_set_idx** – Indexed triples for the training.
- **entity_idxs** – mapping.
- **relation_idxs** – mapping.
- **form** – ?
- **num_workers** – int for <https://pytorch.org/docs/stable/data.html#torch.utils.data.DataLoader>

Return type

torch.utils.data.Dataset

train_data

target_dim

collate_fn = None

__len__()

__getitem__(idx)

```
class dicee.dataset_classes.KvsAll(train_set_idx: numpy.ndarray, entity_idxs, relation_idxs, form,
                                    store=None, label_smoothing_rate: float = 0.0)
```

Bases: torch.utils.data.Dataset

Creates a dataset for KvsAll training by inheriting from torch.utils.data.Dataset.

Let D denote a dataset for KvsAll training and be defined as $D := \{(x,y)_i\}_{i=1}^N$, where $x: (h,r)$ is an unique tuple of an entity h in E and a relation r in R that has been seed in the input graph. $y:$ denotes a multi-label vector in $[0,1]^{|E|}$ is a binary label.

or all $y_i = 1$ s.t. $(h, r) \in E$

 **Note**

TODO

train_set_idx

[numpy.ndarray] n by 3 array representing n triples

entity_idxs

[dictionary] string representation of an entity to its integer id

relation_idxs

[dictionary] string representation of a relation to its integer id

self : torch.utils.data.Dataset

```
>>> a = KvsAll()
>>> a
? array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
```

train_data = None

train_target = None

label_smoothing_rate

```

collate_fn = None
__len__()
__getitem__(idx)

class dicee.dataset_classes.AllvsAll(train_set_idx: numpy.ndarray, entity_idxs, relation_idxs,
label_smoothing_rate=0.0)
Bases: torch.utils.data.Dataset
```

Creates a dataset for AllvsAll training by inheriting from torch.utils.data.Dataset.

Let D denote a dataset for AllvsAll training and be defined as $D := \{(x,y)_i\}_i^N$, where $x: (h,r)$ is a possible unique tuple of an entity h in E and a relation r in R. Hence $N = |E| \times |R|$; y_i denotes a multi-label vector in $[0,1]^{|\{E\}|}$ is a binary label.

or all $y_{-i} = 1$ s.t. $(h \ r \ E_{-i})$ in KG

Note

AllvsAll extends KvsAll via none existing (h,r). Hence, it adds data points that are labelled without 1s, only with 0s.

train_set_idx

[numpy.ndarray] n by 3 array representing n triples

entity_idxs

[dictionary] string representation of an entity to its integer id

relation_idxs

[dictionary] string representation of a relation to its integer id

self : torch.utils.data.Dataset

```

>>> a = AllvsAll()
>>> a
? array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
```

train_data = None

train_target = None

label_smoothing_rate

collate_fn = None

target_dim

__len__()

__getitem__(idx)

```

class dicee.dataset_classes.OnevsSample(train_set: numpy.ndarray, num_entities, num_relations,
neg_sample_ratio: int = None, label_smoothing_rate: float = 0.0)
```

Bases: torch.utils.data.Dataset

A custom PyTorch Dataset class for knowledge graph embeddings, which includes both positive and negative sampling for a given dataset for multi-class classification problem..

Parameters

- **train_set** (*np.ndarray*) – A numpy array containing triples of knowledge graph data. Each triple consists of (head_entity, relation, tail_entity).
- **num_entities** (*int*) – The number of unique entities in the knowledge graph.
- **num_relations** (*int*) – The number of unique relations in the knowledge graph.
- **neg_sample_ratio** (*int, optional*) – The number of negative samples to be generated per positive sample. Must be a positive integer and less than num_entities.
- **label_smoothing_rate** (*float, optional*) – A label smoothing rate to apply to the positive and negative labels. Defaults to 0.0.

train_data

The input data converted into a PyTorch tensor.

Type

torch.Tensor

num_entities

Number of entities in the dataset.

Type

int

num_relations

Number of relations in the dataset.

Type

int

neg_sample_ratio

Ratio of negative samples to be drawn for each positive sample.

Type

int

label_smoothing_rate

The smoothing factor applied to the labels.

Type

torch.Tensor

collate_fn

A function that can be used to collate data samples into batches (set to None by default).

Type

function, optional

train_data

num_entities

num_relations

neg_sample_ratio = None

label_smoothing_rate

collate_fn = None

__len__()
 Returns the number of samples in the dataset.

__getitem__(idx)
 Retrieves a single data sample from the dataset at the given index.

Parameters
idx (*int*) – The index of the sample to retrieve.

Returns
A tuple consisting of:

- **x** (torch.Tensor): The head and relation part of the triple.
- **y_idx** (torch.Tensor): The concatenated indices of the true object (tail entity) and the indices of the negative samples.
- **y_vec** (torch.Tensor): A vector containing the labels for the positive and negative samples, with label smoothing applied.

Return type
tuple

```
class dicee.dataset_classes.KvsSampleDataset (train_set_idx: numpy.ndarray, entity_idxs,
                                             relation_idxs, form, store=None, neg_ratio=None, label_smoothing_rate: float = 0.0)
```

Bases: torch.utils.data.Dataset

KvsSample a Dataset:

D:= {(x,y)_i}_i ^N, where
. x:(h,r) is a unique h in E and a relation r in R and . y in [0,1]^{|E|} is a binary label.

orall y_i =1 s.t. (h r E_i) in KG

At each mini-batch construction, we subsample(y), hence n
 $|new_y| << |E|$ new_y contains all 1's if sum(y)< neg_sample ratio new_y contains

train_set_idx
Indexed triples for the training.

entity_idxs
mapping.

relation_idxs
mapping.

form
?

store
?

label_smoothing_rate
?

torch.utils.data.Dataset

```
train_data = None
train_target = None
```

```

neg_ratio = None
num_entities
label_smoothing_rate
collate_fn = None
max_num_of_classes
__len__()
__getitem__(idx)

```

class dicee.dataset_classes.NegSampleDataset (*train_set: numpy.ndarray, num_entities: int, num_relations: int, neg_sample_ratio: int = 1*)

Bases: torch.utils.data.Dataset

An abstract class representing a Dataset.

All datasets that represent a map from keys to data samples should subclass it. All subclasses should overwrite `__getitem__()`, supporting fetching a data sample for a given key. Subclasses could also optionally overwrite `__len__()`, which is expected to return the size of the dataset by many Sampler implementations and the default options of DataLoader. Subclasses could also optionally implement `__getitems__()`, for speedup batched samples loading. This method accepts list of indices of samples of batch and returns list of samples.

Note

`DataLoader` by default constructs an index sampler that yields integral indices. To make it work with a map-style dataset with non-integral indices/keys, a custom sampler must be provided.

```

neg_sample_ratio
train_triples
length
num_entities
num_relations
labels
train_set = []
__len__()
__getitem__(idx)

```

class dicee.dataset_classes.TriplePredictionDataset (*train_set: numpy.ndarray, num_entities: int, num_relations: int, neg_sample_ratio: int = 1, label_smoothing_rate: float = 0.0*)

Bases: torch.utils.data.Dataset

Triple Dataset

D:= {(x)_i}_i ^N, where

. x:(h,r, t) in KG is a unique h in E and a relation r in R and . collect_fn => Generates negative triples

collect_fn:

orall (h,r,t) in G obtain, create negative triples{(h,r,x),(r,t),(h,m,t)}

y:labels are represented in torch.float16

train_set_idx

Indexed triples for the training.

entity_idxs

mapping.

relation_idxs

mapping.

form

?

store

?

label_smoothing_rate

collate_fn: batch:List[torch.IntTensor] Returns ----- torch.utils.data.Dataset

label_smoothing_rate

neg_sample_ratio

train_set

length

num_entities

num_relations

__len__()

__getitem__(idx)

collate_fn(batch: List[torch.Tensor])

class dicee.dataset_classes.**LiteralDataset**(file_path: str, ent_idx: dict = None, normalization_type: str = 'z-norm', sampling_ratio: float = None, loader_backend: str = 'pandas')

Bases: torch.utils.data.Dataset

Dataset for loading and processing literal data for training Literal Embedding model. This dataset handles the loading, normalization, and preparation of triples for training a literal embedding model.

Extends torch.utils.data.Dataset for supporting PyTorch dataloaders.

train_file_path

Path to the training data file.

Type

str

normalization

Type of normalization to apply ('z-norm', 'min-max', or None).

Type

str

```

normalization_params
    Parameters used for normalization.

        Type
            dict

sampling_ratio
    Fraction of the training set to use for ablations.

        Type
            float

entity_to_idx
    Mapping of entities to their indices.

        Type
            dict

num_entities
    Total number of entities.

        Type
            int

data_property_to_idx
    Mapping of data properties to their indices.

        Type
            dict

num_data_properties
    Total number of data properties.

        Type
            int

loader_backend
    Backend to use for loading data ('pandas' or 'rdflib').

        Type
            str

train_file_path
loader_backend = 'pandas'

normalization_type = 'z-norm'

normalization_params

sampling_ratio = None

entity_to_idx = None

num_entities

__getitem__(index)

__len__()

```

```
static load_and_validate_literal_data(file_path: str = None, loader_backend: str = 'pandas')  
    → pandas.DataFrame
```

Loads and validates the literal data file. :param file_path: Path to the literal data file. :type file_path: str

Returns

DataFrame containing the loaded and validated data.

Return type

pd.DataFrame

```
static denormalize(preds_norm, attributes, normalization_params) → numpy.ndarray
```

Denormalizes the predictions based on the normalization type.

Args: preds_norm (np.ndarray): Normalized predictions to be denormalized. attributes (list): List of attributes corresponding to the predictions. normalization_params (dict): Dictionary containing normalization parameters for each attribute.

Returns

Denormalized predictions.

Return type

np.ndarray

dicee.eval_static_funcs

Static evaluation functions for KGE models.

This module provides backward compatibility by re-exporting from the new dicee.evaluation module.

Deprecated since version Use: dicee.evaluation submodules instead. This module will be removed in a future version.

Functions

<code>evaluate_link_prediction_performance(→ Dict[str, float])</code>	Evaluate link prediction performance with head and tail prediction.
<code>evaluate_link_prediction_performance_with_.</code>	Evaluate link prediction with reciprocal relations.
<code>evaluate_link_prediction_performance_with_j</code>	Evaluate link prediction with BPE encoding (head and tail).
<code>evaluate_link_prediction_performance_with_i</code>	Evaluate link prediction with BPE encoding and reciprocals.
<code>evaluate_lp_bpe_k_vs_all(→ Dict[str, float])</code>	Evaluate BPE link prediction with KvsAll scoring.
<code>evaluate_literal_prediction(→ Optional[pandas.DataFrame])</code>	Evaluate trained literal prediction model on a test file.
<code>evaluate_ensemble_link_prediction_performanc</code>	Evaluate link prediction performance of an ensemble of KGE models.

Module Contents

```
dicee.eval_static_funcs.evaluate_link_prediction_performance(model, triples,  
er_vocab: Dict[Tuple, List], re_vocab: Dict[Tuple, List]) → Dict[str, float]
```

Evaluate link prediction performance with head and tail prediction.

Performs filtered evaluation where known correct answers are filtered out before computing ranks.

Parameters

- **model** – KGE model wrapper with entity/relation mappings.
- **triples** – Test triples as list of (head, relation, tail) strings.
- **er_vocab** – Mapping (entity, relation) -> list of valid tail entities.
- **re_vocab** – Mapping (relation, entity) -> list of valid head entities.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

```
dicee.eval_static_funcs.evaluate_link_prediction_performance_with_reciprocals(
    model, triples, er_vocab: Dict[Tuple, List]) → Dict[str, float]
```

Evaluate link prediction with reciprocal relations.

Optimized for models trained with reciprocal triples where only tail prediction is needed.

Parameters

- **model** – KGE model wrapper.
- **triples** – Test triples as list of (head, relation, tail) strings.
- **er_vocab** – Mapping (entity, relation) -> list of valid tail entities.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

```
dicee.eval_static_funcs.evaluate_link_prediction_performance_with_bpe(model,
    within_entities: List[str], triples: List[Tuple[str]], er_vocab: Dict[Tuple, List],
    re_vocab: Dict[Tuple, List]) → Dict[str, float]
```

Evaluate link prediction with BPE encoding (head and tail).

Parameters

- **model** – KGE model wrapper with BPE support.
- **within_entities** – List of entities to evaluate within.
- **triples** – Test triples as list of (head, relation, tail) tuples.
- **er_vocab** – Mapping (entity, relation) -> list of valid tail entities.
- **re_vocab** – Mapping (relation, entity) -> list of valid head entities.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

```
dicee.eval_static_funcs.evaluate_link_prediction_performance_with_bpe_reciprocals(
    model, within_entities: List[str], triples: List[List[str]], er_vocab: Dict[Tuple, List])
    → Dict[str, float]
```

Evaluate link prediction with BPE encoding and reciprocals.

Parameters

- **model** – KGE model wrapper with BPE support.
- **within_entities** – List of entities to evaluate within.
- **triples** – Test triples as list of [head, relation, tail] strings.
- **er_vocab** – Mapping (entity, relation) -> list of valid tail entities.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

```
dicee.eval_static_funcs.evaluate_lp_bpe_k_vs_all(model, triples: List[List[str]],  
er_vocab: Dict | None = None, batch_size: int | None = None,  
func_triple_to_bpe_representation: Callable | None = None,  
str_to_bpe_entity_to_idx: Dict | None = None) → Dict[str, float]
```

Evaluate BPE link prediction with KvsAll scoring.

Parameters

- **model** – The KGE model wrapper.
- **triples** – List of string triples.
- **er_vocab** – Entity-relation vocabulary for filtering.
- **batch_size** – Batch size for processing.
- **func_triple_to_bpe_representation** – Function to convert triples to BPE.
- **str_to_bpe_entity_to_idx** – Mapping from string entities to BPE indices.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

Raises

ValueError – If batch_size is not provided.

```
dicee.eval_static_funcs.evaluate_literal_prediction(kge_model, eval_file_path: str = None,  
store_lit_preds: bool = True, eval_literals: bool = True, loader_backend: str = 'pandas',  
return_attr_error_metrics: bool = False) → pandas.DataFrame | None
```

Evaluate trained literal prediction model on a test file.

Evaluates the literal prediction capabilities of a KGE model by computing MAE and RMSE metrics for each attribute.

Parameters

- **kge_model** – Trained KGE model with literal prediction capability.
- **eval_file_path** – Path to the evaluation file containing test literals.
- **store_lit_preds** – If True, stores predictions to CSV file.
- **eval_literals** – If True, evaluates and prints error metrics.
- **loader_backend** – Backend for loading dataset ('pandas' or 'rdflib').
- **return_attr_error_metrics** – If True, returns the metrics DataFrame.

Returns

DataFrame with per-attribute MAE and RMSE if return_attr_error_metrics is True, otherwise None.

Raises

- **RuntimeError** – If the KGE model doesn't have a trained literal model.
- **AssertionError** – If model is invalid or test set has no valid data.

Example

```
>>> from dicee import KGE  
>>> from dicee.evaluation import evaluate_literal_prediction  
>>> model = KGE(path="pretrained_model")  
>>> metrics = evaluate_literal_prediction(
```

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```
...     model,
...     eval_file_path="test_literals.csv",
...     return_attr_error_metrics=True
... )
>>> print(metrics)
```

```
dicee.eval_static_funcs.evaluate_ensemble_link_prediction_performance(models: List,
    triples, er_vocab: Dict[Tuple, List], weights: List[float] | None = None, batch_size: int = 512,
    weighted_averaging: bool = True, normalize_scores: bool = True) → Dict[str, float]
```

Evaluate link prediction performance of an ensemble of KGE models.

Combines predictions from multiple models using weighted or simple averaging, with optional score normalization.

Parameters

- **models** – List of KGE models (e.g., snapshots from training).
- **triples** – Test triples as numpy array or list, shape (N, 3), with integer indices (head, relation, tail).
- **er_vocab** – Mapping (head_idx, rel_idx) -> list of tail indices for filtered evaluation.
- **weights** – Weights for model averaging. Required if weighted_averaging is True. Must sum to 1 for proper averaging.
- **batch_size** – Batch size for processing triples.
- **weighted_averaging** – If True, use weighted averaging of predictions. If False, use simple mean.
- **normalize_scores** – If True, normalize scores to [0, 1] range per sample before averaging.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

Raises

AssertionError – If weighted_averaging is True but weights are not provided or have wrong length.

Example

```
>>> from dicee.evaluation import evaluate_ensemble_link_prediction_performance
>>> models = [model1, model2, model3]
>>> weights = [0.5, 0.3, 0.2]
>>> results = evaluate_ensemble_link_prediction_performance(
...     models, test_triples, er_vocab,
...     weights=weights, weighted_averaging=True
... )
>>> print(f"MRR: {results['MRR']:.4f}")
```

dicee.evaluation

Evaluation module for knowledge graph embedding models.

This module provides comprehensive evaluation capabilities for KGE models, including link prediction, literal prediction, and ensemble evaluation.

Modules:

link_prediction: Functions for evaluating link prediction performance
literal_prediction: Functions for evaluating

literal/attribute prediction ensemble: Functions for ensemble model evaluation
evaluator: Main Evaluator class for integrated evaluation
utils: Shared utility functions for evaluation

Example

```
>>> from dicee.evaluation import Evaluator
>>> from dicee.evaluation.link_prediction import evaluate_link_prediction_performance
>>> from dicee.evaluation.ensemble import evaluate_ensemble_link_prediction_
    ↪performance
```

Submodules

dicee.evaluation.ensemble

Ensemble evaluation functions.

This module provides functions for evaluating ensemble models, including weighted averaging and score normalization.

Functions

`evaluate_ensemble_link_prediction_performance` Evaluate link prediction performance of an ensemble of KGE models.

Module Contents

`dicee.evaluation.ensemble.evaluate_ensemble_link_prediction_performance` (*models*: *List*,
triples, *er_vocab*: *Dict[Tuple, List]*, *weights*: *List[float]* | *None* = *None*, *batch_size*: *int* = 512,
weighted_averaging: *bool* = *True*, *normalize_scores*: *bool* = *True*) → *Dict[str, float]*

Evaluate link prediction performance of an ensemble of KGE models.

Combines predictions from multiple models using weighted or simple averaging, with optional score normalization.

Parameters

- **models** – List of KGE models (e.g., snapshots from training).
- **triples** – Test triples as numpy array or list, shape (N, 3), with integer indices (head, relation, tail).
- **er_vocab** – Mapping (head_idx, rel_idx) -> list of tail indices for filtered evaluation.
- **weights** – Weights for model averaging. Required if weighted_averaging is True. Must sum to 1 for proper averaging.
- **batch_size** – Batch size for processing triples.
- **weighted_averaging** – If True, use weighted averaging of predictions. If False, use simple mean.
- **normalize_scores** – If True, normalize scores to [0, 1] range per sample before averaging.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

Raises

`AssertionError` – If weighted_averaging is True but weights are not provided or have wrong length.

Example

```
>>> from dicee.evaluation import evaluate_ensemble_link_prediction_performance
>>> models = [model1, model2, model3]
>>> weights = [0.5, 0.3, 0.2]
>>> results = evaluate_ensemble_link_prediction_performance(
...     models, test_triples, er_vocab,
...     weights=weights, weighted_averaging=True
... )
>>> print(f"MRR: {results['MRR']:.4f}")
```

dicee.evaluation.evaluator

Main Evaluator class for KGE model evaluation.

This module provides the Evaluator class which orchestrates evaluation of knowledge graph embedding models across different datasets and scoring techniques.

Attributes

`VALID_SCORING_TECHNIQUES`

Classes

`Evaluator`

Evaluator class for KGE models in various downstream tasks.

Module Contents

`dicee.evaluation.evaluator.VALID_SCORING_TECHNIQUES`

`class dicee.evaluation.evaluator.Evaluator(args, is_continual_training: bool = False)`

Evaluator class for KGE models in various downstream tasks.

Orchestrates link prediction evaluation with different scoring techniques including standard evaluation and byte-pair encoding based evaluation.

`er_vocab`

Entity-relation to tail vocabulary for filtered ranking.

`re_vocab`

Relation-entity (tail) to head vocabulary.

`ee_vocab`

Entity-entity to relation vocabulary.

`num_entities`

Total number of entities in the knowledge graph.

`num_relations`

Total number of relations in the knowledge graph.

args
 Configuration arguments.

report
 Dictionary storing evaluation results.

during_training
 Whether evaluation is happening during training.

Example

```
>>> from dicee.evaluation import Evaluator
>>> evaluator = Evaluator(args)
>>> results = evaluator.eval(dataset, model, 'EntityPrediction')
>>> print(f"Test MRR: {results['Test']['MRR']:.4f}")
```

```
re_vocab: Dict | None = None
er_vocab: Dict | None = None
ee_vocab: Dict | None = None
func_triple_to_bpe_representation = None
is_continual_training = False
num_entities: int | None = None
num_relations: int | None = None
domain_constraints_per_rel = None
range_constraints_per_rel = None
args
report: Dict
during_training = False
```

vocab_preparation(*dataset*) → None
 Prepare vocabularies from the dataset for evaluation.

Resolves any future objects and saves vocabularies to disk.

Parameters

dataset – Knowledge graph dataset with vocabulary attributes.

eval(*dataset*, *trained_model*, *form_of_labelling*: str, *during_training*: bool = False) → Dict | None
 Evaluate the trained model on the dataset.

Parameters

- **dataset** – Knowledge graph dataset (KG instance).
- **trained_model** – The trained KGE model.
- **form_of_labelling** – Type of labelling ('EntityPrediction' or 'RelationPrediction').
- **during_training** – Whether evaluation is during training.

Returns

Dictionary of evaluation metrics, or None if evaluation is skipped.

eval_rank_of_head_and_tail_entity(**, train_set, valid_set=None, test_set=None, trained_model)*
→ None

Evaluate with negative sampling scoring.

eval_rank_of_head_and_tail_byte_pair_encoded_entity(**, train_set=None, valid_set=None, test_set=None, ordered_bpe_entities, trained_model)* → None

Evaluate with BPE-encoded entities and negative sampling.

eval_with_byte(**, raw_train_set, raw_valid_set=None, raw_test_set=None, trained_model, form_of_labelling)* → None

Evaluate BytE model with generation.

eval_with_bpe_vs_all(**, raw_train_set, raw_valid_set=None, raw_test_set=None, trained_model, form_of_labelling)* → None

Evaluate with BPE and KvsAll scoring.

eval_with_vs_all(**, train_set, valid_set=None, test_set=None, trained_model, form_of_labelling)*
→ None

Evaluate with KvsAll or 1vsAll scoring.

evaluate_lp_k_vs_all(*model, triple_idx, info: str | None = None, form_of_labelling: str | None = None*) → Dict[str, float]

Filtered link prediction evaluation with KvsAll scoring.

Parameters

- **model** – The trained model to evaluate.
- **triple_idx** – Integer-indexed test triples.
- **info** – Description to print.
- **form_of_labelling** – ‘EntityPrediction’ or ‘RelationPrediction’.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

evaluate_lp_with_byte(*model, triples: List[List[str]], info: str | None = None*) → Dict[str, float]

Evaluate ByteE model with text generation.

Parameters

- **model** – BytE model.
- **triples** – String triples.
- **info** – Description to print.

Returns

Dictionary with placeholder metrics (-1 values).

evaluate_lp_bpe_k_vs_all(*model, triples: List[List[str]], info: str | None = None, form_of_labelling: str | None = None*) → Dict[str, float]

Evaluate BPE model with KvsAll scoring.

Parameters

- **model** – BPE-enabled model.
- **triples** – String triples.

- **info** – Description to print.
- **form_of_labelling** – Type of labelling.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

evaluate_lp (*model*, *triple_idx*, *info*: str) → Dict[str, float]

Evaluate link prediction with negative sampling.

Parameters

- **model** – The model to evaluate.
- **triple_idx** – Integer-indexed triples.
- **info** – Description to print.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

dummy_eval (*trained_model*, *form_of_labelling*: str) → None

Run evaluation from saved data (for continual training).

Parameters

- **trained_model** – The trained model.
- **form_of_labelling** – Type of labelling.

eval_with_data (*dataset*, *trained_model*, *triple_idx*: numpy.ndarray, *form_of_labelling*: str)

→ Dict[str, float]

Evaluate a trained model on a given dataset.

Parameters

- **dataset** – Knowledge graph dataset.
- **trained_model** – The trained model.
- **triple_idx** – Integer-indexed triples to evaluate.
- **form_of_labelling** – Type of labelling.

Returns

Dictionary with evaluation metrics.

Raises

ValueError – If scoring technique is invalid.

dicee.evaluation.link_prediction

Link prediction evaluation functions.

This module provides various functions for evaluating link prediction performance of knowledge graph embedding models.

Functions

<code>evaluate_link_prediction_performance</code> (→ Dict[str, float])	Evaluate link prediction performance with head and tail prediction.
<code>evaluate_link_prediction_performance_with_</code>	Evaluate link prediction with reciprocal relations.

continues on next page

Table 13 – continued from previous page

<code>evaluate_link_prediction_performance_with_j</code>	Evaluate link prediction with BPE encoding and reciprocals.
<code>evaluate_link_prediction_performance_with_j</code>	Evaluate link prediction with BPE encoding (head and tail).
<code>evaluate_lp</code> (→ Dict[str, float])	Evaluate link prediction with batched processing.
<code>evaluate_bpe_lp</code> (→ Dict[str, float])	Evaluate link prediction with BPE-encoded entities.
<code>evaluate_lp_bpe_k_vs_all</code> (→ Dict[str, float])	Evaluate BPE link prediction with KvsAll scoring.

Module Contents

`dicee.evaluation.link_prediction.evaluate_link_prediction_performance(model, triples, er_vocab: Dict[Tuple, List], re_vocab: Dict[Tuple, List]) → Dict[str, float]`

Evaluate link prediction performance with head and tail prediction.

Performs filtered evaluation where known correct answers are filtered out before computing ranks.

Parameters

- `model` – KGE model wrapper with entity/relation mappings.
- `triples` – Test triples as list of (head, relation, tail) strings.
- `er_vocab` – Mapping (entity, relation) -> list of valid tail entities.
- `re_vocab` – Mapping (relation, entity) -> list of valid head entities.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

`dicee.evaluation.link_prediction.`

`evaluate_link_prediction_performance_with_reciprocals(model, triples, er_vocab: Dict[Tuple, List]) → Dict[str, float]`

Evaluate link prediction with reciprocal relations.

Optimized for models trained with reciprocal triples where only tail prediction is needed.

Parameters

- `model` – KGE model wrapper.
- `triples` – Test triples as list of (head, relation, tail) strings.
- `er_vocab` – Mapping (entity, relation) -> list of valid tail entities.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

`dicee.evaluation.link_prediction.`

`evaluate_link_prediction_performance_with_bpe_reciprocals(model, within_entities: List[str], triples: List[List[str]], er_vocab: Dict[Tuple, List]) → Dict[str, float]`

Evaluate link prediction with BPE encoding and reciprocals.

Parameters

- `model` – KGE model wrapper with BPE support.
- `within_entities` – List of entities to evaluate within.
- `triples` – Test triples as list of [head, relation, tail] strings.
- `er_vocab` – Mapping (entity, relation) -> list of valid tail entities.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

```
dicee.evaluation.link_prediction.evaluate_link_prediction_performance_with_bpe(  
    model, within_entities: List[str], triples: List[Tuple[str]], er_vocab: Dict[Tuple, List],  
    re_vocab: Dict[Tuple, List]) → Dict[str, float]
```

Evaluate link prediction with BPE encoding (head and tail).

Parameters

- **model** – KGE model wrapper with BPE support.
- **within_entities** – List of entities to evaluate within.
- **triples** – Test triples as list of (head, relation, tail) tuples.
- **er_vocab** – Mapping (entity, relation) -> list of valid tail entities.
- **re_vocab** – Mapping (relation, entity) -> list of valid head entities.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

```
dicee.evaluation.link_prediction.evaluate_lp(model, triple_idx, num_entities: int,  
    er_vocab: Dict[Tuple, List], re_vocab: Dict[Tuple, List], info: str = 'Eval Starts',  
    batch_size: int = 128, chunk_size: int = 1000) → Dict[str, float]
```

Evaluate link prediction with batched processing.

Memory-efficient evaluation using chunked entity scoring.

Parameters

- **model** – The KGE model to evaluate.
- **triple_idx** – Integer-indexed triples as numpy array.
- **num_entities** – Total number of entities.
- **er_vocab** – Mapping (head_idx, rel_idx) -> list of tail indices.
- **re_vocab** – Mapping (rel_idx, tail_idx) -> list of head indices.
- **info** – Description to print.
- **batch_size** – Batch size for triple processing.
- **chunk_size** – Chunk size for entity scoring.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

```
dicee.evaluation.link_prediction.evaluate_bpe_lp(model, triple_idx: List[Tuple],  
    all_bpe_shaped_entities, er_vocab: Dict[Tuple, List], re_vocab: Dict[Tuple, List],  
    info: str = 'Eval Starts') → Dict[str, float]
```

Evaluate link prediction with BPE-encoded entities.

Parameters

- **model** – The KGE model to evaluate.
- **triple_idx** – List of BPE-encoded triple tuples.
- **all_bpe_shaped_entities** – All entities with BPE representations.
- **er_vocab** – Mapping for tail filtering.
- **re_vocab** – Mapping for head filtering.

- **info** – Description to print.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

```
dicee.evaluation.link_prediction.evaluate_lp_bpe_k_vs_all(model, triples: List[List[str]],  
er_vocab: Dict | None = None, batch_size: int | None = None,  
func_triple_to_bpe_representation: Callable | None = None,  
str_to_bpe_entity_to_idx: Dict | None = None) → Dict[str, float]
```

Evaluate BPE link prediction with KvsAll scoring.

Parameters

- **model** – The KGE model wrapper.
- **triples** – List of string triples.
- **er_vocab** – Entity-relation vocabulary for filtering.
- **batch_size** – Batch size for processing.
- **func_triple_to_bpe_representation** – Function to convert triples to BPE.
- **str_to_bpe_entity_to_idx** – Mapping from string entities to BPE indices.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

Raises

ValueError – If batch_size is not provided.

dicee.evaluation.literal_prediction

Literal prediction evaluation functions.

This module provides functions for evaluating literal/attribute prediction performance of knowledge graph embedding models.

Functions

<code>evaluate_literal_prediction</code> (→ Optional[pandas.DataFrame])	Evaluate trained literal prediction model on a test file.
---	---

Module Contents

```
dicee.evaluation.literal_prediction.evaluate_literal_prediction(kge_model,  
eval_file_path: str = None, store_lit_preds: bool = True, eval_literals: bool = True,  
loader_backend: str = 'pandas', return_attr_error_metrics: bool = False)  
→ pandas.DataFrame | None
```

Evaluate trained literal prediction model on a test file.

Evaluates the literal prediction capabilities of a KGE model by computing MAE and RMSE metrics for each attribute.

Parameters

- **kge_model** – Trained KGE model with literal prediction capability.
- **eval_file_path** – Path to the evaluation file containing test literals.

- **store_lit_preds** – If True, stores predictions to CSV file.
- **eval_literals** – If True, evaluates and prints error metrics.
- **loader_backend** – Backend for loading dataset ('pandas' or 'rdflib').
- **return_attr_error_metrics** – If True, returns the metrics DataFrame.

Returns

DataFrame with per-attribute MAE and RMSE if return_attr_error_metrics is True, otherwise None.

Raises

- **RuntimeError** – If the KGE model doesn't have a trained literal model.
- **AssertionError** – If model is invalid or test set has no valid data.

Example

```
>>> from dicee import KGE
>>> from dicee.evaluation import evaluate_literal_prediction
>>> model = KGE(path="pretrained_model")
>>> metrics = evaluate_literal_prediction(
...     model,
...     eval_file_path="test_literals.csv",
...     return_attr_error_metrics=True
... )
>>> print(metrics)
```

dicee.evaluation.utils

Utility functions for evaluation module.

This module contains shared helper functions used across different evaluation components.

Attributes

DEFAULT_HITS_RANGE

ALL_HITS_RANGE

Functions

<i>make_iterable_verbose</i> (→ Iterable)	Wrap an iterable with tqdm progress bar if verbose is True.
<i>compute_metrics_from_ranks</i> (→ Dict[str, float])	Compute standard link prediction metrics from ranks.
<i>compute_metrics_from_ranks_simple</i> (→ Dict[str, float])	Compute link prediction metrics without scaling factor.
<i>update_hits</i> (→ None)	Update hits dictionary based on rank.
<i>create_hits_dict</i> (→ Dict[int, List[float]])	Create an initialized hits dictionary.
<i>efficient_zero_grad</i> (→ None)	Efficiently zero gradients using parameter.grad = None.

Module Contents

```
dicee.evaluation.utils.DEFAULT_HITS_RANGE: List[int] = [1, 3, 10]

dicee.evaluation.utils.ALL_HITS_RANGE: List[int]

dicee.evaluation.utils.make_iterable_verbose (iterable_object: Iterable, verbose: bool,
                                             desc: str = 'Default', position: int | None = None, leave: bool = True) → Iterable
```

Wrap an iterable with tqdm progress bar if verbose is True.

Parameters

- **iterable_object** – The iterable to potentially wrap.
- **verbose** – Whether to show progress bar.
- **desc** – Description for the progress bar.
- **position** – Position of the progress bar.
- **leave** – Whether to leave the progress bar after completion.

Returns

The original iterable or a tqdm-wrapped version.

```
dicee.evaluation.utils.compute_metrics_from_ranks (ranks: List[int], num_triples: int,
                                                 hits_dict: Dict[int, List[float]], scale_factor: int = 1) → Dict[str, float]
```

Compute standard link prediction metrics from ranks.

Parameters

- **ranks** – List of ranks for each prediction.
- **num_triples** – Total number of triples evaluated.
- **hits_dict** – Dictionary mapping hit levels to lists of hits.
- **scale_factor** – Factor to scale the denominator (e.g., 2 for head+tail).

Returns

Dictionary containing H@1, H@3, H@10, and MRR metrics.

```
dicee.evaluation.utils.compute_metrics_from_ranks_simple (ranks: List[int], num_triples: int,
                                                       hits_dict: Dict[int, List[float]]) → Dict[str, float]
```

Compute link prediction metrics without scaling factor.

Parameters

- **ranks** – List of ranks for each prediction.
- **num_triples** – Total number of triples evaluated.
- **hits_dict** – Dictionary mapping hit levels to lists of hits.

Returns

Dictionary containing H@1, H@3, H@10, and MRR metrics.

```
dicee.evaluation.utils.update_hits (hits: Dict[int, List[float]], rank: int,
                                    hits_range: List[int] | None = None) → None
```

Update hits dictionary based on rank.

Parameters

- **hits** – Dictionary to update in-place.
- **rank** – The rank to check against hit levels.

- **hits_range** – List of hit levels to check (default: ALL_HITS_RANGE).

`dicee.evaluation.utils.create_hits_dict(hits_range: List[int] | None = None)`
 \rightarrow Dict[int, List[float]]

Create an initialized hits dictionary.

Parameters

hits_range – List of hit levels to initialize (default: ALL_HITS_RANGE).

Returns

Dictionary with empty lists for each hit level.

`dicee.evaluation.utils.efficient_zero_grad(model) → None`

Efficiently zero gradients using parameter.grad = None.

This is more efficient than optimizer.zero_grad() as it avoids memory operations.

See: https://pytorch.org/tutorials/recipes/recipes/tuning_guide.html

Parameters

model – PyTorch model to zero gradients for.

Attributes

<code>DEFAULT_HITS_RANGE</code>
<code>ALL_HITS_RANGE</code>

Classes

<code>Evaluator</code>	Evaluator class for KGE models in various downstream tasks.
------------------------	---

Functions

<code>evaluate_link_prediction_performance(→ Dict[str, float])</code>	Evaluate link prediction performance with head and tail prediction.
<code>evaluate_link_prediction_performance_with_</code>	Evaluate link prediction with reciprocal relations.
<code>evaluate_link_prediction_performance_with_j</code>	Evaluate link prediction with BPE encoding (head and tail).
<code>evaluate_link_prediction_performance_with_ij</code>	Evaluate link prediction with BPE encoding and reciprocals.
<code>evaluate_lp(→ Dict[str, float])</code>	Evaluate link prediction with batched processing.
<code>evaluate_lp_bpe_k_vs_all(→ Dict[str, float])</code>	Evaluate BPE link prediction with KvsAll scoring.
<code>evaluate_bpe_lp(→ Dict[str, float])</code>	Evaluate link prediction with BPE-encoded entities.
<code>evaluate_literal_prediction(→ Operational[pandas.DataFrame])</code>	Evaluate trained literal prediction model on a test file.
<code>evaluate_ensemble_link_prediction_performanc</code>	Evaluate link prediction performance of an ensemble of KGE models.
<code>compute_metrics_from_ranks(→ Dict[str, float])</code>	Compute standard link prediction metrics from ranks.
<code>compute_metrics_from_ranks_simple(→ Dict[str, float])</code>	Compute link prediction metrics without scaling factor.

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Table 19 – continued from previous page

<code>make_iterable_verbose</code> (→ Iterable)	Wrap an iterable with tqdm progress bar if verbose is True.
<code>update_hits</code> (→ None)	Update hits dictionary based on rank.
<code>create_hits_dict</code> (→ Dict[int, List[float]])	Create an initialized hits dictionary.

Package Contents

class dicee.evaluation.**Evaluator**(*args*, *is_continual_training*: bool = False)

Evaluator class for KGE models in various downstream tasks.

Orchestrates link prediction evaluation with different scoring techniques including standard evaluation and byte-pair encoding based evaluation.

er_vocab

Entity-relation to tail vocabulary for filtered ranking.

re_vocab

Relation-entity (tail) to head vocabulary.

ee_vocab

Entity-entity to relation vocabulary.

num_entities

Total number of entities in the knowledge graph.

num_relations

Total number of relations in the knowledge graph.

args

Configuration arguments.

report

Dictionary storing evaluation results.

during_training

Whether evaluation is happening during training.

Example

```
>>> from dicee.evaluation import Evaluator
>>> evaluator = Evaluator(args)
>>> results = evaluator.eval(dataset, model, 'EntityPrediction')
>>> print(f"Test MRR: {results['Test']['MRR']:.4f}")
```

re_vocab: Dict | None = None

er_vocab: Dict | None = None

ee_vocab: Dict | None = None

func_triple_to_bpe_representation = None

is_continual_training = False

num_entities: int | None = None

```

num_relations: int | None = None
domain_constraints_per_rel = None
range_constraints_per_rel = None
args
report: Dict
during_training = False
vocab_preparation(dataset) → None
    Prepare vocabularies from the dataset for evaluation.
    Resolves any future objects and saves vocabularies to disk.

Parameters
    dataset – Knowledge graph dataset with vocabulary attributes.

eval(dataset, trained_model, form_of_labelling: str, during_training: bool = False) → Dict | None
    Evaluate the trained model on the dataset.

Parameters
    • dataset – Knowledge graph dataset (KG instance).
    • trained_model – The trained KGE model.
    • form_of_labelling – Type of labelling ('EntityPrediction' or 'RelationPrediction').
    • during_training – Whether evaluation is during training.

Returns
    Dictionary of evaluation metrics, or None if evaluation is skipped.

eval_rank_of_head_and_tail_entity(*train_set, valid_set=None, test_set=None, trained_model)
    → None
    Evaluate with negative sampling scoring.

eval_rank_of_head_and_tail_byte_pair_encoded_entity(*train_set=None, valid_set=None,
    test_set=None, ordered_bpe_entities, trained_model) → None
    Evaluate with BPE-encoded entities and negative sampling.

eval_with_byte(*raw_train_set, raw_valid_set=None, raw_test_set=None, trained_model,
    form_of_labelling) → None
    Evaluate ByTE model with generation.

eval_with_bpe_vs_all(*raw_train_set, raw_valid_set=None, raw_test_set=None, trained_model,
    form_of_labelling) → None
    Evaluate with BPE and KvsAll scoring.

eval_with_vs_all(*train_set, valid_set=None, test_set=None, trained_model, form_of_labelling)
    → None
    Evaluate with KvsAll or 1vsAll scoring.

evaluate_lp_k_vs_all(model, triple_idx, info: str | None = None,
    form_of_labelling: str | None = None) → Dict[str, float]
    Filtered link prediction evaluation with KvsAll scoring.

```

Parameters

- **model** – The trained model to evaluate.

- **triple_idx** – Integer-indexed test triples.
- **info** – Description to print.
- **form_of_labelling** – ‘EntityPrediction’ or ‘RelationPrediction’.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

evaluate_lp_with_byte (*model*, *triples*: *List[List[str]]*, *info*: *str* | *None* = *None*) → *Dict[str, float]*

Evaluate BytE model with text generation.

Parameters

- **model** – BytE model.
- **triples** – String triples.
- **info** – Description to print.

Returns

Dictionary with placeholder metrics (-1 values).

evaluate_lp_bpe_k_vs_all (*model*, *triples*: *List[List[str]]*, *info*: *str* | *None* = *None*,
form_of_labelling: *str* | *None* = *None*) → *Dict[str, float]*

Evaluate BPE model with KvsAll scoring.

Parameters

- **model** – BPE-enabled model.
- **triples** – String triples.
- **info** – Description to print.
- **form_of_labelling** – Type of labelling.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

evaluate_lp (*model*, *triple_idx*, *info*: *str*) → *Dict[str, float]*

Evaluate link prediction with negative sampling.

Parameters

- **model** – The model to evaluate.
- **triple_idx** – Integer-indexed triples.
- **info** – Description to print.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

dummy_eval (*trained_model*, *form_of_labelling*: *str*) → *None*

Run evaluation from saved data (for continual training).

Parameters

- **trained_model** – The trained model.
- **form_of_labelling** – Type of labelling.

```
eval_with_data(dataset, trained_model, triple_idx: numpy.ndarray, form_of_labelling: str)
```

→ Dict[str, float]

Evaluate a trained model on a given dataset.

Parameters

- **dataset** – Knowledge graph dataset.
- **trained_model** – The trained model.
- **triple_idx** – Integer-indexed triples to evaluate.
- **form_of_labelling** – Type of labelling.

Returns

Dictionary with evaluation metrics.

Raises

ValueError – If scoring technique is invalid.

```
dicee.evaluation.evaluate_link_prediction_performance(model, triples,  
er_vocab: Dict[Tuple, List], re_vocab: Dict[Tuple, List]) → Dict[str, float]
```

Evaluate link prediction performance with head and tail prediction.

Performs filtered evaluation where known correct answers are filtered out before computing ranks.

Parameters

- **model** – KGE model wrapper with entity/relation mappings.
- **triples** – Test triples as list of (head, relation, tail) strings.
- **er_vocab** – Mapping (entity, relation) -> list of valid tail entities.
- **re_vocab** – Mapping (relation, entity) -> list of valid head entities.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

```
dicee.evaluation.evaluate_link_prediction_performance_with_reciprocals(model, triples,  
er_vocab: Dict[Tuple, List]) → Dict[str, float]
```

Evaluate link prediction with reciprocal relations.

Optimized for models trained with reciprocal triples where only tail prediction is needed.

Parameters

- **model** – KGE model wrapper.
- **triples** – Test triples as list of (head, relation, tail) strings.
- **er_vocab** – Mapping (entity, relation) -> list of valid tail entities.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

```
dicee.evaluation.evaluate_link_prediction_performance_with_bpe(model,  
within_entities: List[str], triples: List[Tuple[str]], er_vocab: Dict[Tuple, List],  
re_vocab: Dict[Tuple, List]) → Dict[str, float]
```

Evaluate link prediction with BPE encoding (head and tail).

Parameters

- **model** – KGE model wrapper with BPE support.
- **within_entities** – List of entities to evaluate within.

- **triples** – Test triples as list of (head, relation, tail) tuples.
- **er_vocab** – Mapping (entity, relation) -> list of valid tail entities.
- **re_vocab** – Mapping (relation, entity) -> list of valid head entities.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

```
dicee.evaluation.evaluate_link_prediction_performance_with_bpe_reciprocals(model,
    within_entities: List[str], triples: List[List[str]], er_vocab: Dict[Tuple, List]) → Dict[str, float]
```

Evaluate link prediction with BPE encoding and reciprocals.

Parameters

- **model** – KGE model wrapper with BPE support.
- **within_entities** – List of entities to evaluate within.
- **triples** – Test triples as list of [head, relation, tail] strings.
- **er_vocab** – Mapping (entity, relation) -> list of valid tail entities.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

```
dicee.evaluation.evaluate_lp(model, triple_idx, num_entities: int, er_vocab: Dict[Tuple, List],
    re_vocab: Dict[Tuple, List], info: str = 'Eval Starts', batch_size: int = 128, chunk_size: int = 1000)
    → Dict[str, float]
```

Evaluate link prediction with batched processing.

Memory-efficient evaluation using chunked entity scoring.

Parameters

- **model** – The KGE model to evaluate.
- **triple_idx** – Integer-indexed triples as numpy array.
- **num_entities** – Total number of entities.
- **er_vocab** – Mapping (head_idx, rel_idx) -> list of tail indices.
- **re_vocab** – Mapping (rel_idx, tail_idx) -> list of head indices.
- **info** – Description to print.
- **batch_size** – Batch size for triple processing.
- **chunk_size** – Chunk size for entity scoring.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

```
dicee.evaluation.evaluate_lp_bpe_k_vs_all(model, triples: List[List[str]],
    er_vocab: Dict | None = None, batch_size: int | None = None,
    func_triple_to_bpe_representation: Callable | None = None,
    str_to_bpe_entity_to_idx: Dict | None = None) → Dict[str, float]
```

Evaluate BPE link prediction with KvsAll scoring.

Parameters

- **model** – The KGE model wrapper.
- **triples** – List of string triples.
- **er_vocab** – Entity-relation vocabulary for filtering.

- **batch_size** – Batch size for processing.
- **func_triple_to_bpe_representation** – Function to convert triples to BPE.
- **str_to_bpe_entity_to_idx** – Mapping from string entities to BPE indices.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

Raises

ValueError – If batch_size is not provided.

```
dicee.evaluation.evaluate_bpe_lp(model, triple_idx: List[Tuple], all_bpe_shaped_entities,
er_vocab: Dict[Tuple, List], re_vocab: Dict[Tuple, List], info: str = 'Eval Starts') → Dict[str, float]
```

Evaluate link prediction with BPE-encoded entities.

Parameters

- **model** – The KGE model to evaluate.
- **triple_idx** – List of BPE-encoded triple tuples.
- **all_bpe_shaped_entities** – All entities with BPE representations.
- **er_vocab** – Mapping for tail filtering.
- **re_vocab** – Mapping for head filtering.
- **info** – Description to print.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

```
dicee.evaluation.evaluate_literal_prediction(kge_model, eval_file_path: str = None,
store_lit_preds: bool = True, eval_literals: bool = True, loader_backend: str = 'pandas',
return_attr_error_metrics: bool = False) → pandas.DataFrame | None
```

Evaluate trained literal prediction model on a test file.

Evaluates the literal prediction capabilities of a KGE model by computing MAE and RMSE metrics for each attribute.

Parameters

- **kge_model** – Trained KGE model with literal prediction capability.
- **eval_file_path** – Path to the evaluation file containing test literals.
- **store_lit_preds** – If True, stores predictions to CSV file.
- **eval_literals** – If True, evaluates and prints error metrics.
- **loader_backend** – Backend for loading dataset ('pandas' or 'rdflib').
- **return_attr_error_metrics** – If True, returns the metrics DataFrame.

Returns

DataFrame with per-attribute MAE and RMSE if return_attr_error_metrics is True, otherwise None.

Raises

- **RuntimeError** – If the KGE model doesn't have a trained literal model.
- **AssertionError** – If model is invalid or test set has no valid data.

Example

```
>>> from dicee import KGE
>>> from dicee.evaluation import evaluate_literal_prediction
>>> model = KGE(path="pretrained_model")
>>> metrics = evaluate_literal_prediction(
...     model,
...     eval_file_path="test_literals.csv",
...     return_attr_error_metrics=True
... )
>>> print(metrics)
```

dicee.evaluation.**evaluate_ensemble_link_prediction_performance**(models: List, triples,
er_vocab: Dict[Tuple, List], weights: List[float] | None = None, batch_size: int = 512,
weighted_averaging: bool = True, normalize_scores: bool = True) → Dict[str, float]

Evaluate link prediction performance of an ensemble of KGE models.

Combines predictions from multiple models using weighted or simple averaging, with optional score normalization.

Parameters

- **models** – List of KGE models (e.g., snapshots from training).
- **triples** – Test triples as numpy array or list, shape (N, 3), with integer indices (head, relation, tail).
- **er_vocab** – Mapping (head_idx, rel_idx) -> list of tail indices for filtered evaluation.
- **weights** – Weights for model averaging. Required if weighted_averaging is True. Must sum to 1 for proper averaging.
- **batch_size** – Batch size for processing triples.
- **weighted_averaging** – If True, use weighted averaging of predictions. If False, use simple mean.
- **normalize_scores** – If True, normalize scores to [0, 1] range per sample before averaging.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

Raises

AssertionError – If weighted_averaging is True but weights are not provided or have wrong length.

Example

```
>>> from dicee.evaluation import evaluate_ensemble_link_prediction_performance
>>> models = [model1, model2, model3]
>>> weights = [0.5, 0.3, 0.2]
>>> results = evaluate_ensemble_link_prediction_performance(
...     models, test_triples, er_vocab,
...     weights=weights, weighted_averaging=True
... )
>>> print(f"MRR: {results['MRR']:.4f}")
```

dicee.evaluation.**compute_metrics_from_ranks**(ranks: List[int], num_triples: int,
hits_dict: Dict[int, List[float]], scale_factor: int = 1) → Dict[str, float]

Compute standard link prediction metrics from ranks.

Parameters

- **ranks** – List of ranks for each prediction.
- **num_triples** – Total number of triples evaluated.
- **hits_dict** – Dictionary mapping hit levels to lists of hits.
- **scale_factor** – Factor to scale the denominator (e.g., 2 for head+tail).

Returns

Dictionary containing H@1, H@3, H@10, and MRR metrics.

```
dicee.evaluation.compute_metrics_from_ranks_simple(ranks: List[int], num_triples: int,  
hits_dict: Dict[int, List[float]]) → Dict[str, float]
```

Compute link prediction metrics without scaling factor.

Parameters

- **ranks** – List of ranks for each prediction.
- **num_triples** – Total number of triples evaluated.
- **hits_dict** – Dictionary mapping hit levels to lists of hits.

Returns

Dictionary containing H@1, H@3, H@10, and MRR metrics.

```
dicee.evaluation.make_iterable_verbose(iterable_object: Iterable, verbose: bool, desc: str = 'Default',  
position: int | None = None, leave: bool = True) → Iterable
```

Wrap an iterable with tqdm progress bar if verbose is True.

Parameters

- **iterable_object** – The iterable to potentially wrap.
- **verbose** – Whether to show progress bar.
- **desc** – Description for the progress bar.
- **position** – Position of the progress bar.
- **leave** – Whether to leave the progress bar after completion.

Returns

The original iterable or a tqdm-wrapped version.

```
dicee.evaluation.update_hits(hits: Dict[int, List[float]], rank: int, hits_range: List[int] | None = None)  
→ None
```

Update hits dictionary based on rank.

Parameters

- **hits** – Dictionary to update in-place.
- **rank** – The rank to check against hit levels.
- **hits_range** – List of hit levels to check (default: ALL_HITS_RANGE).

```
dicee.evaluation.create_hits_dict(hits_range: List[int] | None = None) → Dict[int, List[float]]
```

Create an initialized hits dictionary.

Parameters

hits_range – List of hit levels to initialize (default: ALL_HITS_RANGE).

Returns

Dictionary with empty lists for each hit level.

```
dicee.evaluation.DEFAULT_HITS_RANGE: List[int] = [1, 3, 10]
dicee.evaluation.ALL_HITS_RANGE: List[int]
```

dicee.evaluator

Evaluator module for knowledge graph embedding models.

This module provides backward compatibility by re-exporting from the new dicee.evaluation module.

Deprecated since version Use: dicee.evaluation.Evaluator instead. This module will be removed in a future version.

Classes

<code>Evaluator</code>	Evaluator class for KGE models in various downstream tasks.
------------------------	---

Module Contents

`class dicee.evaluator.Evaluator(args, is_continual_training: bool = False)`

Evaluator class for KGE models in various downstream tasks.

Orchestrates link prediction evaluation with different scoring techniques including standard evaluation and byte-pair encoding based evaluation.

`er_vocab`

Entity-relation to tail vocabulary for filtered ranking.

`re_vocab`

Relation-entity (tail) to head vocabulary.

`ee_vocab`

Entity-entity to relation vocabulary.

`num_entities`

Total number of entities in the knowledge graph.

`num_relations`

Total number of relations in the knowledge graph.

`args`

Configuration arguments.

`report`

Dictionary storing evaluation results.

`during_training`

Whether evaluation is happening during training.

Example

```
>>> from dicee.evaluation import Evaluator
>>> evaluator = Evaluator(args)
>>> results = evaluator.eval(dataset, model, 'EntityPrediction')
>>> print(f"Test MRR: {results['Test']['MRR']:.4f}")
```

```

re_vocab: Dict | None = None
er_vocab: Dict | None = None
ee_vocab: Dict | None = None
func_triple_to_bpe_representation = None
is_continual_training = False
num_entities: int | None = None
num_relations: int | None = None
domain_constraints_per_rel = None
range_constraints_per_rel = None
args
report: Dict
during_training = False

```

vocab_preparation(*dataset*) → None

Prepare vocabularies from the dataset for evaluation.

Resolves any future objects and saves vocabularies to disk.

Parameters

dataset – Knowledge graph dataset with vocabulary attributes.

eval(*dataset, trained_model, form_of_labelling: str, during_training: bool = False*) → Dict | None

Evaluate the trained model on the dataset.

Parameters

- **dataset** – Knowledge graph dataset (KG instance).
- **trained_model** – The trained KGE model.
- **form_of_labelling** – Type of labelling ('EntityPrediction' or 'RelationPrediction').
- **during_training** – Whether evaluation is during training.

Returns

Dictionary of evaluation metrics, or None if evaluation is skipped.

eval_rank_of_head_and_tail_entity(**, train_set, valid_set=None, test_set=None, trained_model*)
→ None

Evaluate with negative sampling scoring.

eval_rank_of_head_and_tail_byte_pair_encoded_entity(**, train_set=None, valid_set=None, test_set=None, ordered_bpe_entities, trained_model*) → None

Evaluate with BPE-encoded entities and negative sampling.

eval_with_byte(**, raw_train_set, raw_valid_set=None, raw_test_set=None, trained_model, form_of_labelling*) → None

Evaluate ByteE model with generation.

```
eval_with_bpe_vs_all(*, raw_train_set, raw_valid_set=None, raw_test_set=None, trained_model,  
form_of_labelling) → None
```

Evaluate with BPE and KvsAll scoring.

```
eval_vs_all(*, train_set, valid_set=None, test_set=None, trained_model, form_of_labelling)  
→ None
```

Evaluate with KvsAll or 1vsAll scoring.

```
evaluate_lp_k_vs_all(model, triple_idx, info: str | None = None,  
form_of_labelling: str | None = None) → Dict[str, float]
```

Filtered link prediction evaluation with KvsAll scoring.

Parameters

- **model** – The trained model to evaluate.
- **triple_idx** – Integer-indexed test triples.
- **info** – Description to print.
- **form_of_labelling** – ‘EntityPrediction’ or ‘RelationPrediction’.

Returns

Dictionary with H@1, H@3, **H@10**, and MRR metrics.

```
evaluate_lp_with_byte(model, triples: List[List[str]], info: str | None = None) → Dict[str, float]
```

Evaluate BytE model with text generation.

Parameters

- **model** – BytE model.
- **triples** – String triples.
- **info** – Description to print.

Returns

Dictionary with placeholder metrics (-1 values).

```
evaluate_lp_bpe_k_vs_all(model, triples: List[List[str]], info: str | None = None,  
form_of_labelling: str | None = None) → Dict[str, float]
```

Evaluate BPE model with KvsAll scoring.

Parameters

- **model** – BPE-enabled model.
- **triples** – String triples.
- **info** – Description to print.
- **form_of_labelling** – Type of labelling.

Returns

Dictionary with H@1, H@3, **H@10**, and MRR metrics.

```
evaluate_lp(model, triple_idx, info: str) → Dict[str, float]
```

Evaluate link prediction with negative sampling.

Parameters

- **model** – The model to evaluate.
- **triple_idx** – Integer-indexed triples.
- **info** – Description to print.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

dummy_eval (*trained_model*, *form_of_labelling*: str) → None

Run evaluation from saved data (for continual training).

Parameters

- **trained_model** – The trained model.
- **form_of_labelling** – Type of labelling.

eval_with_data (*dataset*, *trained_model*, *triple_idx*: numpy.ndarray, *form_of_labelling*: str)

→ Dict[str, float]

Evaluate a trained model on a given dataset.

Parameters

- **dataset** – Knowledge graph dataset.
- **trained_model** – The trained model.
- **triple_idx** – Integer-indexed triples to evaluate.
- **form_of_labelling** – Type of labelling.

Returns

Dictionary with evaluation metrics.

Raises

ValueError – If scoring technique is invalid.

dicee.executor

Executor module for training, retraining and evaluating KGE models.

This module provides the Execute and ContinuousExecute classes for managing the full lifecycle of knowledge graph embedding model training.

Classes

<i>Execute</i>	Executor class for training, retraining and evaluating KGE models.
<i>ContinuousExecute</i>	A subclass of Execute Class for retraining

Module Contents

class dicee.executor.**Execute** (*args*, *continuous_training*: bool = False)

Executor class for training, retraining and evaluating KGE models.

Handles the complete workflow: 1. Loading & Preprocessing & Serializing input data 2. Training & Validation & Testing 3. Storing all necessary information

args

Processed input arguments.

distributed

Whether distributed training is enabled.

```

rank
    Process rank in distributed training.

world_size
    Total number of processes.

local_rank
    Local GPU rank.

trainer
    Training handler instance.

trained_model
    The trained model after training completes.

knowledge_graph
    The loaded knowledge graph.

report
    Dictionary storing training metrics and results.

evaluator
    Model evaluation handler.

distributed

args

is_continual_training = False

trainer: dicee.trainer.DICE_Trainer | None = None

trained_model = None

knowledge_graph: dicee.knowledge_graph.KG | None = None

report: Dict

evaluator: dicee.evaluator.Evaluator | None = None

start_time: float | None = None

is_rank_zero() → bool

cleanup()

setup_executor() → None
    Set up storage directories for the experiment.

    Creates or reuses experiment directories based on configuration. Saves the configuration to a JSON file.

create_and_store_kg() → None
    Create knowledge graph and store as memory-mapped file.

    Only executed on rank 0 in distributed training. Skips if memmap already exists.

load_from_memmap() → None
    Load knowledge graph from memory-mapped file.

```

```
save_trained_model() → None
    Save a knowledge graph embedding model
        (1) Send model to eval mode and cpu.
        (2) Store the memory footprint of the model.
        (3) Save the model into disk.
        (4) Update the stats of KG again ?
```

Parameter

rtype
None

```
end(form_of_labelling: str) → dict
    End training
        (1) Store trained model.
        (2) Report runtimes.
        (3) Eval model if required.
```

Parameter

rtype
A dict containing information about the training and/or evaluation

```
write_report() → None
    Report training related information in a report.json file
start() → dict
    Start training
        # (1) Loading the Data # (2) Create an evaluator object. # (3) Create a trainer object. # (4) Start the training
```

Parameter

rtype
A dict containing information about the training and/or evaluation

```
class dicee.executer.ContinuousExecute(args)
Bases: Execute
A subclass of Execute Class for retraining
    (1) Loading & Preprocessing & Serializing input data.
    (2) Training & Validation & Testing
    (3) Storing all necessary info
```

During the continual learning we can only modify * **num_epochs** * parameter. Trained model stored in the same folder as the seed model for the training. Trained model is noted with the current time.

```
continual_start() → dict
    Start Continual Training
        (1) Initialize training.
        (2) Start continual training.
        (3) Save trained model.
```

Parameter

rtype

A dict containing information about the training and/or evaluation

dicee.knowledge_graph

Knowledge Graph module for data loading and preprocessing.

Provides the KG class for handling knowledge graph data including loading, preprocessing, and indexing operations.

Classes

KG

Knowledge Graph container and processor.

Module Contents

```
class dicee.knowledge_graph.KG(dataset_dir: str | None = None, byte_pair_encoding: bool = False,
                                padding: bool = False, add_noise_rate: float | None = None, sparql_endpoint: str | None = None,
                                path_single_kg: str | None = None, path_for_deserialization: str | None = None,
                                add_reciprocal: bool | None = None, eval_model: str | None = None,
                                read_only_few: int | None = None, sample_triples_ratio: float | None = None,
                                path_for_serialization: str | None = None, entity_to_idx: Dict | None = None,
                                relation_to_idx: Dict | None = None, backend: str | None = None,
                                training_technique: str | None = None, separator: str | None = None)
```

Knowledge Graph container and processor.

Handles loading, preprocessing, and indexing of knowledge graph data from various sources including files, SPARQL endpoints, and serialized formats.

dataset_dir

Path to directory containing train/valid/test files.

num_entities

Total number of unique entities.

num_relations

Total number of unique relations.

train_set

Indexed training triples as numpy array.

valid_set

Indexed validation triples (optional).

test_set

Indexed test triples (optional).

```
entity_to_idx
    Mapping from entity strings to indices.

relation_to_idx
    Mapping from relation strings to indices.

dataset_dir = None

sparql_endpoint = None

path_single_kg = None

byte_pair_encoding = False

ordered_shaped_bpe_tokens = None

add_noise_rate = None

num_entities: int | None = None

num_relations: int | None = None

path_for_deserialization = None

add_reciprocal = None

eval_model = None

read_only_few = None

sample_triples_ratio = None

path_for_serialization = None

entity_to_idx = None

relation_to_idx = None

backend = 'pandas'

training_technique = None

separator = None

raw_train_set = None

raw_valid_set = None

raw_test_set = None

train_set = None

valid_set = None

test_set = None

idx_entity_to_bpe_shaped: Dict

enc

num_tokens
```

```

num_bpe_entities: int | None = None
padding = False
dummy_id
max_length_subword_tokens: int | None = None
train_set_target = None
target_dim: int | None = None
train_target_indices = None
ordered_bpe_entities = None
description_of_input = None
describe() → None
    Generate a description string of the dataset statistics.
property entities_str: List[str]
    Get list of all entity strings.
property relations_str: List[str]
    Get list of all relation strings.
exists(h: str, r: str, t: str) → bool
    Check if a triple exists in the training set.

```

Parameters

- **h** – Head entity string.
- **r** – Relation string.
- **t** – Tail entity string.

Returns

True if the triple exists, False otherwise.

```

__iter__() → Iterator[Tuple[str, str, str]]
    Iterate over training triples as string tuples.
__len__() → int
    Return number of triples in the raw training set.
func_triple_to_bpe_representation(triple: List[str])

```

dicee.knowledge_graph_embeddings

Classes

KGE

Knowledge Graph Embedding Class for interactive usage
of pre-trained models

Module Contents

```
class dicee.knowledge_graph_embeddings.KGE(path=None, url=None, construct_ensemble=False,
model_name=None)

Bases: dicee.abstracts.BaseInteractiveKGE, dicee.abstracts.
InteractiveQueryDecomposition, dicee.abstracts.BaseInteractiveTrainKGE

Knowledge Graph Embedding Class for interactive usage of pre-trained models

__str__()

to(device: str) → None

get_transductive_entity_embeddings(indices: torch.LongTensor | List[str], as_pytorch=False,
as_numpy=False, as_list=True) → torch.FloatTensor | numpy.ndarray | List[float]

create_vector_database(collection_name: str, distance: str, location: str = 'localhost',
port: int = 6333)

generate(h='', r='')

eval_lp_performance(dataset=List[Tuple[str, str, str]], filtered=True)

predict_missing_head_entity(relation: List[str] | str, tail_entity: List[str] | str, within=None,
batch_size=2, topk=1, return_indices=False) → Tuple

Given a relation and a tail entity, return top k ranked head entity.

argmax_{e in E} f(e,r,t), where r in R, t in E.
```

Parameter

relation: Union[List[str], str]
String representation of selected relations.
tail_entity: Union[List[str], str]
String representation of selected entities.
k: int
Highest ranked k entities.

Returns: Tuple

Highest K scores and entities

```
predict_missing_relations(head_entity: List[str] | str, tail_entity: List[str] | str, within=None,
batch_size=2, topk=1, return_indices=False) → Tuple

Given a head entity and a tail entity, return top k ranked relations.

argmax_{r in R} f(h,r,t), where h, t in E.
```

Parameter

head_entity: List[str]
String representation of selected entities.
tail_entity: List[str]
String representation of selected entities.

k: int

Highest ranked k entities.

Returns: Tuple

Highest K scores and entities

```
predict_missing_tail_entity(head_entity: List[str] | str, relation: List[str] | str,  
    within: List[str] = None, batch_size=2, topk=1, return_indices=False) → torch.FloatTensor
```

Given a head entity and a relation, return top k ranked entities

argmax_{e in E} f(h,r,e), where h in E and r in R.

Parameter

head_entity: List[str]

String representation of selected entities.

tail_entity: List[str]

String representation of selected entities.

Returns: Tuple

scores

```
predict (*, h: List[str] | str = None, r: List[str] | str = None, t: List[str] | str = None, within=None,  
    logits=True) → torch.FloatTensor
```

Parameters

- **logits**
- **h**
- **r**
- **t**
- **within**

```
predict_topk (*, h: str | List[str] = None, r: str | List[str] = None, t: str | List[str] = None, topk: int = 10,  
    within: List[str] = None, batch_size: int = 1024)
```

Predict missing item in a given triple.

Returns

- If you query a single (h, r, ?) or (?, r, t) or (h, ?, t), returns List[(item, score)]
- If you query a batch of B, returns List of B such lists.

```
triple_score (h: List[str] | str = None, r: List[str] | str = None, t: List[str] | str = None, logits=False)  
    → torch.FloatTensor
```

Predict triple score

Parameter

head_entity: List[str]

String representation of selected entities.

relation: List[str]
 String representation of selected relations.
 tail_entity: List[str]
 String representation of selected entities.
 logits: bool
 If logits is True, unnormalized score returned

Returns: Tuple

pytorch tensor of triple score

```

return_multi_hop_query_results (aggregated_query_for_all_entities, k: int, only_scores)

single_hop_query_answering (query: tuple, only_scores: bool = True, k: int = None)

answer_multi_hop_query (query_type: str = None, query: Tuple[str | Tuple[str, str]], Ellipsis] = None,
                           queries: List[Tuple[str | Tuple[str, str], Ellipsis]] = None, tnorm: str = 'prod',
                           neg_norm: str = 'standard', lambda_: float = 0.0, k: int = 10, only_scores=False)
                           → List[Tuple[str, torch.Tensor]]

# @TODO: Refactoring is needed # @TODO: Score computation for each query type should be done in a
static function

```

Find an answer set for EPFO queries including negation and disjunction

Parameter

query_type: str The type of the query, e.g., “2p”.
 query: Union[str, Tuple[str, Tuple[str, str]]] The query itself, either a string or a nested tuple.
 queries: List of Tuple[Union[str, Tuple[str, str]], ...]
 tnorm: str The t-norm operator.
 neg_norm: str The negation norm.
lambda_: float lambda parameter for sugeno and yager negation norms
 k: int The top-k substitutions for intermediate variables.

returns

- *List[Tuple[str, torch.Tensor]]*
- *Entities and corresponding scores sorted in the descending order of scores*

```

find_missing_triples (confidence: float, entities: List[str] = None, relations: List[str] = None,
                       topk: int = 10, at_most: int = sys.maxsize) → Set

```

Find missing triples

Iterative over a set of entities E and a set of relation R :

orall e in E and orall r in R f(e,r,x)

Return (e,r,x)

otin G and f(e,r,x) > confidence

confidence: float
 A threshold for an output of a sigmoid function given a triple.
 topk: int
 Highest ranked k item to select triples with $f(e,r,x) > \text{confidence}$.
 at_most: int
 Stop after finding at_most missing triples
 $\{(e,r,x) \mid f(e,r,x) > \text{confidence} \text{ and } (e,r,x)$
 otin G
predict_literals (*entity*: *List[str]* | *str* = *None*, *attribute*: *List[str]* | *str* = *None*,
denormalize_preds: *bool* = *True*) → *numpy.ndarray*
 Predicts literal values for given entities and attributes.

Parameters

- **entity** (*Union[List[str], str]*) – Entity or list of entities to predict literals for.
- **attribute** (*Union[List[str], str]*) – Attribute or list of attributes to predict literals for.
- **denormalize_preds** (*bool*) – If True, denormalizes the predictions.

Returns

Predictions for the given entities and attributes.

Return type

numpy ndarray

dicee.models

Submodules

dicee.models.adopt

ADOPT Optimizer Implementation.

This module implements the ADOPT (Adaptive Optimization with Precise Tracking) algorithm, an advanced optimization method for training neural networks.

ADOPT Overview:

ADOPT is an adaptive learning rate optimization algorithm that combines the benefits of momentum-based methods with per-parameter learning rate adaptation. Unlike Adam, which applies momentum to raw gradients, ADOPT normalizes gradients first and then applies momentum, leading to more stable training dynamics.

Key Features: - Gradient normalization before momentum application - Adaptive per-parameter learning rates - Optional gradient clipping that grows with training steps - Support for decoupled weight decay (AdamW-style) - Multiple execution modes: single-tensor, multi-tensor (foreach), and fused (planned)

Algorithm Comparison:

Adam: $m = \beta_1 * m + (1 - \beta_1) * g, \theta = \theta - \alpha * m / \sqrt{v}$ ADOPT: $m = \beta_1 * m + (1 - \beta_1) * g / \sqrt{v}, \theta = \theta - \alpha * m$

The key difference is that ADOPT normalizes gradients before momentum, which provides better stability and can lead to improved convergence.

Classes:

- ADOPT: Main optimizer class (extends torch.optim.Optimizer)

Functions:

- adopt: Functional API for ADOPT algorithm computation
- _single_tensor_adopt: Single-tensor implementation (TorchScript compatible)
- _multi_tensor_adopt: Multi-tensor implementation using foreach operations

Performance:

- Single-tensor: Default, compatible with torch.jit.script
- Multi-tensor (foreach): 2-3x faster on GPU through vectorization
- Fused (planned): Would provide maximum performance via specialized kernels

Example:

```
>>> import torch
>>> from dicee.models.adopt import ADOPT
>>>
>>> model = torch.nn.Linear(10, 1)
>>> optimizer = ADOPT(model.parameters(), lr=0.001, weight_decay=0.01, decouple=True)
>>>
>>> # Training loop
>>> for epoch in range(num_epochs):
...     optimizer.zero_grad()
...     output = model(input)
...     loss = criterion(output, target)
...     loss.backward()
...     optimizer.step()
```

References:

Original implementation: <https://github.com/iShohei220/adopt>

Notes:

This implementation is based on the original ADOPT implementation and adapted to work with the PyTorch optimizer interface and the dicee framework.

Classes

ADOPT

ADOPT Optimizer.

Functions

<code>adopt(params, grads, exp_avgs, exp_avg_sqs, state_steps)</code>	Functional API that performs ADOPT algorithm computation.
---	---

Module Contents

```
class dicee.models.adopt.ADOPT (params: torch.optim.optimizer.ParamsT,
    lr: float | torch.Tensor = 0.001, betas: Tuple[float, float] = (0.9, 0.9999), eps: float = 1e-06,
    clip_lambda: Callable[[int], float] | None = lambda step: ..., weight_decay: float = 0.0,
    decouple: bool = False, *, foreach: bool | None = None, maximize: bool = False,
    capturable: bool = False, differentiable: bool = False, fused: bool | None = None)
```

Bases: `torch.optim.optimizer.Optimizer`

ADOPT Optimizer.

ADOPT is an adaptive learning rate optimization algorithm that combines momentum-based updates with adaptive per-parameter learning rates. It uses exponential moving averages of gradients and squared gradients, with gradient clipping for stability.

The algorithm performs the following key operations: 1. Normalizes gradients by the square root of the second moment estimate 2. Applies optional gradient clipping based on the training step 3. Updates parameters using momentum-smoothed normalized gradients 4. Supports decoupled weight decay (AdamW-style) or L2 regularization

Mathematical formulation:

$$m_t = \beta_1 * m_{t-1} + (1 - \beta_1) * \text{clip}(g_t / \sqrt{v_t})$$

where:

- θ_t : parameter at step t
- g_t : gradient at step t
- m_t : first moment estimate (momentum)
- v_t : second moment estimate (variance)
- α : learning rate
- β_1, β_2 : exponential decay rates
- `clip()`: optional gradient clipping function

Reference:

Original implementation: <https://github.com/iShohei220/adopt>

Parameters

- **params** (`ParamsT`) – Iterable of parameters to optimize or dicts defining parameter groups.
- **lr** (`float or Tensor, optional`) – Learning rate. Can be a float or 1-element Tensor. Default: 1e-3
- **betas** (`Tuple[float, float], optional`) – Coefficients (β_1, β_2) for computing running averages of gradient and its square. β_1 controls momentum, β_2 controls variance. Default: (0.9, 0.9999)

- **eps** (*float, optional*) – Term added to denominator to improve numerical stability. Default: 1e-6
- **clip_lambda** (*Callable[[int], float], optional*) – Function that takes the step number and returns the gradient clipping threshold. Common choices: - lambda step: $\text{step}^{**0.25}$ (default, gradually increases clipping threshold) - lambda step: 1.0 (constant clipping) - None (no clipping) Default: lambda step: $\text{step}^{**0.25}$
- **weight_decay** (*float, optional*) – Weight decay coefficient (L2 penalty). Default: 0.0
- **decouple** (*bool, optional*) – If True, uses decoupled weight decay (AdamW-style), applying weight decay directly to parameters. If False, adds weight decay to gradients (L2 regularization). Default: False
- **foreach** (*bool, optional*) – If True, uses the faster foreach implementation for multi-tensor operations. Default: None (auto-select)
- **maximize** (*bool, optional*) – If True, maximizes parameters instead of minimizing. Useful for reinforcement learning. Default: False
- **capturable** (*bool, optional*) – If True, the optimizer is safe to capture in a CUDA graph. Requires learning rate as Tensor. Default: False
- **differentiable** (*bool, optional*) – If True, the optimization step can be differentiated. Useful for meta-learning. Default: False
- **fused** (*bool, optional*) – If True, uses fused kernel implementation (currently not supported). Default: None

Raises

- **ValueError** – If learning rate, epsilon, betas, or weight_decay are invalid.
- **RuntimeError** – If fused is enabled (not currently supported).
- **RuntimeError** – If lr is a Tensor with foreach=True and capturable=False.

Example

```
>>> # Basic usage
>>> optimizer = ADOPT(model.parameters(), lr=0.001)
>>> optimizer.zero_grad()
>>> loss.backward()
>>> optimizer.step()

>>> # With decoupled weight decay
>>> optimizer = ADOPT(model.parameters(), lr=0.001, weight_decay=0.01, ↴
    ↴decouple=True)

>>> # Custom gradient clipping
>>> optimizer = ADOPT(model.parameters(), clip_lambda=lambda step: max(1.0, ↴
    ↴step**0.5))
```

Note

- For most use cases, the default hyperparameters work well
- Consider using decouple=True for better generalization (similar to AdamW)

- The clip_lambda function helps stabilize training in early steps

`clip_lambda`

`__setstate__(state)`

Restore optimizer state from a checkpoint.

This method handles backward compatibility when loading optimizer state from older versions. It ensures all required fields are present with default values and properly converts step counters to tensors if needed.

Key responsibilities: 1. Set default values for newly added hyperparameters 2. Convert old-style scalar step counters to tensor format 3. Place step tensors on appropriate devices based on capturable/fused modes

Parameters

`state (dict)` – Optimizer state dictionary (typically from `torch.load()`).

Note

- This enables loading checkpoints saved with older ADOPT versions
- Step counters are converted to appropriate device/dtype for compatibility
- Capturable and fused modes require step tensors on parameter devices

`step(closure=None)`

Perform a single optimization step.

This method executes one iteration of the ADOPT optimization algorithm across all parameter groups. It orchestrates the following workflow:

1. Optionally evaluates a closure to recompute the loss (useful for algorithms like LBFGS or when loss needs multiple evaluations)
2. For each parameter group: - Collects parameters with gradients and their associated state - Extracts hyperparameters (betas, learning rate, etc.) - Calls the functional `adopt()` API to perform the actual update
3. Returns the loss value if a closure was provided

The functional API (`adopt()`) handles three execution modes: - Single-tensor: Updates one parameter at a time (default, JIT-compatible) - Multi-tensor (foreach): Batches operations for better performance - Fused: Uses fused CUDA kernels (not yet implemented)

Gradient scaling support: This method is compatible with automatic mixed precision (AMP) training. It can access `grad_scale` and `found_inf` attributes for gradient unscaling and inf/nan detection when used with `GradScaler`.

Parameters

`closure (Callable, optional)` – A callable that reevaluates the model and returns the loss. The closure should: - Enable gradients (`torch.enable_grad()`) - Compute forward pass - Compute loss - Compute backward pass - Return the loss value Example: `lambda: (loss := model(x), loss.backward(), loss)[-1]` Default: None

Returns

The loss value returned by the closure, or None if no closure was provided.

Return type
Optional[Tensor]

Example

```
>>> # Standard usage
>>> loss = criterion(model(input), target)
>>> loss.backward()
>>> optimizer.step()
```

```
>>> # With closure (e.g., for line search)
>>> def closure():
...     optimizer.zero_grad()
...     output = model(input)
...     loss = criterion(output, target)
...     loss.backward()
...     return loss
>>> loss = optimizer.step(closure)
```

Note

- Call zero_grad() before computing gradients for the next step
- CUDA graph capture is checked for safety when capturable=True
- The method is thread-safe for different parameter groups

```
dicee.models.adopt.adopt(params: List[torch.Tensor], grads: List[torch.Tensor],
    exp_avgs: List[torch.Tensor], exp_avg_sqs: List[torch.Tensor], state_steps: List[torch.Tensor],
    foreach: bool | None = None, capturable: bool = False, differentiable: bool = False,
    fused: bool | None = None, grad_scale: torch.Tensor | None = None,
    found_inf: torch.Tensor | None = None, has_complex: bool = False, *, beta1: float, beta2: float,
    lr: float | torch.Tensor, clip_lambda: Callable[[int], float] | None, weight_decay: float,
    decouple: bool, eps: float, maximize: bool)
```

Functional API that performs ADOPT algorithm computation.

This is the main functional interface for the ADOPT optimization algorithm. It dispatches to one of three implementations based on the execution mode:

1. **Single-tensor mode** (default): Updates parameters one at a time - Compatible with torch.jit.script - More flexible but slower - Used when foreach=False or automatically for small models
2. **Multi-tensor (foreach) mode**: Batches operations across tensors - 2-3x faster on GPU through vectorization - Groups tensors by device/dtype automatically - Used when foreach=True
3. **Fused mode**: Uses specialized fused kernels (not yet implemented) - Would provide maximum performance - Currently raises RuntimeError if enabled

Algorithm overview (ADOPT):

ADOPT adapts learning rates per-parameter while using momentum on normalized gradients. The key innovation is normalizing gradients before momentum, which provides more stable training than standard Adam.

Mathematical formulation:

```
# Normalize gradient by its historical variance normed_g_t = g_t / sqrt(v_t + ε)
```

```

# Optional gradient clipping for stability normed_g_t = clip(normed_g_t, threshold(t))
# Momentum on normalized gradients (key difference from Adam) m_t = β₁ * m_{t-1} + (1 - β₁) *
normed_g_t
# Parameter update θ_t = θ_{t-1} - α * m_t
# Update variance estimate v_t = β₂ * v_{t-1} + (1 - β₂) * g_t²

```

where:

- θ : parameters
- g : gradients
- m : first moment (momentum of normalized gradients)
- v : second moment (variance of raw gradients)
- α : learning rate
- β_1, β_2 : exponential decay rates
- ϵ : numerical stability constant
- `clip()`: gradient clipping function based on step

Automatic mode selection:

When `foreach` and `fused` are both `None` (default), the function automatically selects the best implementation based on:

- Parameter types and devices
- Whether differentiable mode is enabled
- Learning rate type (float vs Tensor)
- Capturable mode requirements

param params
Parameters to optimize.

type params
`List[Tensor]`

param grads
Gradients for each parameter.

type grads
`List[Tensor]`

param exp_avgs
First moment estimates (momentum).

type exp_avgs
`List[Tensor]`

param exp_avg_sqs
Second moment estimates (variance).

type exp_avg_sqs
`List[Tensor]`

param state_steps
Step counters (must be singleton tensors).

type state_steps
`List[Tensor]`

param foreach
Whether to use multi-tensor implementation. `None`: auto-select based on configuration (default).

```

type foreach
    Optional[bool]

param capturable
    If True, ensure CUDA graph capture safety.

type capturable
    bool

param differentiable
    If True, allow gradients through optimization step.

type differentiable
    bool

param fused
    If True, use fused kernels (not implemented).

type fused
    Optional[bool]

param grad_scale
    Gradient scaler for AMP training.

type grad_scale
    Optional[Tensor]

param found_inf
    Flag for inf/nan detection in AMP.

type found_inf
    Optional[Tensor]

param has_complex
    Whether any parameters are complex-valued.

type has_complex
    bool

param beta1
    Exponential decay rate for first moment (momentum). Typical range: 0.9-0.95.

type beta1
    float

param beta2
    Exponential decay rate for second moment (variance). Typical range: 0.999-0.9999 (higher than Adam).

type beta2
    float

param lr
    Learning rate. Can be a scalar Tensor for dynamic learning rate with capturable=True.

type lr
    Union[float, Tensor]

param clip_lambda
    Function that maps step number to gradient clipping threshold. None disables clipping.

type clip_lambda
    Optional[Callable[[int], float]]

```

```

param weight_decay
    Weight decay coefficient (L2 penalty).

type weight_decay
    float

param decouple
    If True, use decoupled weight decay (AdamW-style). Recommended for better generalization.

type decouple
    bool

param eps
    Small constant for numerical stability in normalization.

type eps
    float

param maximize
    If True, maximize objective instead of minimize.

type maximize
    bool

raises RuntimeError
    If torch.jit.script is used with foreach or fused.

raises RuntimeError
    If state_steps contains non-tensor elements.

raises RuntimeError
    If fused=True (not yet implemented).

raises RuntimeError
    If lr is Tensor with foreach=True and capturable=False.

```

Example

```

>>> # Typically called by ADOPT optimizer, not directly
>>> adopt(
...     params=[p1, p2],
...     grads=[g1, g2],
...     exp_avgs=[m1, m2],
...     exp_avg_sqs=[v1, v2],
...     state_steps=[step1, step2],
...     beta1=0.9,
...     beta2=0.9999,
...     lr=0.001,
...     clip_lambda=lambda s: s**0.25,
...     weight_decay=0.01,
...     decouple=True,
...     eps=1e-6,
...     maximize=False,
... )

```

 **Note**

- For distributed training, this API is compatible with torch/distributed/optim
- The foreach mode is generally preferred for GPU training
- Complex parameters are handled transparently by viewing as real
- First optimization step only initializes variance, doesn't update parameters

See also

- ADOPT class: High-level optimizer interface
- `_single_tensor_adopt`: Single-tensor implementation details
- `_multi_tensor_adopt`: Multi-tensor implementation details

dicee.models.base_model

Classes

<code>BaseKGELightning</code>	Base class for all neural network modules.
<code>BaseKGE</code>	Base class for all neural network modules.
<code>IdentityClass</code>	Base class for all neural network modules.

Module Contents

`class dicee.models.base_model.BaseKGELightning(*args, **kwargs)`

Bases: `lightning.LightningModule`

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```
import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))
```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training (bool)` – Boolean represents whether this module is in training or evaluation mode.

`training_step_outputs = []`

`mem_of_model() → Dict`

Size of model in MB and number of params

`training_step(batch, batch_idx=None)`

Here you compute and return the training loss and some additional metrics for e.g. the progress bar or logger.

Parameters

- `batch` – The output of your data iterable, normally a `DataLoader`.
- `batch_idx` – The index of this batch.
- `dataloader_idx` – The index of the dataloader that produced this batch. (only if multiple dataloaders used)

Returns

- `Tensor` - The loss tensor
- `dict` - A dictionary which can include any keys, but must include the key '`'loss'`' in the case of automatic optimization.
- `None` - In automatic optimization, this will skip to the next batch (but is not supported for multi-GPU, TPU, or DeepSpeed). For manual optimization, this has no special meaning, as returning the loss is not required.

In this step you'd normally do the forward pass and calculate the loss for a batch. You can also do fancier things like multiple forward passes or something model specific.

Example:

```
def training_step(self, batch, batch_idx):  
    x, y, z = batch  
    out = self.encoder(x)  
    loss = self.loss(out, x)  
    return loss
```

To use multiple optimizers, you can switch to ‘manual optimization’ and control their stepping:

```
def __init__(self):  
    super().__init__()  
    self.automatic_optimization = False  
  
    # Multiple optimizers (e.g.: GANs)  
    def training_step(self, batch, batch_idx):  
        opt1, opt2 = self.optimizers()
```

(continues on next page)

```
# do training_step with encoder
...
opt1.step()
# do training_step with decoder
...
opt2.step()
```

Note

When `accumulate_grad_batches > 1`, the loss returned here will be automatically normalized by `accumulate_grad_batches` internally.

loss_function (`yhat_batch: torch.FloatTensor`, `y_batch: torch.FloatTensor`)

Parameters

- `yhat_batch`
- `y_batch`

on_train_epoch_end (*args, **kwargs)

Called in the training loop at the very end of the epoch.

To access all batch outputs at the end of the epoch, you can cache step outputs as an attribute of the `LightningModule` and access them in this hook:

```
class MyLightningModule(L.LightningModule):
    def __init__(self):
        super().__init__()
        self.training_step_outputs = []

    def training_step(self):
        loss = ...
        self.training_step_outputs.append(loss)
        return loss

    def on_train_epoch_end(self):
        # do something with all training_step outputs, for example:
        epoch_mean = torch.stack(self.training_step_outputs).mean()
        self.log("training_epoch_mean", epoch_mean)
        # free up the memory
        self.training_step_outputs.clear()
```

test_epoch_end (`outputs: List[Any]`)

test_dataloader () → None

An iterable or collection of iterables specifying test samples.

For more information about multiple dataloaders, see this section.

For data processing use the following pattern:

- download in `prepare_data()`
- process and split in `setup()`

However, the above are only necessary for distributed processing.

⚠ Warning

do not assign state in `prepare_data`

- `test()`
- `prepare_data()`
- `setup()`

ℹ Note

Lightning tries to add the correct sampler for distributed and arbitrary hardware. There is no need to set it yourself.

ℹ Note

If you don't need a test dataset and a `test_step()`, you don't need to implement this method.

`val_dataloader() → None`

An iterable or collection of iterables specifying validation samples.

For more information about multiple dataloaders, see this section.

The dataloader you return will not be reloaded unless you set `:param-ref:`~lightning.pytorch.trainer.Trainer.reload_dataloaders_every_n_epochs`` to a positive integer.

It's recommended that all data downloads and preparation happen in `prepare_data()`.

- `fit()`
- `validate()`
- `prepare_data()`
- `setup()`

ℹ Note

Lightning tries to add the correct sampler for distributed and arbitrary hardware. There is no need to set it yourself.

ℹ Note

If you don't need a validation dataset and a `validation_step()`, you don't need to implement this method.

`predict_dataloader()` → None

An iterable or collection of iterables specifying prediction samples.

For more information about multiple dataloaders, see this section.

It's recommended that all data downloads and preparation happen in `prepare_data()`.

- `predict()`
- `prepare_data()`
- `setup()`

Note

Lightning tries to add the correct sampler for distributed and arbitrary hardware. There is no need to set it yourself.

Returns

A `torch.utils.data.DataLoader` or a sequence of them specifying prediction samples.

`train_dataloader()` → None

An iterable or collection of iterables specifying training samples.

For more information about multiple dataloaders, see this section.

The dataloader you return will not be reloaded unless you set `:param-ref:`~lightning.pytorch.trainer.Trainer.reload_dataloaders_every_n_epochs`` to a positive integer.

For data processing use the following pattern:

- download in `prepare_data()`
- process and split in `setup()`

However, the above are only necessary for distributed processing.

Warning

do not assign state in `prepare_data`

- `fit()`
- `prepare_data()`
- `setup()`

Note

Lightning tries to add the correct sampler for distributed and arbitrary hardware. There is no need to set it yourself.

`configure_optimizers(parameters=None)`

Choose what optimizers and learning-rate schedulers to use in your optimization. Normally you'd need one. But in the case of GANs or similar you might have multiple. Optimization with multiple optimizers only works in the manual optimization mode.

Returns

Any of these 6 options.

- **Single optimizer.**
- **List or Tuple** of optimizers.
- **Two lists** - The first list has multiple optimizers, and the second has multiple LR schedulers (or multiple `lr_scheduler_config`).
- **Dictionary**, with an "optimizer" key, and (optionally) a "lr_scheduler" key whose value is a single LR scheduler or `lr_scheduler_config`.
- **None** - Fit will run without any optimizer.

The `lr_scheduler_config` is a dictionary which contains the scheduler and its associated configuration. The default configuration is shown below.

```
lr_scheduler_config = {
    # REQUIRED: The scheduler instance
    "scheduler": lr_scheduler,
    # The unit of the scheduler's step size, could also be 'step'.
    # 'epoch' updates the scheduler on epoch end whereas 'step'
    # updates it after a optimizer update.
    "interval": "epoch",
    # How many epochs/steps should pass between calls to
    # `scheduler.step()`. 1 corresponds to updating the learning
    # rate after every epoch/step.
    "frequency": 1,
    # Metric to monitor for schedulers like `ReduceLROnPlateau`
    "monitor": "val_loss",
    # If set to `True`, will enforce that the value specified 'monitor'
    # is available when the scheduler is updated, thus stopping
    # training if not found. If set to `False`, it will only produce a warning
    "strict": True,
    # If using the `LearningRateMonitor` callback to monitor the
    # learning rate progress, this keyword can be used to specify
    # a custom logged name
    "name": None,
}
```

When there are schedulers in which the `.step()` method is conditioned on a value, such as the `torch.optim.lr_scheduler.ReduceLROnPlateau` scheduler, Lightning requires that the `lr_scheduler_config` contains the keyword "monitor" set to the metric name that the scheduler should be conditioned on.

Metrics can be made available to monitor by simply logging it using `self.log('metric_to_track', metric_val)` in your `LightningModule`.

Note

Some things to know:

- Lightning calls `.backward()` and `.step()` automatically in case of automatic optimization.
- If a learning rate scheduler is specified in `configure_optimizers()` with key "interval" (default "epoch") in the scheduler configuration, Lightning will call the scheduler's `.step()` method automatically in case of automatic optimization.
- If you use 16-bit precision (`precision=16`), Lightning will automatically handle the optimizer.
- If you use `torch.optim.LBFGS`, Lightning handles the closure function automatically for you.
- If you use multiple optimizers, you will have to switch to 'manual optimization' mode and step them yourself.
- If you need to control how often the optimizer steps, override the `optimizer_step()` hook.

```
class dicee.models.base_model.BaseKGE(args: dict)
```

Bases: `BaseKGELightning`

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```
import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))
```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training` (`bool`) – Boolean represents whether this module is in training or evaluation mode.

`args`

```

embedding_dim = None
num_entities = None
num_relations = None
num_tokens = None
learning_rate = None
apply_unit_norm = None
input_dropout_rate = None
hidden_dropout_rate = None
optimizer_name = None
feature_map_dropout_rate = None
kernel_size = None
num_of_output_channels = None
weight_decay = None
loss
selected_optimizer = None
normalizer_class = None
normalize_head_entity_embeddings
normalize_relation_embeddings
normalize_tail_entity_embeddings
hidden_normalizer
param_init
input_dp_ent_real
input_dp_rel_real
hidden_dropout
loss_history = []
byte_pair_encoding
max_length_subword_tokens
block_size
forward_byte_pair_encoded_k_vs_all(x: torch.LongTensor)

```

Parameters

x ($B \times 2 \times T$)

```

forward_byte_pair_encoded_triple(x: Tuple[torch.LongTensor, torch.LongTensor])
    byte pair encoded neural link predictors

    Parameters
    -----
    init_params_with_sanity_checking()

    forward(x: torch.LongTensor | Tuple[torch.LongTensor, torch.LongTensor],
            y_idx: torch.LongTensor = None)

    Parameters
    *
        • x
        • y_idx
        • ordered_bpe_entities

    forward_triples(x: torch.LongTensor) → torch.Tensor

    Parameters
    x

    forward_k_vs_all(*args, **kwargs)

    forward_k_vs_sample(*args, **kwargs)

    get_triple_representation(idx_hrt)

    get_head_relation_representation(indexed_triple)

    get_sentence_representation(x: torch.LongTensor)

    Parameters
    *
        • (b (x shape)
        • 3
        • t)

    get_bpe_head_and_relation_representation(x: torch.LongTensor)
        → Tuple[torch.FloatTensor, torch.FloatTensor]

    Parameters
    x (B x 2 x T)

    get_embeddings() → Tuple[numpy.ndarray, numpy.ndarray]

class dicee.models.base_model.IdentityClass(args=None)
    Bases: torch.nn.Module

    Base class for all neural network modules.

    Your models should also subclass this class.

    Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```

```

import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))

```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training` (bool) – Boolean represents whether this module is in training or evaluation mode.

```

args = None

__call__(x)

static forward(x)

```

dicee.models.clifford

Classes

<code>Keci</code>	Base class for all neural network modules.
<code>CKeci</code>	Without learning dimension scaling
<code>DeCaL</code>	Base class for all neural network modules.

Module Contents

```

class dicee.models.clifford.Keci(args)
Bases: dicee.models.base_model.BaseKGE
Base class for all neural network modules.
Your models should also subclass this class.
Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-
modules as regular attributes:

```

```

import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))

```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

i Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training (bool)` – Boolean represents whether this module is in training or evaluation mode.

```

name = 'Keci'

p
q
r

requires_grad_for_interactions = True

compute_sigma_pp(hp, rp)
    Compute sigma_{pp} = sum_{i=1}^{p-1} sum_{k=i+1}^p (h_i r_k - h_k r_i) e_i e_k
    sigma_{pp} captures the interactions between along p bases For instance, let p e_1, e_2, e_3, we compute
    interactions between e_1 e_2, e_1 e_3 , and e_2 e_3 This can be implemented with a nested two for loops
    results = [] for i in range(p - 1):
        for k in range(i + 1, p):
            results.append(hp[:, :, i] * rp[:, :, k] - hp[:, :, k] * rp[:, :, i])
    sigma_pp = torch.stack(results, dim=2) assert sigma_pp.shape == (b, r, int((p * (p - 1)) / 2))

```

Yet, this computation would be quite inefficient. Instead, we compute interactions along all p, e.g., e1e1, e1e2, e1e3,

e2e1, e2e2, e2e3, e3e1, e3e2, e3e3

Then select the triangular matrix without diagonals: e1e2, e1e3, e2e3.

```

compute_sigma_qq(hq, rq)
    Compute sigma_{qq} = sum_{j=1}^{p+q-1} sum_{k=j+1}^{p+q} (h_j r_k - h_k r_j) e_j e_k sigma_{q}
    captures the interactions between along q bases For instance, let q e_1, e_2, e_3, we compute interactions
    between e_1 e_2, e_1 e_3 , and e_2 e_3 This can be implemented with a nested two for loops
        results = [] for j in range(q - 1):
            for k in range(j + 1, q):
                results.append(hq[:, :, j] * rq[:, :, k] - hq[:, :, k] * rq[:, :, j])
        sigma_qq = torch.stack(results, dim=2) assert sigma_qq.shape == (b, r, int((q * (q - 1)) / 2))

    Yet, this computation would be quite inefficient. Instead, we compute interactions along all p, e.g., e1e1,
    e1e2, e1e3,
        e2e1, e2e2, e2e3, e3e1, e3e2, e3e3
    Then select the triangular matrix without diagonals: e1e2, e1e3, e2e3.

compute_sigma_pq(*hp, hq, rp, rq)
    sum_{i=1}^p sum_{j=p+1}^{p+q} (h_i r_j - h_j r_i) e_i e_j
    results = [] sigma_pq = torch.zeros(b, r, p, q) for i in range(p):
        for j in range(q):
            sigma_pq[:, :, i, j] = hp[:, :, i] * rq[:, :, j] - hq[:, :, j] * rp[:, :, i]
        print(sigma_pq.shape)

apply_coefficients(hp, hq, rp, rq)
    Multiplying a base vector with its scalar coefficient

clifford_multiplication(h0, hp, hq, r0, rp, rq)
    Compute our CL multiplication

    h = h_0 + sum_{i=1}^p h_i e_i + sum_{j=p+1}^{p+q} h_j e_j r = r_0 + sum_{i=1}^p r_i e_i +
    sum_{j=p+1}^{p+q} r_j e_j

    ei ^2 = +1 for i <= p ej ^2 = -1 for p < j <= p+q ei ej = -eje1 for i
    eq j

    h r = sigma_0 + sigma_p + sigma_q + sigma_pp + sigma_qq + sigma_pq where
    (1) sigma_0 = h_0 r_0 + sum_{i=1}^p (h_0 r_i) e_i - sum_{j=p+1}^{p+q} (h_j r_j) e_j
    (2) sigma_p = sum_{i=1}^p (h_0 r_i + h_i r_0) e_i
    (3) sigma_q = sum_{j=p+1}^{p+q} (h_0 r_j + h_j r_0) e_j
    (4) sigma_pp = sum_{i=1}^{p-1} sum_{k=i+1}^p (h_i r_k - h_k r_i) e_i e_k
    (5) sigma_qq = sum_{j=1}^{p+q-1} sum_{k=j+1}^{p+q} (h_j r_k - h_k r_j) e_j e_k
    (6) sigma_pq = sum_{i=1}^p sum_{j=p+1}^{p+q} (h_i r_j - h_j r_i) e_i e_j

construct_cl_multivector(x: torch.FloatTensor, r: int, p: int, q: int)
    → tuple[torch.FloatTensor, torch.FloatTensor, torch.FloatTensor]
    Construct a batch of multivectors Cl_{p,q}(mathbb{R})^d

```

Parameter

x: torch.FloatTensor with (n,d) shape

returns

- **a0** (torch.FloatTensor with (n,r) shape)
- **ap** (torch.FloatTensor with (n,r,p) shape)
- **aq** (torch.FloatTensor with (n,r,q) shape)

forward_k_vs_with_explicit (x: torch.Tensor)

k_vs_all_score (bpe_head_ent_emb, bpe_rel_ent_emb, E)

forward_k_vs_all (x: torch.Tensor) → torch.FloatTensor

Kvsall training

- (1) Retrieve real-valued embedding vectors for heads and relations \mathbb{R}^d .
- (2) Construct head entity and relation embeddings according to $C_{p,q}(\mathbb{R}^d)$.
- (3) Perform Cl multiplication
- (4) Inner product of (3) and all entity embeddings

forward_k_vs_with_explicit and this funcitons are identical Parameter ——— x: torch.LongTensor with (n,2) shape :rtype: torch.FloatTensor with (n, |E|) shape

construct_batch_selected_cl_multivector (x: torch.FloatTensor, r: int, p: int, q: int)
→ tuple[torch.FloatTensor, torch.FloatTensor, torch.FloatTensor]

Construct a batch of batchs multivectors $C_{p,q}(\mathbb{R}^d)$

Parameter

x: torch.FloatTensor with (n,k, d) shape

returns

- **a0** (torch.FloatTensor with (n,k, m) shape)
- **ap** (torch.FloatTensor with (n,k, m, p) shape)
- **aq** (torch.FloatTensor with (n,k, m, q) shape)

forward_k_vs_sample (x: torch.LongTensor, target_entity_idx: torch.LongTensor) → torch.FloatTensor

Parameter

x: torch.LongTensor with (n,2) shape

target_entity_idx: torch.LongTensor with (n, k) shape k denotes the selected number of examples.

rtype

torch.FloatTensor with (n, k) shape

score (h, r, t)

forward_triples (x: torch.Tensor) → torch.FloatTensor

Parameter

x: torch.LongTensor with (n,3) shape

rtype

torch.FloatTensor with (n) shape

```
class dicee.models.clifford.CKeci(args)
```

Bases: *Keci*

Without learning dimension scaling

```
name = 'CKeci'
```

```
requires_grad_for_interactions = False
```

```
class dicee.models.clifford.DeCaL(args)
```

Bases: *dicee.models.base_model.BaseKGE*

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```
import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))
```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training` (`bool`) – Boolean represents whether this module is in training or evaluation mode.

```
name = 'DeCaL'
```

```
entity_embeddings
```

```
relation_embeddings
```

```


p



q



r



re



forward_triples (x: torch.Tensor) → torch.FloatTensor


```

Parameter

x: *torch.LongTensor* with (n,) shape

rtype

torch.FloatTensor with (n) shape

cl_pqr (*a*: *torch.tensor*) → *torch.tensor*

Input: tensor(batch_size, emb_dim) —> output: tensor with 1+p+q+r components with size (batch_size, emb_dim/(1+p+q+r)) each.

1) takes a tensor of size (batch_size, emb_dim), split it into 1 + p + q +r components, hence 1+p+q+r must be a divisor of the emb_dim. 2) Return a list of the 1+p+q+r components vectors, each are tensors of size (batch_size, emb_dim/(1+p+q+r))

compute_sigmas_single (*list_h_emb*, *list_r_emb*, *list_t_emb*)

here we compute all the sums with no others vectors interaction taken with the scalar product with t, that is,

$$s0 = h_0 r_0 t_0 s1 = \sum_{i=1}^p h_i r_i t_0 s2 = \sum_{j=p+1}^{p+q} h_j r_j t_0 s3 = \sum_{i=1}^q (h_0 r_i t_i + h_i r_0 t_i) s4 = \sum_{i=p+1}^{p+q} (h_0 r_i t_i + h_i r_0 t_i) s5 = \sum_{i=p+q+1}^{p+q+r} (h_0 r_i t_i + h_i r_0 t_i)$$

and return:

$$\sigma_0 t = \sigma_0 \cdot t_0 = s0 + s1 - s2s3, s4ands5$$

compute_sigmas_multivect (*list_h_emb*, *list_r_emb*)

Here we compute and return all the sums with vectors interaction for the same and different bases.

For same bases vectors interaction we have

$$\sigma_{pp} = \sum_{i=1}^{p-1} \sum_{i'=i+1}^p (h_i r_{i'} - h_{i'} r_i) \text{(modelsthe interactions between } e_i \text{ and } e'_{i'} \text{ for } 1 \leq i, i' \leq p\text{)} \sigma_{qq} = \sum_{j=p+1}^{p+q-1} \sum_{j'=j+1}^{p+q} (h_j r_{j'} - h_{j'} r_j)$$

For different base vector interactions, we have

$$\sigma_{pq} = \sum_{i=1}^p \sum_{j=p+1}^{p+q} (h_i r_j - h_j r_i) \text{(interactionsn between } e_i \text{ and } e_j \text{ for } 1 \leq i \leq p \text{ and } p+1 \leq j \leq p+q\text{)} \sigma_{pr} = \sum_{i=1}^p \sum_{j=p+1}^{p+q} (h_i r_j - h_j r_i) \text{(interactionsn between } e_i \text{ and } e_j \text{ for } 1 \leq i \leq p \text{ and } p+1 \leq j \leq p+q\text{)}$$

forward_k_vs_all (*x*: *torch.Tensor*) → *torch.FloatTensor*

Kvsall training

- (1) Retrieve real-valued embedding vectors for heads and relations
- (2) Construct head entity and relation embeddings according to $\text{Cl}_{\{p,q,r\}}(\mathbb{R}^d)$.

(3) Perform Cl multiplication

(4) Inner product of (3) and all entity embeddings

forward_k_vs_with_explicit and this funcitons are identical Parameter ——— x: torch.LongTensor with (n,) shape :rtype: torch.FloatTensor with (n, |E|) shape

apply_coefficients (h0, hp, hq, hk, r0, rp, rq, rk)

Multiplying a base vector with its scalar coefficient

construct_cl_multivector (x: torch.FloatTensor, re: int, p: int, q: int, r: int)

→ tuple[torch.FloatTensor, torch.FloatTensor, torch.FloatTensor]

Construct a batch of multivectors $\text{Cl}_{\{p,q,r\}}(\mathbb{R}^d)$

Parameter

x: torch.FloatTensor with (n,d) shape

returns

- **a0** (torch.FloatTensor)
- **ap** (torch.FloatTensor)
- **aq** (torch.FloatTensor)
- **ar** (torch.FloatTensor)

compute_sigma_pp (hp, rp)

Compute .. math:

$$\sigma_{pp} = \sum_{i=1}^{p-1} \sum_{i'=i+1}^p (x_i y_{i'} - x_{i'} y_i)$$

σ_{pp} captures the interactions between along p bases For instance, let p e_1, e_2, e_3, we compute interactions between e_1 e_2, e_1 e_3 , and e_2 e_3 This can be implemented with a nested two for loops

results = [] for i in range(p - 1):

for k in range(i + 1, p):

results.append(hp[:, :, i] * rp[:, :, k] - hp[:, :, k] * rp[:, :, i])

sigma_pp = torch.stack(results, dim=2) assert sigma_pp.shape == (b, r, int((p * (p - 1)) / 2))

Yet, this computation would be quite inefficient. Instead, we compute interactions along all p, e.g., e1e1, e1e2, e1e3,

e2e1, e2e2, e2e3, e3e1, e3e2, e3e3

Then select the triangular matrix without diagonals: e1e2, e1e3, e2e3.

compute_sigma_qq (hq, rq)

Compute

$$\sigma_{q,q}^* = \sum_{j=p+1}^{p+q-1} \sum_{j'=j+1}^{p+q} (x_j y_{j'} - x_{j'} y_j) \quad \text{Eq.16}$$

σ_{qq} captures the interactions between along q bases For instance, let q e_1, e_2, e_3, we compute interactions between e_1 e_2, e_1 e_3 , and e_2 e_3 This can be implemented with a nested two for loops

results = [] for j in range(q - 1):

for k in range(j + 1, q):

results.append(hq[:, :, j] * rq[:, :, k] - hq[:, :, k] * rq[:, :, j])

```
sigma_qq = torch.stack(results, dim=2) assert sigma_qq.shape == (b, r, int((q * (q - 1)) / 2))
```

Yet, this computation would be quite inefficient. Instead, we compute interactions along all p, e.g., e1e1, e1e2, e1e3,

```
e2e1, e2e2, e2e3, e3e1, e3e2, e3e3
```

Then select the triangular matrix without diagonals: e1e2, e1e3, e2e3.

```
compute_sigma_rr (hk, rk)
```

$$\sigma_{r,r}^* = \sum_{k=p+q+1}^{p+q+r-1} \sum_{k'=k+1}^p (x_k y_{k'} - x_{k'} y_k)$$

```
compute_sigma_pq (*, hp, hq, rp, rq)
```

Compute

$$\sum_{i=1}^p \sum_{j=p+1}^{p+q} (h_i r_j - h_j r_i) e_i e_j$$

```
results = [] sigma_pq = torch.zeros(b, r, p, q) for i in range(p):
```

```
for j in range(q):
```

```
    sigma_pq[:, :, i, j] = hp[:, :, i] * rq[:, :, j] - hq[:, :, j] * rp[:, :, i]
```

```
print(sigma_pq.shape)
```

```
compute_sigma_pr (*, hp, hk, rp, rk)
```

Compute

$$\sum_{i=1}^p \sum_{j=p+1}^{p+q} (h_i r_j - h_j r_i) e_i e_j$$

```
results = [] sigma_pq = torch.zeros(b, r, p, q) for i in range(p):
```

```
for j in range(q):
```

```
    sigma_pq[:, :, i, j] = hp[:, :, i] * rq[:, :, j] - hq[:, :, j] * rp[:, :, i]
```

```
print(sigma_pq.shape)
```

```
compute_sigma_qr (*, hq, hk, rq, rk)
```

$$\sum_{i=1}^p \sum_{j=p+1}^{p+q} (h_i r_j - h_j r_i) e_i e_j$$

```
results = [] sigma_pq = torch.zeros(b, r, p, q) for i in range(p):
```

```
for j in range(q):
```

```
    sigma_pq[:, :, i, j] = hp[:, :, i] * rq[:, :, j] - hq[:, :, j] * rp[:, :, i]
```

```
print(sigma_pq.shape)
```

dicee.models.complex

Classes

<code>ConEx</code>	Convolutional ComplEx Knowledge Graph Embeddings
<code>AConEx</code>	Additive Convolutional ComplEx Knowledge Graph Embeddings
<code>ComplEx</code>	Base class for all neural network modules.

Module Contents

`class dicee.models.complex.ConEx(args)`

Bases: `dicee.models.base_model.BaseKGE`

Convolutional ComplEx Knowledge Graph Embeddings

`name = 'ConEx'`

`conv2d`

`fc_num_input`

`fc1`

`norm_fc1`

`bn_conv2d`

`feature_map_dropout`

`residual_convolution(C_1: Tuple[torch.Tensor, torch.Tensor], C_2: Tuple[torch.Tensor, torch.Tensor]) → torch.FloatTensor`

Compute residual score of two complex-valued embeddings. :param C_1: a tuple of two pytorch tensors that corresponds complex-valued embeddings :param C_2: a tuple of two pytorch tensors that corresponds complex-valued embeddings :return:

`forward_k_vs_all(x: torch.Tensor) → torch.FloatTensor`

`forward_triples(x: torch.Tensor) → torch.FloatTensor`

Parameters

`x`

`forward_k_vs_sample(x: torch.Tensor, target_entity_idx: torch.Tensor)`

`class dicee.models.complex.AConEx(args)`

Bases: `dicee.models.base_model.BaseKGE`

Additive Convolutional ComplEx Knowledge Graph Embeddings

`name = 'AConEx'`

`conv2d`

`fc_num_input`

`fc1`

`norm_fc1`

`bn_conv2d`

```

feature_map_dropout

residual_convolution(C_1: Tuple[torch.Tensor, torch.Tensor],
    C_2: Tuple[torch.Tensor, torch.Tensor]) → torch.FloatTensor
    Compute residual score of two complex-valued embeddings. :param C_1: a tuple of two pytorch tensors that corresponds complex-valued embeddings :param C_2: a tuple of two pytorch tensors that corresponds complex-valued embeddings :return:

forward_k_vs_all(x: torch.Tensor) → torch.FloatTensor
forward_triples(x: torch.Tensor) → torch.FloatTensor

Parameters
    x

forward_k_vs_sample(x: torch.Tensor, target_entity_idx: torch.Tensor)

class dicee.models.complex.ComplEx(args)
Bases: dicee.models.base_model.BaseKGE
Base class for all neural network modules.
Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```

```

import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))

```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training` (bool) – Boolean represents whether this module is in training or evaluation mode.

```

name = 'ComplEx'

static score(head_ent_emb: torch.FloatTensor, rel_ent_emb: torch.FloatTensor,
    tail_ent_emb: torch.FloatTensor)

```

```
static k_vs_all_score(emb_h: torch.FloatTensor, emb_r: torch.FloatTensor,  
emb_E: torch.FloatTensor)
```

Parameters

- **emb_h**
- **emb_r**
- **emb_E**

```
forward_k_vs_all(x: torch.LongTensor) → torch.FloatTensor
```

```
forward_k_vs_sample(x: torch.LongTensor, target_entity_idx: torch.LongTensor)
```

dicee.models.dualE

Classes

Duale

Dual Quaternion Knowledge Graph Embeddings
(<https://ojs.aaai.org/index.php/AAAI/article/download/16850/16657>)

Module Contents

```
class dicee.models.dualE(args)  
Bases: dicee.models.base_model.BaseKGE  
Dual Quaternion Knowledge Graph Embeddings (https://ojs.aaai.org/index.php/AAAI/article/download/16850/16657)  
name = 'DualE'  
entity_embeddings  
relation_embeddings  
num_ent = None  
kvsall_score(e_1_h, e_2_h, e_3_h, e_4_h, e_5_h, e_6_h, e_7_h, e_8_h, e_1_t, e_2_t, e_3_t, e_4_t,  
e_5_t, e_6_t, e_7_t, e_8_t, r_1, r_2, r_3, r_4, r_5, r_6, r_7, r_8) → torch.tensor  
KvsAll scoring function
```

Input

x: torch.LongTensor with (n,) shape

Output

torch.FloatTensor with (n) shape

```
forward_triples(idx_triple: torch.tensor) → torch.tensor
```

Negative Sampling forward pass:

Input

x: torch.LongTensor with (n,) shape

Output

torch.FloatTensor with (n) shape

forward_k_vs_all (x)

KvsAll forward pass

Input

x: torch.LongTensor with (n,) shape

Output

torch.FloatTensor with (n) shape

T (x: *torch.tensor*) → *torch.tensor*

Transpose function

Input: Tensor with shape (nxm) Output: Tensor with shape (mxn)

dicee.models.ensemble

Classes

EnsembleKGE

Module Contents

```
class dicee.models.ensemble.EnsembleKGE (models: list = None, seed_model=None,
                                             pretrained_models: List = None)

    name
    train_mode = True
    args
    named_children()
    property example_input_array
    parameters()
    modules()
    __iter__()
    __len__()
    eval()
    to(device)
```

```

state_dict ()
    Return the state dict of the ensemble.

load_state_dict (state_dict, strict=True)
    Load the state dict into the ensemble.

mem_of_model ()

__call__ (x_batch)

step ()

get_embeddings ()

__str__ ()

```

dicee.models.function_space

Classes

<i>FMult</i>	Learning Knowledge Neural Graphs
<i>GFMult</i>	Learning Knowledge Neural Graphs
<i>FMult2</i>	Learning Knowledge Neural Graphs
<i>LFMult1</i>	Embedding with trigonometric functions. We represent all entities and relations in the complex number space as:
<i>LFMult</i>	Embedding with polynomial functions. We represent all entities and relations in the polynomial space as:

Module Contents

```

class dicee.models.function_space.FMult (args)
    Bases: dicee.models.base_model.BaseKGE

    Learning Knowledge Neural Graphs

    name = 'FMult'

    entity_embeddings

    relation_embeddings

    k

    num_sample = 50

    gamma

    roots

    weights

    compute_func (weights: torch.FloatTensor, x) → torch.FloatTensor

    chain_func (weights, x: torch.FloatTensor)

```

```

forward_triples (idx_triple: torch.Tensor) → torch.Tensor

    Parameters
        x

class dicee.models.function_space.GFMult (args)
    Bases: dicee.models.base_model.BaseKGE
    Learning Knowledge Neural Graphs
    name = 'GFMult'
    entity_embeddings
    relation_embeddings
    k
    num_sample = 250
    roots
    weights
    compute_func (weights: torch.FloatTensor, x) → torch.FloatTensor
    chain_func (weights, x: torch.FloatTensor)
    forward_triples (idx_triple: torch.Tensor) → torch.Tensor

    Parameters
        x

class dicee.models.function_space.FMult2 (args)
    Bases: dicee.models.base_model.BaseKGE
    Learning Knowledge Neural Graphs
    name = 'FMult2'
    n_layers = 3
    k
    n = 50
    score_func = 'compositional'
    discrete_points
    entity_embeddings
    relation_embeddings
    build_func (Vec)
    build_chain_funcs (list_Vec)
    compute_func (W, b, x) → torch.FloatTensor
    function (list_W, list_b)

```

```

trapezoid(list_W, list_b)

forward_triples(idx_triple: torch.Tensor) → torch.Tensor

    Parameters
        x

class dicee.models.function_space.LFMult1(args)
    Bases: dicee.models.base_model.BaseKGE

    Embedding with trigonometric functions. We represent all entities and relations in the complex number space as:  $f(x) = \sum_{k=0}^{\lfloor d/2 \rfloor} w_k e^{ikx}$ . and use the three different scoring function as in the paper to evaluate the score

    name = 'LFMult1'

    entity_embeddings

    relation_embeddings

    forward_triples(idx_triple)

    Parameters
        x

        tri_score(h, r, t)

        vtp_score(h, r, t)

class dicee.models.function_space.LFMult(args)
    Bases: dicee.models.base_model.BaseKGE

    Embedding with polynomial functions. We represent all entities and relations in the polynomial space as:  $f(x) = \sum_{i=0}^{d-1} a_i x^{i \% d}$  and use the three different scoring function as in the paper to evaluate the score. We also consider combining with Neural Networks.

    name = 'LFMult'

    entity_embeddings

    relation_embeddings

    degree

    m

    x_values

    forward_triples(idx_triple)

    Parameters
        x

        construct_multi_coeff(x)

        poly_NN(x, coefh, coefr, coeft)
            Constructing a 2 layers NN to represent the embeddings.  $h = \sigma(w_h^T x + b_h)$ ,  $r = \sigma(w_r^T x + b_r)$ ,  $t = \sigma(w_t^T x + b_t)$ 

        linear(x, w, b)

```

scalar_batch_NN(*a, b, c*)
 element wise multiplication between *a,b* and *c*: Inputs : *a, b, c* =====> torch.tensor of size batch_size x m x d Output : a tensor of size batch_size x d

tri_score(*coeff_h, coeff_r, coeff_t*)

this part implement the trilinear scoring techniques:

$\text{score}(h, r, t) = \int_{\{0\}}^{\{1\}} h(x)r(x)t(x) dx = \sum_{i,j,k=0}^{d-1} \frac{a_i * b_j * c_k}{(1+(i+j+k)\%d)}$

1. generate the range for *i,j* and *k* from [0 d-1]
2. perform $\frac{a_i * b_j * c_k}{(1+(i+j+k)\%d)}$ in parallel for every batch
3. take the sum over each batch

vtp_score(*h, r, t*)

this part implement the vector triple product scoring techniques:

$\text{score}(h, r, t) = \int_{\{0\}}^{\{1\}} h(x)r(x)t(x) dx = \sum_{i,j,k=0}^{d-1} \frac{a_i * c_j * b_k - b_i * c_j * a_k}{((1+i+j)\%d)(1+k)}$

1. generate the range for *i,j* and *k* from [0 d-1]
2. Compute the first and second terms of the sum
3. Multiply with then denominator and take the sum
4. take the sum over each batch

comp_func(*h, r, t*)

this part implement the function composition scoring techniques: i.e. $\text{score} = \langle h, r, t \rangle$

polynomial(*coeff, x, degree*)

This function takes a matrix tensor of coefficients (*coeff*), a tensor vector of points *x* and range of integer [0,1,...d] and return a vector tensor (*coeff[0][0] + coeff[0][1]x + ... + coeff[0][d]x^d*,

coeff[1][0] + coeff[1][1]x +...+ coeff[1][d]x^d)

pop(*coeff, x, degree*)

This function allow us to evaluate the composition of two polynomes without for loops :) it takes a matrix tensor of coefficients (*coeff*), a matrix tensor of points *x* and range of integer [0,1,...d]

and return a tensor (coeff[0][0] + coeff[0][1]x +....+ coeff[0][d]x^d,

coeff[1][0] + coeff[1][1]x +...+ coeff[1][d]x^d)

dicee.models.literal

Classes

LiteralEmbeddings

A model for learning and predicting numerical literals using pre-trained KGE.

Module Contents

```
class dicee.models.literal.LiteralEmbeddings(num_of_data_properties: int, embedding_dims: int,
entity_embeddings: torch.tensor, dropout: float = 0.3, gate_residual=True,
freeze_entity_embeddings=True)
```

Bases: `torch.nn.Module`

A model for learning and predicting numerical literals using pre-trained KGE.

num_of_data_properties

Number of data properties (attributes).

Type

`int`

embedding_dims

Dimension of the embeddings.

Type

`int`

entity_embeddings

Pre-trained entity embeddings.

Type

`torch.tensor`

dropout

Dropout rate for regularization.

Type

`float`

gate_residual

Whether to use gated residual connections.

Type

`bool`

freeze_entity_embeddings

Whether to freeze the entity embeddings during training.

Type

`bool`

embedding_dim

num_of_data_properties

hidden_dim

gate_residual = True

freeze_entity_embeddings = True

entity_embeddings

data_property_embeddings

fc

fc_out

dropout

```
gated_residual_proj
layer_norm
forward(entity_idx, attr_idx)
```

Parameters

- **entity_idx** (*Tensor*) – Entity indices (batch).
- **attr_idx** (*Tensor*) – Attribute (Data property) indices (batch).

Returns

scalar predictions.

Return type

Tensor

property device

dicee.models.octonion

Classes

<i>OMult</i>	Base class for all neural network modules.
<i>Convo</i>	Base class for all neural network modules.
<i>AConvo</i>	Additive Convolutional Octonion Knowledge Graph Embeddings

Functions

```
octonion_mul(* , O_1, O_2)
octonion_mul_norm(* , O_1, O_2)
```

Module Contents

```
dicee.models.octonion.octonion_mul(* , O_1, O_2)
dicee.models.octonion.octonion_mul_norm(* , O_1, O_2)
```

class dicee.models.octonion.**OMult** (*args*)

Bases: *dicee.models.base_model.BaseKGE*

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```
import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
```

(continues on next page)

```

def __init__(self) -> None:
    super().__init__()
    self.conv1 = nn.Conv2d(1, 20, 5)
    self.conv2 = nn.Conv2d(20, 20, 5)

def forward(self, x):
    x = F.relu(self.conv1(x))
    return F.relu(self.conv2(x))

```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training (bool)` – Boolean represents whether this module is in training or evaluation mode.

```

name = 'OMult'

static octonion_normalizer(emb_rel_e0, emb_rel_e1, emb_rel_e2, emb_rel_e3, emb_rel_e4,
                           emb_rel_e5, emb_rel_e6, emb_rel_e7)

score(head_ent_emb: torch.FloatTensor, rel_ent_emb: torch.FloatTensor,
      tail_ent_emb: torch.FloatTensor)

k_vs_all_score(bpe_head_ent_emb, bpe_rel_ent_emb, E)

forward_k_vs_all(x)

```

Completed. Given a head entity and a relation (h,r), we compute scores for all possible triples,i.e., [score(h,r,x)|x in Entities] => [0.0,0.1,...,0.8], shape=> (1, |Entities|) Given a batch of head entities and relations => shape (size of batch,| Entities|)

`class dicee.models.octonion.ConvO(args: dict)`

Bases: `dicee.models.base_model.BaseKGE`

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```

import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

```

(continues on next page)

```
def forward(self, x):
    x = F.relu(self.conv1(x))
    return F.relu(self.conv2(x))
```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training (bool)` – Boolean represents whether this module is in training or evaluation mode.

```
name = 'ConvO'

conv2d

fc_num_input

fc1

bn_conv2d

norm_fc1

feature_map_dropout

static octonion_normalizer(emb_rel_e0, emb_rel_e1, emb_rel_e2, emb_rel_e3, emb_rel_e4,
                           emb_rel_e5, emb_rel_e6, emb_rel_e7)

residual_convolution(O_1, O_2)

forward_triples(x: torch.Tensor) → torch.Tensor
```

Parameters

`x`

`forward_k_vs_all(x: torch.Tensor)`

Given a head entity and a relation (h,r), we compute scores for all entities. [score(h,r,x)|x in Entities] => [0.0,0.1,...,0.8], shape=> (1, |Entities|) Given a batch of head entities and relations => shape (size of batch,|Entities|)

`class dicee.models.octonion.AConvO(args: dict)`

Bases: `dicee.models.base_model.BaseKGE`

Additive Convolutional Octonion Knowledge Graph Embeddings

`name = 'AConvO'`

`conv2d`

`fc_num_input`

```

fc1
bn_conv2d
norm_fc1
feature_map_dropout

static octonion_normalizer(emb_rel_e0, emb_rel_e1, emb_rel_e2, emb_rel_e3, emb_rel_e4,
    emb_rel_e5, emb_rel_e6, emb_rel_e7)

residual_convolution(O_1, O_2)

forward_triples(x: torch.Tensor) → torch.Tensor

    Parameters
        x

forward_k_vs_all(x: torch.Tensor)

    Given a head entity and a relation (h,r), we compute scores for all entities. [score(h,r,x)|x in Entities] => [0.0,0.1,...,0.8], shape=> (1, |Entities|) Given a batch of head entities and relations => shape (size of batch,|Entities|)
```

dicee.models.pykeen_models

Classes

<i>PykeenKGE</i>	A class for using knowledge graph embedding models implemented in Pykeen
------------------	--

Module Contents

class dicee.models.pykeen_models.**PykeenKGE** (args: dict)

Bases: *dicee.models.base_model.BaseKGE*

A class for using knowledge graph embedding models implemented in Pykeen

Notes: Pykeen_DistMult: C Pykeen_ComplEx: Pykeen_QuatE: Pykeen_MuRE: Pykeen_CP: Pykeen_Hole: Pykeen_HolE: Pykeen_HolE: Pykeen_TransD: Pykeen_TransE: Pykeen_TransF: Pykeen_TransH: Pykeen_TransR:

model_kwargs

name

model

loss_history = []

args

entity_embeddings = None

relation_embeddings = None

```

forward_k_vs_all(x: torch.LongTensor)
    # => Explicit version by this we can apply bn and dropout
    # (1) Retrieve embeddings of heads and relations + apply Dropout & Normalization if given. h, r =
    self.get_head_relation_representation(x) # (2) Reshape (1). if self.last_dim > 0:
        h = h.reshape(len(x), self.embedding_dim, self.last_dim) r = r.reshape(len(x), self.embedding_dim,
        self.last_dim)
    # (3) Reshape all entities. if self.last_dim > 0:
        t = self.entity_embeddings.weight.reshape(self.num_entities, self.embedding_dim, self.last_dim)

    else:
        t = self.entity_embeddings.weight

    # (4) Call the score_t from interactions to generate triple scores. return self.interaction.score_t(h=h, r=r,
    all_entities=t, slice_size=1)

forward_triples(x: torch.LongTensor) → torch.FloatTensor
    # => Explicit version by this we can apply bn and dropout
    # (1) Retrieve embeddings of heads, relations and tails and apply Dropout & Normalization if given. h, r, t =
    self.get_triple_representation(x) # (2) Reshape (1). if self.last_dim > 0:
        h = h.reshape(len(x), self.embedding_dim, self.last_dim) r = r.reshape(len(x), self.embedding_dim,
        self.last_dim) t = t.reshape(len(x), self.embedding_dim, self.last_dim)
    # (3) Compute the triple score return self.interaction.score(h=h, r=r, t=t, slice_size=None, slice_dim=0)

abstractmethod forward_k_vs_sample(x: torch.LongTensor, target_entity_idx)

```

dicee.models.quaternion

Classes

<i>QMult</i>	Base class for all neural network modules.
<i>ConvQ</i>	Convolutional Quaternion Knowledge Graph Embeddings
<i>AConvQ</i>	Additive Convolutional Quaternion Knowledge Graph Embeddings

Functions

quaternion_mul_with_unit_norm(**, Q_1, Q_2)*

Module Contents

dicee.models.quaternion.quaternion_mul_with_unit_norm(**, Q_1, Q_2)*

class *dicee.models.quaternion.QMult*(*args*)

Bases: *dicee.models.base_model.BaseKGE*

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```
import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))
```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training (bool)` – Boolean represents whether this module is in training or evaluation mode.

```
name = 'QMult'
explicit = True
quaternion_multiplication_followed_by_inner_product(h, r, t)
```

Parameters

- `h` – shape: (`*batch_dims, dim`) The head representations.
- `r` – shape: (`*batch_dims, dim`) The head representations.
- `t` – shape: (`*batch_dims, dim`) The tail representations.

Returns

Triple scores.

`static quaternion_normalizer(x: torch.FloatTensor) → torch.FloatTensor`

Normalize the length of relation vectors, if the forward constraint has not been applied yet.

Absolute value of a quaternion

$$|a + bi + cj + dk| = \sqrt{a^2 + b^2 + c^2 + d^2}$$

L2 norm of quaternion vector:

$$\|x\|^2 = \sum_{i=1}^d |x_i|^2 = \sum_{i=1}^d (x_i.re^2 + x_i.im_1^2 + x_i.im_2^2 + x_i.im_3^2)$$

Parameters

x – The vector.

Returns

The normalized vector.

```
score (head_ent_emb: torch.FloatTensor, rel_ent_emb: torch.FloatTensor,  

       tail_ent_emb: torch.FloatTensor)
```

```
k_vs_all_score (bpe_head_ent_emb, bpe_rel_ent_emb, E)
```

Parameters

- **bpe_head_ent_emb**
- **bpe_rel_ent_emb**
- **E**

```
forward_k_vs_all (x)
```

Parameters

x

```
forward_k_vs_sample (x, target_entity_idx)
```

Completed. Given a head entity and a relation (h,r), we compute scores for all possible triples,i.e., [score(h,r,x)|x in Entities] => [0.0,0.1,...,0.8], shape=> (1, |Entities|) Given a batch of head entities and relations => shape (size of batch,| Entities|)

```
class dicee.models.quaternion.ConvQ (args)
```

Bases: *dicee.models.base_model.BaseKGE*

Convolutional Quaternion Knowledge Graph Embeddings

```
name = 'ConvQ'
```

```
entity_embeddings
```

```
relation_embeddings
```

```
conv2d
```

```
fc_num_input
```

```
fc1
```

```
bn_conv1
```

```
bn_conv2
```

```
feature_map_dropout
```

```
residual_convolution (Q_1, Q_2)
```

```
forward_triples (indexed_triple: torch.Tensor) → torch.Tensor
```

Parameters

x

```
forward_k_vs_all (x: torch.Tensor)
```

Given a head entity and a relation (h,r), we compute scores for all entities. [score(h,r,x)|x in Entities] => [0.0,0.1,...,0.8], shape=> (1, |Entities|) Given a batch of head entities and relations => shape (size of batch,| Entities|)

```

class dicee.models.quaternion.AConvQ (args)
Bases: dicee.models.base_model.BaseKGE

Additive Convolutional Quaternion Knowledge Graph Embeddings

name = 'AConvQ'

entity_embeddings

relation_embeddings

conv2d

fc_num_input

fc1

bn_conv1

bn_conv2

feature_map_dropout

residual_convolution (Q_1, Q_2)

forward_triples (indexed_triple: torch.Tensor) → torch.Tensor

```

Parameters

x

forward_k_vs_all (*x: torch.Tensor*)

Given a head entity and a relation (h,r), we compute scores for all entities. [score(h,r,x)|x in Entities] => [0.0,0.1,...,0.8], shape=> (1, |**Entities**|) Given a batch of head entities and relations => shape (size of batch,| Entities|)

dicee.models.real

Classes

<i>DistMult</i>	Embedding Entities and Relations for Learning and Inference in Knowledge Bases
<i>TransE</i>	Translating Embeddings for Modeling
<i>Shallow</i>	A shallow neural model for relation prediction (https://arxiv.org/abs/2101.09090)
<i>Pyke</i>	A Physical Embedding Model for Knowledge Graphs
<i>CoKEConfig</i>	Configuration for the CoKE (Contextualized Knowledge Graph Embedding) model.
<i>CoKE</i>	Contextualized Knowledge Graph Embedding (CoKE) model.

Module Contents

```

class dicee.models.real.DistMult (args)
Bases: dicee.models.base_model.BaseKGE

```

Embedding Entities and Relations for Learning and Inference in Knowledge Bases <https://arxiv.org/abs/1412.6575>

```

name = 'DistMult'

k_vs_all_score(emb_h: torch.FloatTensor, emb_r: torch.FloatTensor, emb_E: torch.FloatTensor)

Parameters

- emb_h
- emb_r
- emb_E

forward_k_vs_all(x: torch.LongTensor)

forward_k_vs_sample(x: torch.LongTensor, target_entity_idx: torch.LongTensor)

score(h, r, t)

class dicee.models.real.TransE(args)
Bases: dicee.models.base_model.BaseKGE
Translating Embeddings for Modeling Multi-relational Data https://proceedings.neurips.cc/paper/2013/file/1cecc7a77928ca8133fa24680a88d2f9-Paper.pdf
name = 'TransE'

margin = 4

score(head_ent_emb, rel_ent_emb, tail_ent_emb)

forward_k_vs_all(x: torch.Tensor) → torch.FloatTensor

class dicee.models.real.Shallom(args)
Bases: dicee.models.base_model.BaseKGE
A shallow neural model for relation prediction (https://arxiv.org/abs/2101.09090)
name = 'Shallom'

shallom

get_embeddings() → Tuple[numpy.ndarray, None]

forward_k_vs_all(x) → torch.FloatTensor

forward_triples(x) → torch.FloatTensor

Parameters
x

Returns

class dicee.models.real.Pyke(args)
Bases: dicee.models.base_model.BaseKGE
A Physical Embedding Model for Knowledge Graphs
name = 'Pyke'

dist_func

margin = 1.0

```

```

forward_triples (x: torch.LongTensor)
```

Parameters

x

```

class dicee.models.real.CoKEConfig
    Configuration for the CoKE (Contextualized Knowledge Graph Embedding) model.
```

block_size
 Sequence length for transformer (3 for triples: head, relation, tail)

vocab_size
 Total vocabulary size (num_entities + num_relations)

n_layer
 Number of transformer layers

n_head
 Number of attention heads per layer

n_embd
 Embedding dimension (set to match model embedding_dim)

dropout
 Dropout rate applied throughout the model

bias
 Whether to use bias in linear layers

causal
 Whether to use causal masking (False for bidirectional attention)

```

block_size: int = 3
vocab_size: int = None
n_layer: int = 6
n_head: int = 8
n_embd: int = None
dropout: float = 0.3
bias: bool = True
causal: bool = False
```

```

class dicee.models.real.CoKE (args, config: CoKEConfig = CoKEConfig())
    Bases: dicee.models.base_model.BaseKGE

    Contextualized Knowledge Graph Embedding (CoKE) model. Based on: https://arxiv.org/pdf/1911.02168.
```

CoKE uses a transformer encoder to learn contextualized representations of entities and relations. For link prediction, it predicts masked elements in (head, relation, tail) triples using bidirectional attention, similar to BERT's masked language modeling approach.

The model creates a sequence [head_emb, relation_emb, mask_emb], adds positional embeddings, and processes it through transformer layers to predict the tail entity.

```

name = 'CoKE'

config

pos_emb

mask_emb

blocks

ln_f

coke_dropout

forward_k_vs_all(x: torch.Tensor) → torch.Tensor

score(emb_h, emb_r, emb_t) → torch.Tensor

forward_k_vs_sample(x: torch.LongTensor, target_entity_idx: torch.LongTensor) → torch.Tensor

```

dicee.models.static_funcs

Functions

<code>quaternion_mul</code> (→ Tuple[<i>torch.Tensor</i> , <i>torch.Tensor</i> , ...])	Perform quaternion multiplication
---	-----------------------------------

Module Contents

```

dicee.models.static_funcs.quaternion\_mul(*Q_1, Q_2)
    → Tuple[torch.Tensor, torch.Tensor, torch.Tensor, torch.Tensor]
Perform quaternion multiplication :param Q_1: :param Q_2: :return:

```

dicee.models.transformers

Full definition of a GPT Language Model, all of it in this single file. References: 1) the official GPT-2 TensorFlow implementation released by OpenAI: <https://github.com/openai/gpt-2/blob/master/src/model.py> 2) huggingface/transformers PyTorch implementation: https://github.com/huggingface/transformers/blob/main/src/transformers/models/gpt2/modeling_gpt2.py

Classes

<code>ByteE</code>	Base class for all neural network modules.
<code>LayerNorm</code>	LayerNorm but with an optional bias. PyTorch doesn't support simply bias=False
<code>SelfAttention</code>	Base class for all neural network modules.
<code>MLP</code>	Base class for all neural network modules.
<code>Block</code>	Base class for all neural network modules.
<code>GPTConfig</code>	
<code>GPT</code>	Base class for all neural network modules.

Module Contents

```
class dicee.models.transformers.BytE(*args, **kwargs)
```

Bases: `dicee.models.base_model.BaseKGE`

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```
import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))
```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training (bool)` – Boolean represents whether this module is in training or evaluation mode.

```
name = 'BytE'

config

temperature = 0.5

topk = 2

transformer

lm_head

loss_function(yhat_batch, y_batch)
```

Parameters

- `yhat_batch`
- `y_batch`

```
forward(x: torch.LongTensor)
```

Parameters

x (B by T tensor)

```
generate(idx, max_new_tokens, temperature=1.0, top_k=None)
```

Take a conditioning sequence of indices idx (LongTensor of shape (b,t)) and complete the sequence max_new_tokens times, feeding the predictions back into the model each time. Most likely you'll want to make sure to be in model.eval() mode of operation for this.

```
training_step(batch, batch_idx=None)
```

Here you compute and return the training loss and some additional metrics for e.g. the progress bar or logger.

Parameters

- **batch** – The output of your data iterable, normally a DataLoader.
- **batch_idx** – The index of this batch.
- **dataloader_idx** – The index of the dataloader that produced this batch. (only if multiple dataloaders used)

Returns

- **Tensor** - The loss tensor
- **dict** - A dictionary which can include any keys, but must include the key 'loss' in the case of automatic optimization.
- **None** - In automatic optimization, this will skip to the next batch (but is not supported for multi-GPU, TPU, or DeepSpeed). For manual optimization, this has no special meaning, as returning the loss is not required.

In this step you'd normally do the forward pass and calculate the loss for a batch. You can also do fancier things like multiple forward passes or something model specific.

Example:

```
def training_step(self, batch, batch_idx):  
    x, y, z = batch  
    out = self.encoder(x)  
    loss = self.loss(out, x)  
    return loss
```

To use multiple optimizers, you can switch to 'manual optimization' and control their stepping:

```
def __init__(self):  
    super().__init__()  
    self.automatic_optimization = False  
  
    # Multiple optimizers (e.g.: GANs)  
def training_step(self, batch, batch_idx):  
    opt1, opt2 = self.optimizers()  
  
    # do training_step with encoder  
    ...  
    opt1.step()  
    # do training_step with decoder
```

(continues on next page)

```
...  
opt2.step()
```

Note

When `accumulate_grad_batches > 1`, the loss returned here will be automatically normalized by `accumulate_grad_batches` internally.

class dicee.models.transformers.**LayerNorm** (*ndim, bias*)

Bases: `torch.nn.Module`

LayerNorm but with an optional bias. PyTorch doesn't support simply `bias=False`

weight

bias

forward (*input*)

class dicee.models.transformers.**SelfAttention** (*config*)

Bases: `torch.nn.Module`

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```
import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))
```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

training (`bool`) – Boolean represents whether this module is in training or evaluation mode.

```

c_attn
c_proj
attn_dropout
resid_dropout
n_head
n_embd
dropout
causal
flash = True
forward(x)

```

class dicee.models.transformers.MLP(*config*)

Bases: torch.nn.Module

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```

import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))

```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training` (`bool`) – Boolean represents whether this module is in training or evaluation mode.

`c_fc`

```

gelu
c_proj
dropout
forward(x)

class dicee.models.transformers.Block(config)

```

Bases: `torch.nn.Module`

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```

import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))

```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training (bool)` – Boolean represents whether this module is in training or evaluation mode.

```

ln_1
attn
ln_2
mlp
forward(x)

class dicee.models.transformers.GPTConfig

block_size: int = 1024
```

```

vocab_size: int = 50304
n_layer: int = 12
n_head: int = 12
n_embd: int = 768
dropout: float = 0.0
bias: bool = False
causal: bool = True

class dicee.models.transformers.GPT(config)

```

Bases: torch.nn.Module

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```

import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))

```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training` (bool) – Boolean represents whether this module is in training or evaluation mode.

`config`

`transformer`

`lm_head`

```

get_num_params (non_embedding=True)
    Return the number of parameters in the model. For non-embedding count (default), the position embeddings get subtracted. The token embeddings would too, except due to the parameter sharing these params are actually used as weights in the final layer, so we include them.

forward (idx, targets=None)
crop_block_size (block_size)
classmethod from_pretrained (model_type, override_args=None)
configure_optimizers (weight_decay, learning_rate, betas, device_type)
estimate_mfu (fwdbwd_per_iter, dt)
    estimate model flops utilization (MFU) in units of A100 bfloat16 peak FLOPS

```

Classes

<i>ADOPT</i>	ADOPT Optimizer.
<i>BaseKGELightning</i>	Base class for all neural network modules.
<i>BaseKGE</i>	Base class for all neural network modules.
<i>IdentityClass</i>	Base class for all neural network modules.
<i>BaseKGE</i>	Base class for all neural network modules.
<i>Block</i>	Base class for all neural network modules.
<i>DistMult</i>	Embedding Entities and Relations for Learning and Inference in Knowledge Bases
<i>TransE</i>	Translating Embeddings for Modeling
<i>Shallom</i>	A shallow neural model for relation prediction (https://arxiv.org/abs/2101.09090)
<i>Pyke</i>	A Physical Embedding Model for Knowledge Graphs
<i>CoKEConfig</i>	Configuration for the CoKE (Contextualized Knowledge Graph Embedding) model.
<i>CoKE</i>	Contextualized Knowledge Graph Embedding (CoKE) model.
<i>BaseKGE</i>	Base class for all neural network modules.
<i>ConEx</i>	Convolutional ComplEx Knowledge Graph Embeddings
<i>AConEx</i>	Additive Convolutional ComplEx Knowledge Graph Embeddings
<i>ComplEx</i>	Base class for all neural network modules.
<i>BaseKGE</i>	Base class for all neural network modules.
<i>IdentityClass</i>	Base class for all neural network modules.
<i>QMult</i>	Base class for all neural network modules.
<i>ConvQ</i>	Convolutional Quaternion Knowledge Graph Embeddings
<i>AConvQ</i>	Additive Convolutional Quaternion Knowledge Graph Embeddings
<i>BaseKGE</i>	Base class for all neural network modules.
<i>IdentityClass</i>	Base class for all neural network modules.
<i>OMult</i>	Base class for all neural network modules.
<i>Convo</i>	Base class for all neural network modules.
<i>AConvO</i>	Additive Convolutional Octonion Knowledge Graph Embeddings
<i>Keci</i>	Base class for all neural network modules.

continues on next page

Table 41 – continued from previous page

<i>CKeci</i>	Without learning dimension scaling
<i>DeCaL</i>	Base class for all neural network modules.
<i>BaseKGE</i>	Base class for all neural network modules.
<i>PykeenKGE</i>	A class for using knowledge graph embedding models implemented in Pykeen
<i>BaseKGE</i>	Base class for all neural network modules.
<i>FMult</i>	Learning Knowledge Neural Graphs
<i>GFMult</i>	Learning Knowledge Neural Graphs
<i>FMult2</i>	Learning Knowledge Neural Graphs
<i>LFMult1</i>	Embedding with trigonometric functions. We represent all entities and relations in the complex number space as:
<i>LFMult</i>	Embedding with polynomial functions. We represent all entities and relations in the polynomial space as:
<i>Duale</i>	Dual Quaternion Knowledge Graph Embeddings (https://ojs.aaai.org/index.php/AAAI/article/download/16850/16657)

Functions

```

quaternion_mul(→ Tuple[torch.Tensor, torch.Tensor, ...]) Perform quaternion multiplication
quaternion_mul_with_unit_norm(*, Q_1, Q_2)
octonion_mul(*, O_1, O_2)
octonion_mul_norm(*, O_1, O_2)

```

Package Contents

```

class dicee.models.ADOPT (params: torch.optim.optimizer.ParamsT, lr: float | torch.Tensor = 0.001, betas: Tuple[float, float] = (0.9, 0.9999), eps: float = 1e-06, clip_lambda: Callable[[int], float] | None = lambda step: ..., weight_decay: float = 0.0, decouple: bool = False, *, foreach: bool | None = None, maximize: bool = False, capturable: bool = False, differentiable: bool = False, fused: bool | None = None)

```

Bases: *torch.optim.optimizer.Optimizer*

ADOPT Optimizer.

ADOPT is an adaptive learning rate optimization algorithm that combines momentum-based updates with adaptive per-parameter learning rates. It uses exponential moving averages of gradients and squared gradients, with gradient clipping for stability.

The algorithm performs the following key operations: 1. Normalizes gradients by the square root of the second moment estimate 2. Applies optional gradient clipping based on the training step 3. Updates parameters using momentum-smoothed normalized gradients 4. Supports decoupled weight decay (AdamW-style) or L2 regularization

Mathematical formulation:

$$m_t = \beta_1 * m_{t-1} + (1 - \beta_1) * \text{clip}(g_t / \sqrt(v_t))$$

where:

- θ_t : parameter at step t
- g_t : gradient at step t

- `m_t`: first moment estimate (momentum)
- `v_t`: second moment estimate (variance)
- α : learning rate
- β_1, β_2 : exponential decay rates
- `clip()`: optional gradient clipping function

Reference:

Original implementation: <https://github.com/iShohei220/adopt>

Parameters

- `params` (*ParamsT*) – Iterable of parameters to optimize or dicts defining parameter groups.
- `lr` (*float or Tensor, optional*) – Learning rate. Can be a float or 1-element Tensor. Default: 1e-3
- `betas` (*Tuple[float, float], optional*) – Coefficients (β_1, β_2) for computing running averages of gradient and its square. β_1 controls momentum, β_2 controls variance. Default: (0.9, 0.9999)
- `eps` (*float, optional*) – Term added to denominator to improve numerical stability. Default: 1e-6
- `clip_lambda` (*Callable[[int], float], optional*) – Function that takes the step number and returns the gradient clipping threshold. Common choices: - lambda step: $step^{**0.25}$ (default, gradually increases clipping threshold) - lambda step: 1.0 (constant clipping) - None (no clipping) Default: lambda step: $step^{**0.25}$
- `weight_decay` (*float, optional*) – Weight decay coefficient (L2 penalty). Default: 0.0
- `decouple` (*bool, optional*) – If True, uses decoupled weight decay (AdamW-style), applying weight decay directly to parameters. If False, adds weight decay to gradients (L2 regularization). Default: False
- `foreach` (*bool, optional*) – If True, uses the faster foreach implementation for multi-tensor operations. Default: None (auto-select)
- `maximize` (*bool, optional*) – If True, maximizes parameters instead of minimizing. Useful for reinforcement learning. Default: False
- `capturable` (*bool, optional*) – If True, the optimizer is safe to capture in a CUDA graph. Requires learning rate as Tensor. Default: False
- `differentiable` (*bool, optional*) – If True, the optimization step can be differentiated. Useful for meta-learning. Default: False
- `fused` (*bool, optional*) – If True, uses fused kernel implementation (currently not supported). Default: None

Raises

- `ValueError` – If learning rate, epsilon, betas, or weight_decay are invalid.
- `RuntimeError` – If fused is enabled (not currently supported).
- `RuntimeError` – If lr is a Tensor with foreach=True and capturable=False.

Example

```
>>> # Basic usage
>>> optimizer = ADOPT(model.parameters(), lr=0.001)
>>> optimizer.zero_grad()
>>> loss.backward()
>>> optimizer.step()

>>> # With decoupled weight decay
>>> optimizer = ADOPT(model.parameters(), lr=0.001, weight_decay=0.01,
    ↪decouple=True)

>>> # Custom gradient clipping
>>> optimizer = ADOPT(model.parameters(), clip_lambda=lambda step: max(1.0,
    ↪step**0.5))
```

Note

- For most use cases, the default hyperparameters work well
- Consider using decouple=True for better generalization (similar to AdamW)
- The clip_lambda function helps stabilize training in early steps

clip_lambda

__setstate__(state)

Restore optimizer state from a checkpoint.

This method handles backward compatibility when loading optimizer state from older versions. It ensures all required fields are present with default values and properly converts step counters to tensors if needed.

Key responsibilities: 1. Set default values for newly added hyperparameters 2. Convert old-style scalar step counters to tensor format 3. Place step tensors on appropriate devices based on capturable/fused modes

Parameters

`state (dict)` – Optimizer state dictionary (typically from `torch.load()`).

Note

- This enables loading checkpoints saved with older ADOPT versions
- Step counters are converted to appropriate device/dtype for compatibility
- Capturable and fused modes require step tensors on parameter devices

step(closure=None)

Perform a single optimization step.

This method executes one iteration of the ADOPT optimization algorithm across all parameter groups. It orchestrates the following workflow:

1. Optionally evaluates a closure to recompute the loss (useful for algorithms like LBFGS or when loss needs multiple evaluations)

2. For each parameter group:
 - Collects parameters with gradients and their associated state
 - Extracts hyperparameters (betas, learning rate, etc.)
 - Calls the functional adopt() API to perform the actual update
3. Returns the loss value if a closure was provided

The functional API (adopt()) handles three execution modes:

- Single-tensor: Updates one parameter at a time (default, JIT-compatible)
- Multi-tensor (foreach): Batches operations for better performance
- Fused: Uses fused CUDA kernels (not yet implemented)

Gradient scaling support: This method is compatible with automatic mixed precision (AMP) training. It can access grad_scale and found_inf attributes for gradient unscaling and inf/nan detection when used with GradScaler.

Parameters

closure (*Callable, optional*) – A callable that reevaluates the model and returns the loss. The closure should:

- Enable gradients (torch.enable_grad())
- Compute forward pass
- Compute loss
- Compute backward pass
- Return the loss value Example: lambda: (loss := model(x), loss.backward(), loss)[-1]

Default: None

Returns

The loss value returned by the closure, or None if no closure was provided.

Return type

Optional[Tensor]

Example

```
>>> # Standard usage
>>> loss = criterion(model(input), target)
>>> loss.backward()
>>> optimizer.step()
```

```
>>> # With closure (e.g., for line search)
>>> def closure():
...     optimizer.zero_grad()
...     output = model(input)
...     loss = criterion(output, target)
...     loss.backward()
...     return loss
>>> loss = optimizer.step(closure)
```

Note

- Call zero_grad() before computing gradients for the next step
- CUDA graph capture is checked for safety when capturable=True
- The method is thread-safe for different parameter groups

```
class dicee.models.BaseKGELightning(*args, **kwargs)
```

Bases: lightning.LightningModule

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```
import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))
```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training` (bool) – Boolean represents whether this module is in training or evaluation mode.

`training_step_outputs` = []

`mem_of_model()` → Dict

Size of model in MB and number of params

`training_step`(batch, batch_idx=None)

Here you compute and return the training loss and some additional metrics for e.g. the progress bar or logger.

Parameters

- `batch` – The output of your data iterable, normally a `DataLoader`.
- `batch_idx` – The index of this batch.
- `dataloader_idx` – The index of the dataloader that produced this batch. (only if multiple dataloaders used)

Returns

- `Tensor` - The loss tensor
- `dict` - A dictionary which can include any keys, but must include the key '`'loss'`' in the case of automatic optimization.
- `None` - In automatic optimization, this will skip to the next batch (but is not supported for multi-GPU, TPU, or DeepSpeed). For manual optimization, this has no special meaning, as returning the loss is not required.

In this step you'd normally do the forward pass and calculate the loss for a batch. You can also do fancier things like multiple forward passes or something model specific.

Example:

```
def training_step(self, batch, batch_idx):
    x, y, z = batch
    out = self.encoder(x)
    loss = self.loss(out, x)
    return loss
```

To use multiple optimizers, you can switch to ‘manual optimization’ and control their stepping:

```
def __init__(self):
    super().__init__()
    self.automatic_optimization = False

# Multiple optimizers (e.g.: GANs)
def training_step(self, batch, batch_idx):
    opt1, opt2 = self.optimizers()

    # do training_step with encoder
    ...
    opt1.step()
    # do training_step with decoder
    ...
    opt2.step()
```

Note

When `accumulate_grad_batches > 1`, the loss returned here will be automatically normalized by `accumulate_grad_batches` internally.

`loss_function(yhat_batch: torch.FloatTensor, y_batch: torch.FloatTensor)`

Parameters

- `yhat_batch`
- `y_batch`

`on_train_epoch_end(*args, **kwargs)`

Called in the training loop at the very end of the epoch.

To access all batch outputs at the end of the epoch, you can cache step outputs as an attribute of the `LightningModule` and access them in this hook:

```
class MyLightningModule(L.LightningModule):
    def __init__(self):
        super().__init__()
        self.training_step_outputs = []

    def training_step(self):
        loss = ...
```

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```
    self.training_step_outputs.append(loss)
    return loss

    def on_train_epoch_end(self):
        # do something with all training_step outputs, for example:
        epoch_mean = torch.stack(self.training_step_outputs).mean()
        self.log("training_epoch_mean", epoch_mean)
        # free up the memory
        self.training_step_outputs.clear()
```

`test_epoch_end(outputs: List[Any])`

`test_dataloader() → None`

An iterable or collection of iterables specifying test samples.

For more information about multiple dataloaders, see this section.

For data processing use the following pattern:

- download in `prepare_data()`
- process and split in `setup()`

However, the above are only necessary for distributed processing.

⚠ Warning

do not assign state in `prepare_data`

- `test()`
- `prepare_data()`
- `setup()`

ℹ Note

Lightning tries to add the correct sampler for distributed and arbitrary hardware. There is no need to set it yourself.

ℹ Note

If you don't need a test dataset and a `test_step()`, you don't need to implement this method.

`val_dataloader() → None`

An iterable or collection of iterables specifying validation samples.

For more information about multiple dataloaders, see this section.

The dataloader you return will not be reloaded unless you set `:param-ref:`~lightning.pytorch.trainer.Trainer.reload_dataloaders_every_n_epochs`` to a positive integer.

It's recommended that all data downloads and preparation happen in `prepare_data()`.

- `fit()`
- `validate()`
- `prepare_data()`
- `setup()`

Note

Lightning tries to add the correct sampler for distributed and arbitrary hardware There is no need to set it yourself.

Note

If you don't need a validation dataset and a `validation_step()`, you don't need to implement this method.

`predict_dataloader() → None`

An iterable or collection of iterables specifying prediction samples.

For more information about multiple dataloaders, see this section.

It's recommended that all data downloads and preparation happen in `prepare_data()`.

- `predict()`
- `prepare_data()`
- `setup()`

Note

Lightning tries to add the correct sampler for distributed and arbitrary hardware There is no need to set it yourself.

Returns

A `torch.utils.data.DataLoader` or a sequence of them specifying prediction samples.

`train_dataloader() → None`

An iterable or collection of iterables specifying training samples.

For more information about multiple dataloaders, see this section.

The dataloader you return will not be reloaded unless you set `:param-ref:`~lightning.pytorch.trainer.Trainer.reload_dataloaders_every_n_epochs`` to a positive integer.

For data processing use the following pattern:

- download in `prepare_data()`
- process and split in `setup()`

However, the above are only necessary for distributed processing.

Warning

do not assign state in prepare_data

- fit()
- prepare_data()
- setup()

Note

Lightning tries to add the correct sampler for distributed and arbitrary hardware. There is no need to set it yourself.

`configure_optimizers(parameters=None)`

Choose what optimizers and learning-rate schedulers to use in your optimization. Normally you'd need one. But in the case of GANs or similar you might have multiple. Optimization with multiple optimizers only works in the manual optimization mode.

Returns

Any of these 6 options.

- **Single optimizer.**
- **List or Tuple** of optimizers.
- **Two lists** - The first list has multiple optimizers, and the second has multiple LR schedulers (or multiple lr_scheduler_config).
- **Dictionary**, with an "optimizer" key, and (optionally) a "lr_scheduler" key whose value is a single LR scheduler or lr_scheduler_config.
- **None** - Fit will run without any optimizer.

The lr_scheduler_config is a dictionary which contains the scheduler and its associated configuration. The default configuration is shown below.

```
lr_scheduler_config = {
    # REQUIRED: The scheduler instance
    "scheduler": lr_scheduler,
    # The unit of the scheduler's step size, could also be 'step'.
    # 'epoch' updates the scheduler on epoch end whereas 'step'
    # updates it after a optimizer update.
    "interval": "epoch",
    # How many epochs/steps should pass between calls to
    # `scheduler.step()`. 1 corresponds to updating the learning
    # rate after every epoch/step.
    "frequency": 1,
    # Metric to monitor for schedulers like `ReduceLROnPlateau`
    "monitor": "val_loss",
    # If set to `True`, will enforce that the value specified 'monitor'
    # is available when the scheduler is updated, thus stopping
    # training if not found. If set to `False`, it will only produce a warning
}
```

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```

    "strict": True,
    # If using the `LearningRateMonitor` callback to monitor the
    # learning rate progress, this keyword can be used to specify
    # a custom logged name
    "name": None,
}

```

When there are schedulers in which the `.step()` method is conditioned on a value, such as the `torch.optim.lr_scheduler.ReduceLROnPlateau` scheduler, Lightning requires that the `lr_scheduler_config` contains the keyword "monitor" set to the metric name that the scheduler should be conditioned on.

Metrics can be made available to monitor by simply logging it using `self.log('metric_to_track', metric_val)` in your `LightningModule`.

Note

Some things to know:

- Lightning calls `.backward()` and `.step()` automatically in case of automatic optimization.
- If a learning rate scheduler is specified in `configure_optimizers()` with key "interval" (default "epoch") in the scheduler configuration, Lightning will call the scheduler's `.step()` method automatically in case of automatic optimization.
- If you use 16-bit precision (`precision=16`), Lightning will automatically handle the optimizer.
- If you use `torch.optim.LBFGS`, Lightning handles the closure function automatically for you.
- If you use multiple optimizers, you will have to switch to 'manual optimization' mode and step them yourself.
- If you need to control how often the optimizer steps, override the `optimizer_step()` hook.

`class dicee.models.BaseKGE(args: dict)`

Bases: `BaseKGELightning`

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```

import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):

```

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```
x = F.relu(self.conv1(x))
return F.relu(self.conv2(x))
```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training` (`bool`) – Boolean represents whether this module is in training or evaluation mode.

```
args

embedding_dim = None

num_entities = None

num_relations = None

num_tokens = None

learning_rate = None

apply_unit_norm = None

input_dropout_rate = None

hidden_dropout_rate = None

optimizer_name = None

feature_map_dropout_rate = None

kernel_size = None

num_of_output_channels = None

weight_decay = None

loss

selected_optimizer = None

normalizer_class = None

normalize_head_entity_embeddings

normalize_relation_embeddings

normalize_tail_entity_embeddings

hidden_normalizer
```

```

param_init
input_dp_ent_real
input_dp_rel_real
hidden_dropout
loss_history = []
byte_pair_encoding
max_length_subword_tokens
block_size

forward_byte_pair_encoded_k_vs_all(x: torch.LongTensor)
Parameters
  x (B × 2 × T)
forward_byte_pair_encoded_triple(x: Tuple[torch.LongTensor, torch.LongTensor])
  byte pair encoded neural link predictors
Parameters
  -----
init_params_with_sanity_checking()

forward(x: torch.LongTensor | Tuple[torch.LongTensor, torch.LongTensor],
  y_idx: torch.LongTensor = None)
Parameters
  • x
  • y_idx
  • ordered_bpe_entities
forward_triples(x: torch.LongTensor) → torch.Tensor
Parameters
  x
forward_k_vs_all(*args, **kwargs)
forward_k_vs_sample(*args, **kwargs)
get_triple_representation(idx_hrt)
get_head_relation_representation(indexed_triple)
get_sentence_representation(x: torch.LongTensor)
Parameters
  • (b (x shape)
  • 3
  • t)

```

```
get_bpe_head_and_relation_representation(x: torch.LongTensor)
    → Tuple[torch.FloatTensor, torch.FloatTensor]
```

Parameters

x (B x 2 x T)

```
get_embeddings() → Tuple[numpy.ndarray, numpy.ndarray]
```

```
class dicee.models.IdentityClass(args=None)
```

Bases: torch.nn.Module

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```
import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))
```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training` (bool) – Boolean represents whether this module is in training or evaluation mode.

```
args = None

__call__(x)

static forward(x)

class dicee.models.BaseKGE(args: dict)
```

Bases: `BaseKGLightning`

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```

import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))

```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training (bool)` – Boolean represents whether this module is in training or evaluation mode.

```

args

embedding_dim = None

num_entities = None

num_relations = None

num_tokens = None

learning_rate = None

apply_unit_norm = None

input_dropout_rate = None

hidden_dropout_rate = None

optimizer_name = None

feature_map_dropout_rate = None

kernel_size = None

num_of_output_channels = None

weight_decay = None

loss

```

```

selected_optimizer = None
normalizer_class = None
normalize_head_entity_embeddings
normalize_relation_embeddings
normalize_tail_entity_embeddings
hidden_normalizer
param_init
input_dp_ent_real
input_dp_rel_real
hidden_dropout
loss_history = []
byte_pair_encoding
max_length_subword_tokens
block_size
forward_byte_pair_encoded_k_vs_all(x: torch.LongTensor)

Parameters
x (B x 2 x T)

forward_byte_pair_encoded_triple(x: Tuple[torch.LongTensor, torch.LongTensor])
by byte pair encoded neural link predictors

Parameters
-----
init_params_with_sanity_checking()

forward(x: torch.LongTensor | Tuple[torch.LongTensor, torch.LongTensor],
y_idx: torch.LongTensor = None)

Parameters
• x
• y_idx
• ordered_bpe_entities

forward_triples(x: torch.LongTensor) → torch.Tensor

Parameters
x
forward_k_vs_all(*args, **kwargs)
forward_k_vs_sample(*args, **kwargs)
get_triple_representation(idx_hrt)

```

```

get_head_relation_representation(indexed_triple)
get_sentence_representation(x: torch.LongTensor)
```

Parameters

- (**b** (*x shape*))
- 3
- t)

```

get_bpe_head_and_relation_representation(x: torch.LongTensor)
→ Tuple[torch.FloatTensor, torch.FloatTensor]
```

Parameters

- **x** (*B x 2 x T*)

```

get_embeddings() → Tuple[numpy.ndarray, numpy.ndarray]
```

```
class dicee.models.Block(config)
```

Bases: *torch.nn.Module*

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```

import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))
```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call *to()*, etc.

Note

As per the example above, an *__init__()* call to the parent class must be made before assignment on the child.

Variables

training (*bool*) – Boolean represents whether this module is in training or evaluation mode.

ln_1

```

attn
ln_2
mlp
forward(x)
```

class dicee.models.**DistMult**(*args*)
Bases: *dicee.models.base_model.BaseKGE*
Embedding Entities and Relations for Learning and Inference in Knowledge Bases <https://arxiv.org/abs/1412.6575>

```

name = 'DistMult'
k_vs_all_score(emb_h: torch.FloatTensor, emb_r: torch.FloatTensor, emb_E: torch.FloatTensor)
```

Parameters

- **emb_h**
- **emb_r**
- **emb_E**

```

forward_k_vs_all(x: torch.LongTensor)
forward_k_vs_sample(x: torch.LongTensor, target_entity_idx: torch.LongTensor)
score(h, r, t)
```

class dicee.models.**TransE**(*args*)
Bases: *dicee.models.base_model.BaseKGE*
Translating Embeddings for Modeling Multi-relational Data <https://proceedings.neurips.cc/paper/2013/file/1cecc7a77928ca8133fa24680a88d2f9-Paper.pdf>

```

name = 'TransE'
margin = 4
score(head_ent_emb, rel_ent_emb, tail_ent_emb)
forward_k_vs_all(x: torch.Tensor) → torch.FloatTensor
```

class dicee.models.**Shallom**(*args*)
Bases: *dicee.models.base_model.BaseKGE*
A shallow neural model for relation prediction (<https://arxiv.org/abs/2101.09090>)

```

name = 'Shallom'
shallom
get_embeddings() → Tuple[numpy.ndarray, None]
forward_k_vs_all(x) → torch.FloatTensor
```

```

forward_triples(x) → torch.FloatTensor

Parameters
    x

Returns

class dicee.models.Pyke(args)
Bases: dicee.models.base_model.BaseKGE
A Physical Embedding Model for Knowledge Graphs
name = 'Pyke'

dist_func

margin = 1.0

forward_triples(x: torch.LongTensor)

Parameters
    x

class dicee.models.CoKEConfig
Configuration for the CoKE (Contextualized Knowledge Graph Embedding) model.

block_size
    Sequence length for transformer (3 for triples: head, relation, tail)

vocab_size
    Total vocabulary size (num_entities + num_relations)

n_layer
    Number of transformer layers

n_head
    Number of attention heads per layer

n_embd
    Embedding dimension (set to match model embedding_dim)

dropout
    Dropout rate applied throughout the model

bias
    Whether to use bias in linear layers

causal
    Whether to use causal masking (False for bidirectional attention)

block_size: int = 3

vocab_size: int = None

n_layer: int = 6

n_head: int = 8

n_embd: int = None

```

```

dropout: float = 0.3
bias: bool = True
causal: bool = False

class dicee.models.CoKE(args, config: CoKEConfig = CoKEConfig())
Bases: dicee.models.base_model.BaseKGE

```

Contextualized Knowledge Graph Embedding (CoKE) model. Based on: <https://arxiv.org/pdf/1911.02168>.

CoKE uses a transformer encoder to learn contextualized representations of entities and relations. For link prediction, it predicts masked elements in (head, relation, tail) triples using bidirectional attention, similar to BERT's masked language modeling approach.

The model creates a sequence [head_emb, relation_emb, mask_emb], adds positional embeddings, and processes it through transformer layers to predict the tail entity.

```

name = 'CoKE'

config

pos_emb

mask_emb

blocks

ln_f

coke_dropout

forward_k_vs_all(x: torch.Tensor)
score(emb_h, emb_r, emb_t)

forward_k_vs_sample(x: torch.LongTensor, target_entity_idx: torch.LongTensor)

```

```

class dicee.models.BaseKGE(args: dict)
Bases: BaseKGELightning

```

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```

import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))

```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training (bool)` – Boolean represents whether this module is in training or evaluation mode.

```
args  
  
embedding_dim = None  
  
num_entities = None  
  
num_relations = None  
  
num_tokens = None  
  
learning_rate = None  
  
apply_unit_norm = None  
  
input_dropout_rate = None  
  
hidden_dropout_rate = None  
  
optimizer_name = None  
  
feature_map_dropout_rate = None  
  
kernel_size = None  
  
num_of_output_channels = None  
  
weight_decay = None  
  
loss  
  
selected_optimizer = None  
  
normalizer_class = None  
  
normalize_head_entity_embeddings  
  
normalize_relation_embeddings  
  
normalize_tail_entity_embeddings  
  
hidden_normalizer  
  
param_init  
  
input_dp_ent_real  
  
input_dp_rel_real
```

```

hidden_dropout
loss_history = []
byte_pair_encoding
max_length_subword_tokens
block_size

forward_byte_pair_encoded_k_vs_all(x: torch.LongTensor)
  Parameters
    x (B × 2 × T)
  forward_byte_pair_encoded_triple(x: Tuple[torch.LongTensor, torch.LongTensor])
    byte pair encoded neural link predictors
    Parameters
    -----
    init_params_with_sanity_checking()

  forward(x: torch.LongTensor | Tuple[torch.LongTensor, torch.LongTensor],
         y_idx: torch.LongTensor = None)
    Parameters
      • x
      • y_idx
      • ordered_bpe_entities

  forward_triples(x: torch.LongTensor) → torch.Tensor
    Parameters
      x
    forward_k_vs_all(*args, **kwargs)
    forward_k_vs_sample(*args, **kwargs)
    get_triple_representation(idx_hrt)
    get_head_relation_representation(indexed_triple)
    get_sentence_representation(x: torch.LongTensor)
    Parameters
      • (b (x shape)
      • 3
      • t)
    get_bpe_head_and_relation_representation(x: torch.LongTensor)
      → Tuple[torch.FloatTensor, torch.FloatTensor]
    Parameters
      x (B × 2 × T)

```

```

get_embeddings() → Tuple[numpy.ndarray, numpy.ndarray]

class dicee.models.ConEx(args)
    Bases: dicee.models.base_model.BaseKGE

    Convolutional ComplEx Knowledge Graph Embeddings

    name = 'ConEx'

    conv2d

    fc_num_input

    fc1

    norm_fc1

    bn_conv2d

    feature_map_dropout

    residual_convolution(C_1: Tuple[torch.Tensor, torch.Tensor],
                           C_2: Tuple[torch.Tensor, torch.Tensor]) → torch.FloatTensor
        Compute residual score of two complex-valued embeddings. :param C_1: a tuple of two pytorch tensors that corresponds complex-valued embeddings :param C_2: a tuple of two pytorch tensors that corresponds complex-valued embeddings :return:

    forward_k_vs_all(x: torch.Tensor) → torch.FloatTensor

    forward_triples(x: torch.Tensor) → torch.FloatTensor

    Parameters
        x

    forward_k_vs_sample(x: torch.Tensor, target_entity_idx: torch.Tensor)

class dicee.models.AConEx(args)
    Bases: dicee.models.base_model.BaseKGE

    Additive Convolutional ComplEx Knowledge Graph Embeddings

    name = 'AConEx'

    conv2d

    fc_num_input

    fc1

    norm_fc1

    bn_conv2d

    feature_map_dropout

    residual_convolution(C_1: Tuple[torch.Tensor, torch.Tensor],
                           C_2: Tuple[torch.Tensor, torch.Tensor]) → torch.FloatTensor
        Compute residual score of two complex-valued embeddings. :param C_1: a tuple of two pytorch tensors that corresponds complex-valued embeddings :param C_2: a tuple of two pytorch tensors that corresponds complex-valued embeddings :return:

```

```

forward_k_vs_all(x: torch.Tensor) → torch.FloatTensor
forward_triples(x: torch.Tensor) → torch.FloatTensor

Parameters
    x

forward_k_vs_sample(x: torch.Tensor, target_entity_idx: torch.Tensor)

```

class dicee.models.ComplEx(args)
Bases: dicee.models.base_model.BaseKGE

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```

import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))

```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training` (`bool`) – Boolean represents whether this module is in training or evaluation mode.

```

name = 'ComplEx'

static score(head_ent_emb: torch.FloatTensor, rel_ent_emb: torch.FloatTensor,
            tail_ent_emb: torch.FloatTensor)

static k_vs_all_score(emb_h: torch.FloatTensor, emb_r: torch.FloatTensor,
                      emb_E: torch.FloatTensor)

```

Parameters

- `emb_h`
- `emb_r`

- `emb_E`

`forward_k_vs_all`(*x*: `torch.LongTensor`) → `torch.FloatTensor`

`forward_k_vs_sample`(*x*: `torch.LongTensor`, *target_entity_idx*: `torch.LongTensor`)

`dicee.models.quaternion_mul`(**Q_1, Q_2*)
 → `Tuple[torch.Tensor, torch.Tensor, torch.Tensor, torch.Tensor]`

Perform quaternion multiplication :param *Q_1*: :param *Q_2*: :return:

`class dicee.models.BaseKGE(args: dict)`

Bases: `BaseKGELightning`

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```
import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))
```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training`(*bool*) – Boolean represents whether this module is in training or evaluation mode.

args

```
embedding_dim = None
num_entities = None
num_relations = None
num_tokens = None
learning_rate = None
```

```

apply_unit_norm = None
input_dropout_rate = None
hidden_dropout_rate = None
optimizer_name = None
feature_map_dropout_rate = None
kernel_size = None
num_of_output_channels = None
weight_decay = None
loss
selected_optimizer = None
normalizer_class = None
normalize_head_entity_embeddings
normalize_relation_embeddings
normalize_tail_entity_embeddings
hidden_normalizer
param_init
input_dp_ent_real
input_dp_rel_real
hidden_dropout
loss_history = []
byte_pair_encoding
max_length_subword_tokens
block_size
forward_byte_pair_encoded_k_vs_all(x: torch.LongTensor)

Parameters
  x (B x 2 x T)

forward_byte_pair_encoded_triple(x: Tuple[torch.LongTensor, torch.LongTensor])
  byte pair encoded neural link predictors

Parameters
-----
init_params_with_sanity_checking()

```

```
forward(x: torch.LongTensor | Tuple[torch.LongTensor, torch.LongTensor],  
        y_idx: torch.LongTensor = None)
```

Parameters

- **x**
- **y_idx**
- **ordered_bpe_entities**

```
forward_triples(x: torch.LongTensor) → torch.Tensor
```

Parameters

x

```
forward_k_vs_all(*args, **kwargs)
```

```
forward_k_vs_sample(*args, **kwargs)
```

```
get_triple_representation(idx_hrt)
```

```
get_head_relation_representation(indexed_triple)
```

```
get_sentence_representation(x: torch.LongTensor)
```

Parameters

- (**b** (x shape))
- **3**
- **t**)

```
get_bpe_head_and_relation_representation(x: torch.LongTensor)  
→ Tuple[torch.FloatTensor, torch.FloatTensor]
```

Parameters

x (B x 2 x T)

```
get_embeddings() → Tuple[numpy.ndarray, numpy.ndarray]
```

```
class dicee.models.IdentityClass(args=None)
```

Bases: `torch.nn.Module`

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```
import torch.nn as nn  
import torch.nn.functional as F  
  
class Model(nn.Module):  
    def __init__(self) -> None:  
        super().__init__()  
        self.conv1 = nn.Conv2d(1, 20, 5)  
        self.conv2 = nn.Conv2d(20, 20, 5)
```

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```
def forward(self, x):
    x = F.relu(self.conv1(x))
    return F.relu(self.conv2(x))
```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training` (`bool`) – Boolean represents whether this module is in training or evaluation mode.

```
args = None

__call__(x)

static forward(x)

dicee.models.quaternion_mul_with_unit_norm(*, Q_1, Q_2)
```

`class` `dicee.models.QMult` (`args`)

Bases: `dicee.models.base_model.BaseKGE`

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the submodules as regular attributes:

```
import torch.nn as nn
import torch.nn.functional as F


class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))
```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training (bool)` – Boolean represents whether this module is in training or evaluation mode.

```
name = 'QMult'

explicit = True

quaternion_multiplication_followed_by_inner_product (h, r, t)
```

Parameters

- `h` – shape: (`*batch_dims`, dim) The head representations.
- `r` – shape: (`*batch_dims`, dim) The head representations.
- `t` – shape: (`*batch_dims`, dim) The tail representations.

Returns

Triple scores.

```
static quaternion_normalizer (x: torch.FloatTensor) → torch.FloatTensor
```

Normalize the length of relation vectors, if the forward constraint has not been applied yet.

Absolute value of a quaternion

$$|a + bi + cj + dk| = \sqrt{a^2 + b^2 + c^2 + d^2}$$

L2 norm of quaternion vector:

$$\|x\|^2 = \sum_{i=1}^d |x_i|^2 = \sum_{i=1}^d (x_i.re^2 + x_i.im_1^2 + x_i.im_2^2 + x_i.im_3^2)$$

Parameters

`x` – The vector.

Returns

The normalized vector.

```
score (head_ent_emb: torch.FloatTensor, rel_ent_emb: torch.FloatTensor,
tail_ent_emb: torch.FloatTensor)
```

```
k_vs_all_score (bpe_head_ent_emb, bpe_rel_ent_emb, E)
```

Parameters

- `bpe_head_ent_emb`
- `bpe_rel_ent_emb`
- `E`

```
forward_k_vs_all (x)
```

Parameters

`x`

```

forward_k_vs_sample(x, target_entity_idx)
Completed. Given a head entity and a relation (h,r), we compute scores for all possible triples,i.e.,
[score(h,r,x)|x in Entities] => [0.0,0.1,...,0.8], shape=> (1, |Entities|) Given a batch of head entities and
relations => shape (size of batch,| Entities|)

class dicee.models.ConvQ(args)
Bases: dicee.models.base_model.BaseKGE
Convolutional Quaternion Knowledge Graph Embeddings
name = 'ConvQ'

entity_embeddings
relation_embeddings
conv2d
fc_num_input
fc1
bn_conv1
bn_conv2
feature_map_dropout
residual_convolution(Q_1, Q_2)
forward_triples(indexed_triple: torch.Tensor) → torch.Tensor

Parameters
x
forward_k_vs_all(x: torch.Tensor)
Given a head entity and a relation (h,r), we compute scores for all entities. [score(h,r,x)|x in Entities] =>
[0.0,0.1,...,0.8], shape=> (1, |Entities|) Given a batch of head entities and relations => shape (size of batch,| Entities|)

class dicee.models.AConvQ(args)
Bases: dicee.models.base_model.BaseKGE
Additive Convolutional Quaternion Knowledge Graph Embeddings
name = 'AConvQ'

entity_embeddings
relation_embeddings
conv2d
fc_num_input
fc1
bn_conv1
bn_conv2

```

```

feature_map_dropout
residual_convolution(Q_1, Q_2)
forward_triples(indexed_triple: torch.Tensor) → torch.Tensor

Parameters
    x

forward_k_vs_all(x: torch.Tensor)
    Given a head entity and a relation (h,r), we compute scores for all entities. [score(h,r,x)|x in Entities] => [0.0,0.1,...,0.8], shape=> (1, |Entities|) Given a batch of head entities and relations => shape (size of batch,|Entities|)

class dicee.models.BaseKGE(args: dict)
Bases: BaseKGELightning

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```

```

import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))

```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training` (bool) – Boolean represents whether this module is in training or evaluation mode.

```

args

embedding_dim = None

num_entities = None

num_relations = None

```

```

num_tokens = None
learning_rate = None
apply_unit_norm = None
input_dropout_rate = None
hidden_dropout_rate = None
optimizer_name = None
feature_map_dropout_rate = None
kernel_size = None
num_of_output_channels = None
weight_decay = None
loss
selected_optimizer = None
normalizer_class = None
normalize_head_entity_embeddings
normalize_relation_embeddings
normalize_tail_entity_embeddings
hidden_normalizer
param_init
input_dp_ent_real
input_dp_rel_real
hidden_dropout
loss_history = []
byte_pair_encoding
max_length_subword_tokens
block_size
forward_byte_pair_encoded_k_vs_all(x: torch.LongTensor)

Parameters
  x (B x 2 x T)

forward_byte_pair_encoded_triple(x: Tuple[torch.LongTensor, torch.LongTensor])
  byte pair encoded neural link predictors
Parameters
  -----

```

```
init_params_with_sanity_checking()
forward(x: torch.LongTensor | Tuple[torch.LongTensor, torch.LongTensor],
         y_idx: torch.LongTensor = None)
```

Parameters

- **x**
- **y_idx**
- **ordered_bpe_entities**

```
forward_triples(x: torch.LongTensor) → torch.Tensor
```

Parameters

x

```
forward_k_vs_all(*args, **kwargs)
```

```
forward_k_vs_sample(*args, **kwargs)
```

```
get_triple_representation(idx_hrt)
```

```
get_head_relation_representation(indexed_triple)
```

```
get_sentence_representation(x: torch.LongTensor)
```

Parameters

- (**b** (*x shape*))
- **3**
- **t**)

```
get_bpe_head_and_relation_representation(x: torch.LongTensor)
    → Tuple[torch.FloatTensor, torch.FloatTensor]
```

Parameters

x (*B x 2 x T*)

```
get_embeddings() → Tuple[numpy.ndarray, numpy.ndarray]
```

```
class dicee.models.IdentityClass(args=None)
```

Bases: *torch.nn.Module*

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```
import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
```

(continues on next page)

```
self.conv2 = nn.Conv2d(20, 20, 5)

def forward(self, x):
    x = F.relu(self.conv1(x))
    return F.relu(self.conv2(x))
```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training` (bool) – Boolean represents whether this module is in training or evaluation mode.

```
args = None

__call__(x)

static forward(x)

dicee.models.octonion_mul(*, O_1, O_2)

dicee.models.octonion_mul_norm(*, O_1, O_2)
```

`class dicee.models.OMult(args)`

Bases: `dicee.models.base_model.BaseKGE`

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the submodules as regular attributes:

```
import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))
```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training (bool)` – Boolean represents whether this module is in training or evaluation mode.

```
name = 'OMult'

static octonion_normalizer(emb_rel_e0, emb_rel_e1, emb_rel_e2, emb_rel_e3, emb_rel_e4,
                           emb_rel_e5, emb_rel_e6, emb_rel_e7)

score(head_ent_emb: torch.FloatTensor, rel_ent_emb: torch.FloatTensor,
      tail_ent_emb: torch.FloatTensor)

k_vs_all_score(bpe_head_ent_emb, bpe_rel_ent_emb, E)
```

`forward_k_vs_all(x)`

Completed. Given a head entity and a relation (h,r), we compute scores for all possible triples,i.e., [score(h,r,x)|x in Entities] => [0.0,0.1,...,0.8], shape=> (1, |Entities|) Given a batch of head entities and relations => shape (size of batch,| Entities|)

```
class dicee.models.ConvO(args: dict)
Bases: dicee.models.base_model.BaseKGE
```

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```
import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))
```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training (bool)` – Boolean represents whether this module is in training or evaluation mode.

```
name = 'ConvO'

conv2d

fc_num_input

fc1

bn_conv2d

norm_fc1

feature_map_dropout

static octonion_normalizer(emb_rel_e0, emb_rel_e1, emb_rel_e2, emb_rel_e3, emb_rel_e4,
                           emb_rel_e5, emb_rel_e6, emb_rel_e7)

residual_convolution(O_1, O_2)

forward_triples(x: torch.Tensor) → torch.Tensor
```

Parameters

`x`

`forward_k_vs_all(x: torch.Tensor)`

Given a head entity and a relation (h,r), we compute scores for all entities. [score(h,r,x)|x in Entities] => [0.0,0.1,...,0.8], shape=>(1, |Entities|) Given a batch of head entities and relations => shape (size of batch,|Entities|)

`class dicee.models.AConvO(args: dict)`

Bases: `dicee.models.base_model.BaseKGE`

Additive Convolutional Octonion Knowledge Graph Embeddings

`name = 'AConvO'`

`conv2d`

`fc_num_input`

`fc1`

`bn_conv2d`

`norm_fc1`

`feature_map_dropout`

```
static octonion_normalizer(emb_rel_e0, emb_rel_e1, emb_rel_e2, emb_rel_e3, emb_rel_e4,
                           emb_rel_e5, emb_rel_e6, emb_rel_e7)
```

`residual_convolution(O_1, O_2)`

`forward_triples(x: torch.Tensor) → torch.Tensor`

Parameters

`x`

```
forward_k_vs_all(x: torch.Tensor)
```

Given a head entity and a relation (h,r), we compute scores for all entities. [score(h,r,x)|x in Entities] => [0.0,0.1,...,0.8], shape=>(1, |Entities|) Given a batch of head entities and relations => shape (size of batch,|Entities|)

```
class dicee.models.Keci(args)
```

Bases: *dicee.models.base_model.BaseKGE*

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```
import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))
```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training` (`bool`) – Boolean represents whether this module is in training or evaluation mode.

```
name = 'Keci'
```

```
p
```

```
q
```

```
r
```

```
requires_grad_for_interactions = True
```

```
compute_sigma_pp(hp, rp)
```

Compute $\sigma_{pp} = \sum_{i=1}^{p-1} \sum_{k=i+1}^p (h_i r_k - h_k r_i) e_i e_k$

σ_{pp} captures the interactions between along p bases For instance, let p e_1, e_2, e_3, we compute interactions between e_1 e_2, e_1 e_3 , and e_2 e_3 This can be implemented with a nested two for loops

```
results = [] for i in range(p - 1):
```

```

for k in range(i + 1, p):
    results.append(hp[:, :, i] * rp[:, :, k] - hp[:, :, k] * rp[:, :, i])

```

`sigma_pp = torch.stack(results, dim=2)` assert `sigma_pp.shape == (b, r, int((p * (p - 1)) / 2))`

Yet, this computation would be quite inefficient. Instead, we compute interactions along all p, e.g., `e1e1, e1e2, e1e3,`

`e2e1, e2e2, e2e3, e3e1, e3e2, e3e3`

Then select the triangular matrix without diagonals: `e1e2, e1e3, e2e3.`

compute_sigma_qq(hq, rq)

Compute `sigma_qq = sum_{j=1}^{p+q-1} sum_{k=j+1}^{p+q} (h_j r_k - h_k r_j) e_j e_k` sigma_qq captures the interactions between along q bases For instance, let q e_1, e_2, e_3, we compute interactions between e_1 e_2, e_1 e_3 , and e_2 e_3 This can be implemented with a nested two for loops

`results = []` for j in range(q - 1):

for k in range(j + 1, q):

`results.append(hq[:, :, j] * rq[:, :, k] - hq[:, :, k] * rq[:, :, j])`

`sigma_qq = torch.stack(results, dim=2)` assert `sigma_qq.shape == (b, r, int((q * (q - 1)) / 2))`

Yet, this computation would be quite inefficient. Instead, we compute interactions along all p, e.g., `e1e1, e1e2, e1e3,`

`e2e1, e2e2, e2e3, e3e1, e3e2, e3e3`

Then select the triangular matrix without diagonals: `e1e2, e1e3, e2e3.`

compute_sigma_pq(*, hp, hq, rp, rq)

`sum_{i=1}^p sum_{j=p+1}^{p+q} (h_i r_j - h_j r_i) e_i e_j`

`results = []` sigma_pq = `torch.zeros(b, r, p, q)` for i in range(p):

for j in range(q):

`sigma_pq[:, :, i, j] = hp[:, :, i] * rq[:, :, j] - hq[:, :, j] * rp[:, :, i]`

`print(sigma_pq.shape)`

apply_coefficients(hp, hq, rp, rq)

Multiplying a base vector with its scalar coefficient

clifford_multiplication(h0, hp, hq, r0, rp, rq)

Compute our CL multiplication

$$h = h_0 + \sum_{i=1}^p h_i e_i + \sum_{j=p+1}^{p+q} h_j e_j \quad r = r_0 + \sum_{i=1}^p r_i e_i + \sum_{j=p+1}^{p+q} r_j e_j$$

$$ei^2 = +1 \text{ for } i <= p \quad ej^2 = -1 \text{ for } p < j <= p+q \quad ei ej = -ejei \text{ for } i$$

`eq j`

$$h r = \sigma_0 + \sigma_p + \sigma_q + \sigma_{pp} + \sigma_{qq} + \sigma_{pq} \text{ where}$$

(1) $\sigma_0 = h_0 r_0 + \sum_{i=1}^p (h_i r_i) e_i - \sum_{j=p+1}^{p+q} (h_j r_j) e_j$

(2) $\sigma_p = \sum_{i=1}^p (h_0 r_i + h_i r_0) e_i$

(3) $\sigma_q = \sum_{j=p+1}^{p+q} (h_0 r_j + h_j r_0) e_j$

(4) $\sigma_{pp} = \sum_{i=1}^{p-1} \sum_{k=i+1}^p (h_i r_k - h_k r_i) e_i e_k$

(5) $\sigma_{qq} = \sum_{j=1}^{p+q-1} \sum_{k=j+1}^{p+q} (h_j r_k - h_k r_j) e_j e_k$

(6) $\sigma_{pq} = \sum_{i=1}^p \sum_{j=p+1}^{p+q} (h_i r_j - h_j r_i) e_i e_j$

construct_cl_multivector (*x*: torch.FloatTensor, *r*: int, *p*: int, *q*: int)
 \rightarrow tuple[torch.FloatTensor, torch.FloatTensor, torch.FloatTensor]

Construct a batch of multivectors $Cl_{\{p,q\}}(\mathbb{R}^d)$

Parameter

x: torch.FloatTensor with (n,d) shape

returns

- **a0** (torch.FloatTensor with (n,r) shape)
- **ap** (torch.FloatTensor with (n,r,p) shape)
- **aq** (torch.FloatTensor with (n,r,q) shape)

forward_k_vs_with_explicit (*x*: torch.Tensor)

k_vs_all_score (*bpe_head_ent_emb*, *bpe_rel_ent_emb*, *E*)

forward_k_vs_all (*x*: torch.Tensor) \rightarrow torch.FloatTensor

Kvsall training

- (1) Retrieve real-valued embedding vectors for heads and relations \mathbb{R}^d .
- (2) Construct head entity and relation embeddings according to $Cl_{\{p,q\}}(\mathbb{R}^d)$.
- (3) Perform Cl multiplication
- (4) Inner product of (3) and all entity embeddings

forward_k_vs_with_explicit and this funcitons are identical Parameter ——— *x*: torch.LongTensor with (n,2) shape :rtype: torch.FloatTensor with (n, |E|) shape

construct_batch_selected_cl_multivector (*x*: torch.FloatTensor, *r*: int, *p*: int, *q*: int)
 \rightarrow tuple[torch.FloatTensor, torch.FloatTensor, torch.FloatTensor]

Construct a batch of batchs multivectors $Cl_{\{p,q\}}(\mathbb{R}^d)$

Parameter

x: torch.FloatTensor with (n,k, d) shape

returns

- **a0** (torch.FloatTensor with (n,k, m) shape)
- **ap** (torch.FloatTensor with (n,k, m, p) shape)
- **aq** (torch.FloatTensor with (n,k, m, q) shape)

forward_k_vs_sample (*x*: torch.LongTensor, *target_entity_idx*: torch.LongTensor) \rightarrow torch.FloatTensor

Parameter

x: torch.LongTensor with (n,2) shape

target_entity_idx: torch.LongTensor with (n, k) shape k denotes the selected number of examples.

rtype

torch.FloatTensor with (n, k) shape

```

score(h, r, t)
forward_triples(x: torch.Tensor) → torch.FloatTensor

```

Parameter

x: *torch.LongTensor* with (n,3) shape

rtype

torch.FloatTensor with (n) shape

```
class dicee.models.CKeci(args)
```

Bases: *Keci*

Without learning dimension scaling

```
name = 'CKeci'
```

```
requires_grad_for_interactions = False
```

```
class dicee.models.DeCaL(args)
```

Bases: *dicee.models.base_model.BaseKGE*

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```

import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))

```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training` (*bool*) – Boolean represents whether this module is in training or evaluation mode.

```
name = 'DeCaL'
```

```

entity_embeddings
relation_embeddings

p



q



r



re



forward_triples (x: torch.Tensor) → torch.FloatTensor


```

Parameter

x: *torch.LongTensor* with (n,) shape

rtype

torch.FloatTensor with (n) shape

c1_pqr (*a*: *torch.tensor*) → *torch.tensor*

Input: tensor(batch_size, emb_dim) —> output: tensor with 1+p+q+r components with size (batch_size, emb_dim/(1+p+q+r)) each.

1) takes a tensor of size (batch_size, emb_dim), split it into 1 + p + q +r components, hence 1+p+q+r must be a divisor of the emb_dim. 2) Return a list of the 1+p+q+r components vectors, each are tensors of size (batch_size, emb_dim/(1+p+q+r))

compute_sigmas_single (*list_h_emb*, *list_r_emb*, *list_t_emb*)

here we compute all the sums with no others vectors interaction taken with the scalar product with t, that is,

$$s0 = h_0 r_0 t_0 s1 = \sum_{i=1}^p h_i r_i t_0 s2 = \sum_{j=p+1}^{p+q} h_j r_j t_0 s3 = \sum_{i=1}^q (h_0 r_i t_i + h_i r_0 t_i) s4 = \sum_{i=p+1}^{p+q} (h_0 r_i t_i + h_i r_0 t_i) s5 = \sum_{i=p+q+1}^{p+q+r} (h_0 r_i t_i + h_i r_0 t_i)$$

and return:

$$\sigma_0 t = \sigma_0 \cdot t_0 = s0 + s1 - s2s3, s4ands5$$

compute_sigmas_multivect (*list_h_emb*, *list_r_emb*)

Here we compute and return all the sums with vectors interaction for the same and different bases.

For same bases vectors interaction we have

$$\sigma_{pp} = \sum_{i=1}^{p-1} \sum_{i'=i+1}^p (h_i r_{i'} - h_{i'} r_i) (modelsthe interactions between e_i and e'_{i'} for 1 \leq i, i' \leq p) \sigma_{qq} = \sum_{j=p+1}^{p+q-1} \sum_{j'=j+1}^{p+q} (h_j r_{j'} - h_{j'} r_j)$$

For different base vector interactions, we have

$$\sigma_{pq} = \sum_{i=1}^p \sum_{j=p+1}^{p+q} (h_i r_j - h_j r_i) (interactions n between e_i and e_j for 1 \leq i \leq p and p+1 \leq j \leq p+q) \sigma_{pr} = \sum_{i=1}^p \sum_{j=p+1}^{p+q} (h_i r_j - h_j r_i) (interactions n between e_i and e_j for 1 \leq i \leq p and p+1 \leq j \leq p+q)$$

forward_k_vs_all (*x*: *torch.Tensor*) → *torch.FloatTensor*
 Kvsall training
 (1) Retrieve real-valued embedding vectors for heads and relations
 (2) Construct head entity and relation embeddings according to $\text{Cl}_{\{p,q,r\}}(\mathbb{R}^d)$.
 (3) Perform Cl multiplication
 (4) Inner product of (3) and all entity embeddings

forward_k_vs_with_explicit and this funcitons are identical Parameter ——— *x*: *torch.LongTensor* with (n,) shape :*dtype*: *torch.FloatTensor* with (n, |E|) shape

apply_coefficients (*h0, hp, hq, hk, r0, rp, rq, rk*)

Multiplying a base vector with its scalar coefficient

construct_cl_multivector (*x*: *torch.FloatTensor*, *re*: int, *p*: int, *q*: int, *r*: int)
 → tuple[*torch.FloatTensor*, *torch.FloatTensor*, *torch.FloatTensor*]

Construct a batch of multivectors $\text{Cl}_{\{p,q,r\}}(\mathbb{R}^d)$

Parameter

x: *torch.FloatTensor* with (n,d) shape

returns

- **a0** (*torch.FloatTensor*)
- **ap** (*torch.FloatTensor*)
- **aq** (*torch.FloatTensor*)
- **ar** (*torch.FloatTensor*)

compute_sigma_pp (*hp, rp*)

Compute .. math:

$$\sigma_{pp} = \sum_{i=1}^{p-1} \sum_{i'=i+1}^p (x_i y_{i'} - x_{i'} y_i)$$

σ_{pp} captures the interactions between along p bases For instance, let p e_1, e_2, e_3, we compute interactions between e_1 e_2, e_1 e_3 , and e_2 e_3 This can be implemented with a nested two for loops

results = [] for i in range(p - 1):

```
for k in range(i + 1, p):
    results.append(hp[:, :, i] * rp[:, :, k] - hp[:, :, k] * rp[:, :, i])
sigma_pp = torch.stack(results, dim=2) assert sigma_pp.shape == (b, r, int((p * (p - 1)) / 2))
```

Yet, this computation would be quite inefficient. Instead, we compute interactions along all p, e.g., e1e1, e1e2, e1e3,

e2e1, e2e2, e2e3, e3e1, e3e2, e3e3

Then select the triangular matrix without diagonals: e1e2, e1e3, e2e3.

compute_sigma_qq (*hq, rq*)

Compute

$$\sigma_{q,q}^* = \sum_{j=p+1}^{p+q-1} \sum_{j'=j+1}^{p+q} (x_j y_{j'} - x_{j'} y_j) \quad \text{Eq.16}$$

`sigma_{q}` captures the interactions between along q bases For instance, let q e_1, e_2, e_3, we compute interactions between e_1 e_2, e_1 e_3 , and e_2 e_3 This can be implemented with a nested two for loops

results = [] for j in range(q - 1):

for k in range(j + 1, q):

results.append(hq[:, :, j] * rq[:, :, k] - hq[:, :, k] * rq[:, :, j])

sigma_qq = torch.stack(results, dim=2) assert sigma_qq.shape == (b, r, int((q * (q - 1)) / 2))

Yet, this computation would be quite inefficient. Instead, we compute interactions along all p, e.g., e1e1, e1e2, e1e3,

e2e1, e2e2, e2e3, e3e1, e3e2, e3e3

Then select the triangular matrix without diagonals: e1e2, e1e3, e2e3.

compute_sigma_rr(hk, rk)

$$\sigma_{r,r}^* = \sum_{k=p+q+1}^{p+q+r-1} \sum_{k'=k+1}^p (x_k y_{k'} - x_{k'} y_k)$$

compute_sigma_pq(* hp, hq, rp, rq)

Compute

$$\sum_{i=1}^p \sum_{j=p+1}^{p+q} (h_i r_j - h_j r_i) e_i e_j$$

results = [] sigma_pq = torch.zeros(b, r, p, q) for i in range(p):

for j in range(q):

sigma_pq[:, :, i, j] = hp[:, :, i] * rq[:, :, j] - hq[:, :, j] * rp[:, :, i]

print(sigma_pq.shape)

compute_sigma_pr(* hp, hk, rp, rk)

Compute

$$\sum_{i=1}^p \sum_{j=p+1}^{p+q} (h_i r_j - h_j r_i) e_i e_j$$

results = [] sigma_pq = torch.zeros(b, r, p, q) for i in range(p):

for j in range(q):

sigma_pq[:, :, i, j] = hp[:, :, i] * rq[:, :, j] - hq[:, :, j] * rp[:, :, i]

print(sigma_pq.shape)

compute_sigma_qr(* hq, hk, rq, rk)

$$\sum_{i=1}^p \sum_{j=p+1}^{p+q} (h_i r_j - h_j r_i) e_i e_j$$

results = [] sigma_pq = torch.zeros(b, r, p, q) for i in range(p):

for j in range(q):

sigma_pq[:, :, i, j] = hp[:, :, i] * rq[:, :, j] - hq[:, :, j] * rp[:, :, i]

print(sigma_pq.shape)

```
class dicee.models.BaseKGE(args: dict)
```

Bases: `BaseKGELightning`

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-modules as regular attributes:

```
import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))
```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training (bool)` – Boolean represents whether this module is in training or evaluation mode.

```
args
embedding_dim = None
num_entities = None
num_relations = None
num_tokens = None
learning_rate = None
apply_unit_norm = None
input_dropout_rate = None
hidden_dropout_rate = None
optimizer_name = None
feature_map_dropout_rate = None
```

```

kernel_size = None
num_of_output_channels = None
weight_decay = None
loss
selected_optimizer = None
normalizer_class = None
normalize_head_entity_embeddings
normalize_relation_embeddings
normalize_tail_entity_embeddings
hidden_normalizer
param_init
input_dp_ent_real
input_dp_rel_real
hidden_dropout
loss_history = []
byte_pair_encoding
max_length_subword_tokens
block_size
forward_byte_pair_encoded_k_vs_all(x: torch.LongTensor)

Parameters
  x (B x 2 x T)

forward_byte_pair_encoded_triple(x: Tuple[torch.LongTensor, torch.LongTensor])
  byte pair encoded neural link predictors

Parameters
-----
init_params_with_sanity_checking()

forward(x: torch.LongTensor | Tuple[torch.LongTensor, torch.LongTensor],
      y_idx: torch.LongTensor = None)

Parameters
  • x
  • y_idx
  • ordered_bpe_entities

```

```
forward_triples (x: torch.LongTensor) → torch.Tensor
```

Parameters

x

```
forward_k_vs_all (*args, **kwargs)
```

```
forward_k_vs_sample (*args, **kwargs)
```

```
get_triple_representation (idx_hrt)
```

```
get_head_relation_representation (indexed_triple)
```

```
get_sentence_representation (x: torch.LongTensor)
```

Parameters

- (b (x shape)

- 3

- t)

```
get_bpe_head_and_relation_representation (x: torch.LongTensor)
```

→ Tuple[torch.FloatTensor, torch.FloatTensor]

Parameters

x (B x 2 x T)

```
get_embeddings () → Tuple[numpy.ndarray, numpy.ndarray]
```

```
class dicee.models.PykeenKGE (args: dict)
```

Bases: dicee.models.base_model.BaseKGE

A class for using knowledge graph embedding models implemented in Pykeen

Notes: Pykeen_DistMult: C Pykeen_ComplEx: Pykeen_QuatE: Pykeen_MuRE: Pykeen_CP: Pykeen_HolE: Pykeen_HolE: Pykeen_HolE: Pykeen_TransD: Pykeen_TransE: Pykeen_TransF: Pykeen_TransH: Pykeen_TransR:

model_kwargs

name

model

loss_history = []

args

entity_embeddings = None

relation_embeddings = None

```
forward_k_vs_all (x: torch.LongTensor)
```

=> Explicit version by this we can apply bn and dropout

(1) Retrieve embeddings of heads and relations + apply Dropout & Normalization if given. h, r = self.get_head_relation_representation(x) # (2) Reshape (1). if self.last_dim > 0:

h = h.reshape(len(x), self.embedding_dim, self.last_dim) r = r.reshape(len(x), self.embedding_dim, self.last_dim)

(3) Reshape all entities. if self.last_dim > 0:

```

t = self.entity_embeddings.weight.reshape(self.num_entities, self.embedding_dim, self.last_dim)

else:
    t = self.entity_embeddings.weight

# (4) Call the score_t from interactions to generate triple scores. return self.interaction.score_t(h=h, r=r,
all_entities=t, slice_size=1)

forward_triples (x: torch.LongTensor) → torch.FloatTensor
# => Explicit version by this we can apply bn and dropout
# (1) Retrieve embeddings of heads, relations and tails and apply Dropout & Normalization if given. h, r, t =
self.get_triple_representation(x) # (2) Reshape (1). if self.last_dim > 0:
    h = h.reshape(len(x), self.embedding_dim, self.last_dim) r = r.reshape(len(x), self.embedding_dim,
    self.last_dim) t = t.reshape(len(x), self.embedding_dim, self.last_dim)
# (3) Compute the triple score return self.interaction.score(h=h, r=r, t=t, slice_size=None, slice_dim=0)

abstractmethod forward_k_vs_sample (x: torch.LongTensor, target_entity_idx)

class dicee.models.BaseKGE (args: dict)
Bases: BaseKGELightning

Base class for all neural network modules.

Your models should also subclass this class.

Modules can also contain other Modules, allowing them to be nested in a tree structure. You can assign the sub-
modules as regular attributes:

```

```

import torch.nn as nn
import torch.nn.functional as F

class Model(nn.Module):
    def __init__(self) -> None:
        super().__init__()
        self.conv1 = nn.Conv2d(1, 20, 5)
        self.conv2 = nn.Conv2d(20, 20, 5)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        return F.relu(self.conv2(x))

```

Submodules assigned in this way will be registered, and will also have their parameters converted when you call `to()`, etc.

Note

As per the example above, an `__init__()` call to the parent class must be made before assignment on the child.

Variables

`training (bool)` – Boolean represents whether this module is in training or evaluation mode.

```

args
embedding_dim = None
num_entities = None
num_relations = None
num_tokens = None
learning_rate = None
apply_unit_norm = None
input_dropout_rate = None
hidden_dropout_rate = None
optimizer_name = None
feature_map_dropout_rate = None
kernel_size = None
num_of_output_channels = None
weight_decay = None
loss
selected_optimizer = None
normalizer_class = None
normalize_head_entity_embeddings
normalize_relation_embeddings
normalize_tail_entity_embeddings
hidden_normalizer
param_init
input_dp_ent_real
input_dp_rel_real
hidden_dropout
loss_history = []
byte_pair_encoding
max_length_subword_tokens
block_size
forward_byte_pair_encoded_k_vs_all(x: torch.LongTensor)

```

Parameters

x ($B \times 2 \times T$)

```

forward_byte_pair_encoded_triple(x: Tuple[torch.LongTensor, torch.LongTensor])
    byte pair encoded neural link predictors

    Parameters
    -----
    init_params_with_sanity_checking()

    forward(x: torch.LongTensor | Tuple[torch.LongTensor, torch.LongTensor],
            y_idx: torch.LongTensor = None)

    Parameters
    • x
    • y_idx
    • ordered_bpe_entities

    forward_triples(x: torch.LongTensor) → torch.Tensor

    Parameters
    x

    forward_k_vs_all(*args, **kwargs)

    forward_k_vs_sample(*args, **kwargs)

    get_triple_representation(idx_hrt)

    get_head_relation_representation(indexed_triple)

    get_sentence_representation(x: torch.LongTensor)

    Parameters
    • (b (x shape)
    • 3
    • t)

    get_bpe_head_and_relation_representation(x: torch.LongTensor)
        → Tuple[torch.FloatTensor, torch.FloatTensor]

    Parameters
    x (B x 2 x T)

    get_embeddings() → Tuple[numpy.ndarray, numpy.ndarray]

class dicee.models.FMult(args)
    Bases: dicee.models.base_model.BaseKGE

    Learning Knowledge Neural Graphs

    name = 'FMult'

    entity_embeddings

    relation_embeddings

    k

```

```

num_sample = 50
gamma
roots
weights

compute_func (weights: torch.FloatTensor, x) → torch.FloatTensor
chain_func (weights, x: torch.FloatTensor)
forward_triples (idx_triple: torch.Tensor) → torch.Tensor

Parameters
x

class dicee.models.GFMult (args)
Bases: dicee.models.base_model.BaseKGE
Learning Knowledge Neural Graphs
name = 'GFMult'

entity_embeddings
relation_embeddings

k
num_sample = 250
roots
weights

compute_func (weights: torch.FloatTensor, x) → torch.FloatTensor
chain_func (weights, x: torch.FloatTensor)
forward_triples (idx_triple: torch.Tensor) → torch.Tensor

Parameters
x

class dicee.models.FMult2 (args)
Bases: dicee.models.base_model.BaseKGE
Learning Knowledge Neural Graphs
name = 'FMult2'

n_layers = 3
k
n = 50
score_func = 'compositional'
discrete_points

```

```

entity_embeddings
relation_embeddings
build_func (Vec)
build_chain_funcs (list_Vec)
compute_func (W, b, x) → torch.FloatTensor
function (list_W, list_b)
trapezoid (list_W, list_b)
forward_triples (idx_triple: torch.Tensor) → torch.Tensor

```

Parameters

x

```
class dicee.models.LFMult1 (args)
```

Bases: *dicee.models.base_model.BaseKGE*

Embedding with trigonometric functions. We represent all entities and relations in the complex number space as: $f(x) = \sum_{k=0}^d \{k=0\}^k w_k e^{ikx}$. and use the three different scoring function as in the paper to evaluate the score

```

name = 'LFMult1'

entity_embeddings
relation_embeddings
forward_triples (idx_triple)

```

Parameters

x

tri_score (*h, r, t*)

vtp_score (*h, r, t*)

```
class dicee.models.LFMult (args)
```

Bases: *dicee.models.base_model.BaseKGE*

Embedding with polynomial functions. We represent all entities and relations in the polynomial space as: $f(x) = \sum_{i=0}^d a_i x^i$ and use the three different scoring function as in the paper to evaluate the score. We also consider combining with Neural Networks.

```

name = 'LFMult'

entity_embeddings
relation_embeddings
degree
m
x_values

```

```

forward_triples (idx_triple)

Parameters
    x

construct_multi_coeff (x)

poly_NN (x, coefh, coefr, coeft)
    Constructing a 2 layers NN to represent the embeddings. h = sigma( $wh^T x + bh$ ), r = sigma( $wr^T x + br$ ), t = sigma( $wt^T x + bt$ )

linear (x, w, b)

scalar_batch_NN (a, b, c)
    element wise multiplication between a,b and c: Inputs : a, b, c =====> torch.tensor of size batch_size x m x d Output : a tensor of size batch_size x d

tri_score (coeff_h, coeff_r, coeff_t)
    this part implement the trilinear scoring techniques:
    score( $h, r, t$ ) =  $\int_{\{0\}} \{1\} h(x)r(x)t(x) dx = \sum_{\{i,j,k=0\}}^{d-1} \frac{a_i * b_j * c_k}{(1+(i+j+k)\%d)}$ 
    1. generate the range for i,j and k from [0 d-1]
    2. perform  $\frac{a_i * b_j * c_k}{(1+(i+j+k)\%d)}$  in parallel for every batch
    3. take the sum over each batch

vtp_score ( $h, r, t$ )
    this part implement the vector triple product scoring techniques:
    score( $h, r, t$ ) =  $\int_{\{0\}} \{1\} h(x)r(x)t(x) dx = \sum_{\{i,j,k=0\}}^{d-1} \frac{a_i * c_j * b_k - b_i * c_j * a_k}{((1+(i+j)\%d)(1+k))}$ 
    1. generate the range for i,j and k from [0 d-1]
    2. Compute the first and second terms of the sum
    3. Multiply with then denominator and take the sum
    4. take the sum over each batch

comp_func ( $h, r, t$ )
    this part implement the function composition scoring techniques: i.e. score = <hor, t>

polynomial (coeff, x, degree)
    This function takes a matrix tensor of coefficients (coeff), a tensor vector of points x and range of integer [0,1,...d] and return a vector tensor ( $coeff[0][0] + coeff[0][1]x + ... + coeff[0][d]x^d$ )

coeff[1][0] + coeff[1][1]x +...+ coeff[1][d]x^d

pop (coeff, x, degree)
    This function allow us to evaluate the composition of two polynomials without for loops :) it takes a matrix tensor of coefficients (coeff), a matrix tensor of points x and range of integer [0,1,...d]
    and return a tensor ( $coeff[0][0] + coeff[0][1]x + ... + coeff[0][d]x^d$ )

coeff[1][0] + coeff[1][1]x +...+ coeff[1][d]x^d

class dicee.models.Duale (args)
Bases: dicee.models.base_model.BaseKGE

Dual Quaternion Knowledge Graph Embeddings (https://ojs.aaai.org/index.php/AAAI/article/download/16850/16657)

```

```
name = 'DualE'

entity_embeddings
relation_embeddings

num_ent = None

kvsall_score (e_1_h, e_2_h, e_3_h, e_4_h, e_5_h, e_6_h, e_7_h, e_8_h, e_1_t, e_2_t, e_3_t, e_4_t,
              e_5_t, e_6_t, e_7_t, e_8_t, r_1, r_2, r_3, r_4, r_5, r_6, r_7, r_8) → torch.tensor
    KvsAll scoring function
```

Input

x: torch.LongTensor with (n,) shape

Output

torch.FloatTensor with (n) shape

```
forward_triples (idx_triple: torch.tensor) → torch.tensor
```

Negative Sampling forward pass:

Input

x: torch.LongTensor with (n,) shape

Output

torch.FloatTensor with (n) shape

```
forward_k_vs_all (x)
```

KvsAll forward pass

Input

x: torch.LongTensor with (n,) shape

Output

torch.FloatTensor with (n) shape

```
T (x: torch.tensor) → torch.tensor
```

Transpose function

Input: Tensor with shape (nxm) Output: Tensor with shape (mxn)

dicee.query_generator

Classes

QueryGenerator

Module Contents

```
class dicee.query_generator.QueryGenerator (train_path: str, val_path: str, test_path: str,
    ent2id: Dict = None, rel2id: Dict = None, seed: int = 1, gen_valid: bool = False,
    gen_test: bool = True)

    train_path
    val_path
    test_path
    gen_valid = False
    gen_test = True
    seed = 1
    max_ans_num = 1000000.0
    mode
    ent2id = None
    rel2id: Dict = None
    ent_in: Dict
    ent_out: Dict
    query_name_to_struct
    list2tuple (list_data)
    tuple2list (x: List | Tuple) → List | Tuple
        Convert a nested tuple to a nested list.
    set_global_seed (seed: int)
        Set seed
    construct_graph (paths: List[str]) → Tuple[Dict, Dict]
        Construct graph from triples Returns dicts with incoming and outgoing edges
    fill_query (query_structure: List[str | List], ent_in: Dict, ent_out: Dict, answer: int) → bool
        Private method for fill_query logic.
    achieve_answer (query: List[str | List], ent_in: Dict, ent_out: Dict) → set
        Private method for achieve_answer logic. @TODO: Document the code
    write_links (ent_out, small_ent_out)
    ground_queries (query_structure: List[str | List], ent_in: Dict, ent_out: Dict, small_ent_in: Dict,
        small_ent_out: Dict, gen_num: int, query_name: str)
        Generating queries and achieving answers
    unmap (query_type, queries, tp_answers, fp_answers, fn_answers)
    unmap_query (query_structure, query, id2ent, id2rel)
```

```

generate_queries (query_struct: List, gen_num: int, query_type: str)
    Passing incoming and outgoing edges to ground queries depending on mode [train valid or text] and getting
    queries and answers in return @ TODO: create a class for each single query struct

save_queries (query_type: str, gen_num: int, save_path: str)

abstractmethod load_queries (path)

get_queries (query_type: str, gen_num: int)

static save_queries_and_answers (path: str, data: List[Tuple[str, Tuple[collections.defaultdict]]])
    → None
    Save Queries into Disk

static load_queries_and_answers (path: str) → List[Tuple[str, Tuple[collections.defaultdict]]]
    Load Queries from Disk to Memory

```

dicee.read_preprocess_save_load_kg

Submodules

dicee.read_preprocess_save_load_kg.preprocess

Classes

<i>PreprocessKG</i>	Preprocess the data in memory
---------------------	-------------------------------

Module Contents

```

class dicee.read_preprocess_save_load_kg.preprocess.PreprocessKG (kg)
    Preprocess the data in memory

    kg

    start () → None
        Preprocess train, valid and test datasets stored in knowledge graph instance

```

Parameter

rtype	None
preprocess_with_byte_pair_encoding()	
preprocess_with_byte_pair_encoding_with_padding()	→ None
Preprocess with byte pair encoding and add padding	
preprocess_with_pandas()	→ None
Preprocess with pandas: add reciprocal triples, construct vocabulary, and index datasets	
preprocess_with_polars()	→ None
Preprocess with polars: add reciprocal triples and create indexed datasets	

```
sequential_vocabulary_construction() → None  
    (1) Read input data into memory  
    (2) Remove triples with a condition  
    (3) Serialize vocabularies in a pandas dataframe where  
        => the index is integer and => a single column is string (e.g. URI)
```

dicee.read_preprocess_save_load_kg.read_from_disk

Classes

<i>ReadFromDisk</i>	Read the data from disk into memory
---------------------	-------------------------------------

Module Contents

```
class dicee.read_preprocess_save_load_kg.read_from_disk.ReadFromDisk(kg)  
    Read the data from disk into memory  
  
kg  
  
start() → None  
    Read a knowledge graph from disk into memory  
    Data will be available at the train_set, test_set, valid_set attributes.
```

Parameter

None

rtype
None

```
add_noisy_triples_into_training()
```

dicee.read_preprocess_save_load_kg.save_load_disk

Classes

<i>LoadSaveToDisk</i>

Module Contents

```
class dicee.read_preprocess_save_load_kg.save_load_disk.LoadSaveToDisk(kg)  
  
kg  
  
save()  
  
load()
```

dicee.read_preprocess_save_load_kg.util

Functions

<code>polars_dataframe_indexer</code> (→ polars.DataFrame)	Replaces 'subject', 'relation', and 'object' columns in the input Polars DataFrame with their corresponding index values
<code>pandas_dataframe_indexer</code> (→ pandas.DataFrame)	Replaces 'subject', 'relation', and 'object' columns in the input Pandas DataFrame with their corresponding index values
<code>apply_reciprocal_or_noise</code> (add_reciprocal, eval_model)	Add reciprocal triples if conditions are met
<code>timeit</code> (func)	
<code>read_with_polars</code> (→ polars.DataFrame)	Load and Preprocess via Polars
<code>read_with_pandas</code> (data_path[, read_only_few, ...])	Load and Preprocess via Pandas
<code>read_from_disk</code> (→ Tuple[polars.DataFrame, pandas.DataFrame])	
<code>count_triples</code> (→ int)	Returns the total number of triples in the triple store.
<code>fetch_worker</code> (endpoint, offsets, chunk_size, ...)	Worker process: fetch assigned chunks and save to disk with per-worker tqdm.
<code>read_from_triple_store_with_polars</code> (endpoint[, ...])	Main function to read all triples in parallel, save as Parquet, and load into Polars dataframe.
<code>read_from_triple_store_with_pandas</code> ([endpoint])	Read triples from triple store into pandas dataframe
<code>get_er_vocab</code> (data[, file_path])	
<code>get_re_vocab</code> (data[, file_path])	
<code>get_ee_vocab</code> (data[, file_path])	
<code>create_constraints</code> (triples[, file_path])	
<code>load_with_pandas</code> (→ None)	Deserialize data
<code>save_numpy_ndarray</code> (*[, data, file_path])	
<code>load_numpy_ndarray</code> (*[, file_path])	
<code>save_pickle</code> (*[, data[, file_path]])	
<code>load_pickle</code> (*[, file_path])	
<code>create_reciprocal_triples</code> (x)	Add inverse triples into dask dataframe
<code>dataset_sanity_checking</code> (→ None)	

Module Contents

```
dicee.read_preprocess_save_load_kg.util.polars_dataframe_indexer(  
    df_polars: polars.DataFrame, idx_entity: polars.DataFrame, idx_relation: polars.DataFrame)  
    → polars.DataFrame
```

Replaces ‘subject’, ‘relation’, and ‘object’ columns in the input Polars DataFrame with their corresponding index values from the entity and relation index DataFrames.

This function processes the DataFrame in three main steps: 1. Replace the ‘relation’ values with the corresponding index from *idx_relation*. 2. Replace the ‘subject’ values with the corresponding index from *idx_entity*. 3. Replace the ‘object’ values with the corresponding index from *idx_entity*.

Parameters:

`df_polars`

[polars.DataFrame] The input Polars DataFrame containing columns: ‘subject’, ‘relation’, and ‘object’.

`idx_entity`

[polars.DataFrame] A Polars DataFrame that contains the mapping between entity names and their corresponding indices. Must have columns: ‘entity’ and ‘index’.

idx_relation

[polars.DataFrame] A Polars DataFrame that contains the mapping between relation names and their corresponding indices. Must have columns: ‘relation’ and ‘index’.

Returns:

polars.DataFrame

A DataFrame with the ‘subject’, ‘relation’, and ‘object’ columns replaced by their corresponding indices.

Example Usage:

```
>>> df_polars = pl.DataFrame({
    "subject": ["Alice", "Bob", "Charlie"],
    "relation": ["knows", "works_with", "lives_in"],
    "object": ["Dave", "Eve", "Frank"]
})
>>> idx_entity = pl.DataFrame({
    "entity": ["Alice", "Bob", "Charlie", "Dave", "Eve", "Frank"],
    "index": [0, 1, 2, 3, 4, 5]
})
>>> idx_relation = pl.DataFrame({
    "relation": ["knows", "works_with", "lives_in"],
    "index": [0, 1, 2]
})
>>> polars_dataframe_indexer(df_polars, idx_entity, idx_relation)
```

Steps:

1. Join the input DataFrame *df_polars* on the ‘relation’ column with *idx_relation* to replace the relations with their indices.
2. Join on ‘subject’ to replace it with the corresponding entity index using a left join on *idx_entity*.
3. Join on ‘object’ to replace it with the corresponding entity index using a left join on *idx_entity*.
4. Select only the ‘subject’, ‘relation’, and ‘object’ columns to return the final result.

```
dicee.read_preprocess_save_load_kg.util.pandas_dataframe_indexer(
    df_pandas: pandas.DataFrame, idx_entity: pandas.DataFrame, idx_relation: pandas.DataFrame)
    → pandas.DataFrame
```

Replaces ‘subject’, ‘relation’, and ‘object’ columns in the input Pandas DataFrame with their corresponding index values from the entity and relation index DataFrames.

Parameters:

df_pandas

[pd.DataFrame] The input Pandas DataFrame containing columns: ‘subject’, ‘relation’, and ‘object’.

idx_entity

[pd.DataFrame] A Pandas DataFrame that contains the mapping between entity names and their corresponding indices. Must have columns: ‘entity’ and ‘index’.

idx_relation

[pd.DataFrame] A Pandas DataFrame that contains the mapping between relation names and their corresponding indices. Must have columns: ‘relation’ and ‘index’.

Returns:

pd.DataFrame

A DataFrame with the ‘subject’, ‘relation’, and ‘object’ columns replaced by their corresponding indices.

```
dicee.read_preprocess_save_load_kg.util.apply_reciprocal_or_noise(add_reciprocal: bool,  
eval_model: str, df: object = None, info: str = None)
```

Add reciprocal triples if conditions are met

```
dicee.read_preprocess_save_load_kg.util.timeit(func)
```

```
dicee.read_preprocess_save_load_kg.util.read_with_polars(data_path,  
read_only_few: int = None, sample_triples_ratio: float = None, separator: str = None)  
→ polars.DataFrame
```

Load and Preprocess via Polars

```
dicee.read_preprocess_save_load_kg.util.read_with_pandas(data_path,  
read_only_few: int = None, sample_triples_ratio: float = None, separator: str = None)
```

Load and Preprocess via Pandas

```
dicee.read_preprocess_save_load_kg.util.read_from_disk(data_path: str,  
read_only_few: int = None, sample_triples_ratio: float = None, backend: str = None,  
separator: str = None) → Tuple[polars.DataFrame, pandas.DataFrame]
```

```
dicee.read_preprocess_save_load_kg.util.count_triples(endpoint: str) → int
```

Returns the total number of triples in the triple store.

```
dicee.read_preprocess_save_load_kg.util.fetch_worker(endpoint: str, offsets: list[int],  
chunk_size: int, output_dir: str, worker_id: int)
```

Worker process: fetch assigned chunks and save to disk with per-worker tqdm.

```
dicee.read_preprocess_save_load_kg.util.read_from_triple_store_with_polars(  
endpoint: str, chunk_size: int = 500000, output_dir: str = 'triples_parquet')
```

Main function to read all triples in parallel, save as Parquet, and load into Polars dataframe.

```
dicee.read_preprocess_save_load_kg.util.read_from_triple_store_with_pandas(  
endpoint: str = None)
```

Read triples from triple store into pandas dataframe

```
dicee.read_preprocess_save_load_kg.util.get_er_vocab(data, file_path: str = None)
```

```
dicee.read_preprocess_save_load_kg.util.get_re_vocab(data, file_path: str = None)
```

```
dicee.read_preprocess_save_load_kg.util.get_ee_vocab(data, file_path: str = None)
```

```
dicee.read_preprocess_save_load_kg.util.create_constraints(triples, file_path: str = None)
```

(1) Extract domains and ranges of relations

(2) Store a mapping from relations to entities that are outside of the domain and range. Create constrained entities based on the range of relations :param triples: :return: Tuple[dict, dict]

```
dicee.read_preprocess_save_load_kg.util.load_with_pandas(self) → None
```

Deserialize data

```

dicee.read_preprocess_save_load_kg.util.save_numpy_ndarray(*, data: numpy.ndarray,
    file_path: str)

dicee.read_preprocess_save_load_kg.util.load_numpy_ndarray(*, file_path: str)

dicee.read_preprocess_save_load_kg.util.save_pickle(*, data: object, file_path=str)

dicee.read_preprocess_save_load_kg.util.load_pickle(*, file_path=str)

dicee.read_preprocess_save_load_kg.util.create_recipriocal_triples(x)
    Add inverse triples into dask dataframe :param x: :return:

dicee.read_preprocess_save_load_kg.util.dataset_sanity_checking(
    train_set: numpy.ndarray, num_entities: int, num_relations: int) → None

```

Parameters

- **train_set**
- **num_entities**
- **num_relations**

Returns

Classes

<i>PreprocessKG</i>	Preprocess the data in memory
<i>LoadSaveToDisk</i>	
<i>ReadFromDisk</i>	Read the data from disk into memory

Package Contents

```

class dicee.read_preprocess_save_load_kg.PreprocessKG(kg)
    Preprocess the data in memory

    kg

    start() → None
        Preprocess train, valid and test datasets stored in knowledge graph instance

```

Parameter

rtype	
None	
preprocess_with_byte_pair_encoding()	
preprocess_with_byte_pair_encoding_with_padding()	→ None
Preprocess with byte pair encoding and add padding	
preprocess_with_pandas()	→ None
Preprocess with pandas: add reciprocal triples, construct vocabulary, and index datasets	
preprocess_with_polars()	→ None
Preprocess with polars: add reciprocal triples and create indexed datasets	

```

sequential_vocabulary_construction() → None
    (1) Read input data into memory
    (2) Remove triples with a condition
    (3) Serialize vocabularies in a pandas dataframe where
        => the index is integer and => a single column is string (e.g. URI)

class dicee.read_preprocess_save_load_kg.LoadSaveToDisk(kg)

    kg

    save()

    load()

class dicee.read_preprocess_save_load_kg.ReadFromDisk(kg)
    Read the data from disk into memory

    kg

    start() → None
        Read a knowledge graph from disk into memory
        Data will be available at the train_set, test_set, valid_set attributes.

```

Parameter

None

rtype

None

add_noisy_triples_into_training()

dicee.sanity_checkers

Functions

<code>is_sparql_endpoint_alive([sparql_endpoint])</code>	
<code>validate_knowledge_graph(args)</code>	Validating the source of knowledge graph
<code>sanity_checking_with_arguments(args)</code>	
<code>sanity_check_callback_args(args)</code>	Perform sanity checks on callback-related arguments.

Module Contents

`dicee.sanity_checkers.is_sparql_endpoint_alive(sparql_endpoint: str = None)`

`dicee.sanity_checkers.validate_knowledge_graph(args)`

Validating the source of knowledge graph

`dicee.sanity_checkers.sanity_checking_with_arguments(args)`

`dicee.sanity_checkers.sanity_check_callback_args(args)`

Perform sanity checks on callback-related arguments.

dicee.scripts

Submodules

dicee.scripts.index_serve

```
$ docker pull qdrant/qdrant && docker run -p 6333:6333 -p 6334:6334 -v $(pwd)/qdrant_storage:/qdrant/storage:z  
qdrant/qdrant $ dicee_vector_db --index --serve --path CountryEmbeddings --collection "countries_vdb"
```

Attributes

```
app  
neural_searcher
```

Classes

```
NeuralSearcher  
StringListRequest
```

Functions

```
get_default_arguments()  
index(args)  
root()  
search_embeddings(q)  
retrieve_embeddings(q)  
search_embeddings_batch(request)  
serve(args)  
main()
```

Module Contents

```
dicee.scripts.index_serve.get_default_arguments()  
  
dicee.scripts.index_serve.index(args)  
  
dicee.scripts.index_serve.app  
  
dicee.scripts.index_serve.neural_searcher = None  
  
class dicee.scripts.index_serve.NeuralSearcher(args)  
  
    collection_name  
  
    entity_to_idx = None  
  
    qdrant_client  
  
    topk = 5  
  
    retrieve_embedding(entity: str = None, entities: List[str] = None) → List
```

```

search(entity: str)

async dicee.scripts.index_server.root()

async dicee.scripts.index_server.search_embeddings(q: str)

async dicee.scripts.index_server.retrieve_embeddings(q: str)

class dicee.scripts.index_server.StringListRequest
    Bases: pydantic.BaseModel

        queries: List[str]

        reducer: str | None = None

async dicee.scripts.index_server.search_embeddings_batch(request: StringListRequest)

dicee.scripts.index_server.serve(args)

dicee.scripts.index_server.main()

```

dicee.scripts.run

Functions

<code>get_default_arguments([description])</code>	Extends pytorch_lightning Trainer's arguments with ours
<code>main()</code>	

Module Contents

`dicee.scripts.run.get_default_arguments(description=None)`

Extends pytorch_lightning Trainer's arguments with ours

`dicee.scripts.run.main()`

dicee.static_funcs

Static utility functions for DICE embeddings.

This module provides utility functions for model initialization, data loading, serialization, and various helper operations.

Attributes

<code>MODEL_REGISTRY</code>

Functions

<code>create_reciprocal_triples(→ pandas.DataFrame)</code>	Add inverse triples to a DataFrame.
<code>get_er_vocab(→ Dict[Tuple[int, int], List[int]])</code>	Build entity-relation to tail vocabulary.
<code>get_re_vocab(→ Dict[Tuple[int, int], List[int]])</code>	Build relation-entity (tail) to head vocabulary.

continues on next page

Table 55 – continued from previous page

<code>get_ee_vocab</code> (→ Dict[Tuple[int, int], List[int]])	Build entity-entity to relation vocabulary.
<code>timeit</code> (→ Callable)	Decorator to measure and print execution time and memory usage.
<code>save_pickle</code> (→ None)	Save data to a pickle file.
<code>load_pickle</code> (→ object)	Load data from a pickle file.
<code>load_term_mapping</code> (→ Union[dict, pandas.DataFrame])	Load term-to-index mapping from pickle or CSV file.
<code>select_model</code> (args[, is_continual_training, storage_path])	
<code>load_model</code> (→ Tuple[object, Tuple[dict, dict]])	Load weights and initialize pytorch module from namespace arguments
<code>load_model_ensemble</code> (...)	Construct Ensemble Of weights and initialize pytorch module from namespace arguments
<code>save_numpy_ndarray</code> (* , data, file_path)	
<code>numpy_data_type_changer</code> (→ numpy.ndarray)	Detect most efficient data type for a given triples
<code>save_checkpoint_model</code> (→ None)	Store Pytorch model into disk
<code>store</code> (→ None)	
<code>add_noisy_triples</code> (→ pandas.DataFrame)	Add randomly constructed triples
<code>read_or_load_kg</code> (args, cls)	
<code>initialize_model</code> (...)	Initialize a knowledge graph embedding model.
<code>load_json</code> (→ Dict)	Load JSON file into a dictionary.
<code>save_embeddings</code> (→ None)	Save embeddings to a CSV file.
<code>vocab_to_parquet</code> (vocab_to_idx, name, ...)	
<code>create_experiment_folder</code> (→ str)	Create a timestamped experiment folder.
<code>continual_training_setup_executor</code> (→ None)	
<code>exponential_function</code> (→ torch.FloatTensor)	
<code>load_numpy</code> (→ numpy.ndarray)	
<code>evaluate</code> (entity_to_idx, scores, easy_answers, hard_answers)	# @TODO: CD: Renamed this function
<code>download_file</code> (url[, destination_folder])	
<code>download_files_from_url</code> (→ None)	
<code>download_pretrained_model</code> (→ str)	
<code>write_csv_from_model_parallel</code> (path)	Create
<code>from_pretrained_model_write_embeddings_int</code> (None)	

Module Contents

```
dicee.static_funcs.MODEL_REGISTRY: Dict[str, Tuple[Type, str]]  
  
dicee.static_funcs.create_reciprocal_triples(df: pandas.DataFrame) → pandas.DataFrame  
Add inverse triples to a DataFrame.  
For each triple (s, p, o), creates an inverse triple (o, p_inverse, s).
```

Parameters

`df` – DataFrame with ‘subject’, ‘relation’, and ‘object’ columns.

Returns

DataFrame with original and inverse triples concatenated.

```
dicee.static_funcs.get_er_vocab(data: numpy.ndarray, file_path: str | None = None)  
→ Dict[Tuple[int, int], List[int]]
```

Build entity-relation to tail vocabulary.

Parameters

- **data** – Array of triples with shape (n, 3) where columns are (head, relation, tail).
- **file_path** – Optional path to save the vocabulary as pickle.

Returns

Dictionary mapping (head, relation) pairs to list of tail entities.

```
dicee.static_funcs.get_re_vocab(data: numpy.ndarray, file_path: str | None = None)
    → Dict[Tuple[int, int], List[int]]
```

Build relation-entity (tail) to head vocabulary.

Parameters

- **data** – Array of triples with shape (n, 3) where columns are (head, relation, tail).
- **file_path** – Optional path to save the vocabulary as pickle.

Returns

Dictionary mapping (relation, tail) pairs to list of head entities.

```
dicee.static_funcs.get_ee_vocab(data: numpy.ndarray, file_path: str | None = None)
    → Dict[Tuple[int, int], List[int]]
```

Build entity-entity to relation vocabulary.

Parameters

- **data** – Array of triples with shape (n, 3) where columns are (head, relation, tail).
- **file_path** – Optional path to save the vocabulary as pickle.

Returns

Dictionary mapping (head, tail) pairs to list of relations.

```
dicee.static_funcs.timeit(func: Callable) → Callable
```

Decorator to measure and print execution time and memory usage.

Parameters

func – Function to be timed.

Returns

Wrapped function that prints timing information.

```
dicee.static_funcs.save_pickle(*, data: object | None = None, file_path: str) → None
```

Save data to a pickle file.

Note: Consider using more portable formats (JSON, Parquet) for new code.

Parameters

- **data** – Object to serialize. If None, nothing is saved.
- **file_path** – Path where the pickle file will be saved.

```
dicee.static_funcs.load_pickle(file_path: str) → object
```

Load data from a pickle file.

Note: Consider using more portable formats (JSON, Parquet) for new code.

Parameters

file_path – Path to the pickle file.

Returns

Deserialized object from the pickle file.

```
dicee.static_funcs.load_term_mapping(file_path: str) → dict | polars.DataFrame
```

Load term-to-index mapping from pickle or CSV file.

Attempts to load from pickle first, falls back to CSV if not found.

Parameters

file_path – Base path without extension.

Returns

Dictionary or Polars DataFrame containing the mapping.

```
dicee.static_funcs.select_model(args: dict, is_continual_training: bool = None,  
storage_path: str = None)
```

```
dicee.static_funcs.load_model(path_of_experiment_folder: str, model_name='model.pt', verbose=0)  
→ Tuple[object, Tuple[dict, dict]]
```

Load weights and initialize pytorch module from namespace arguments

```
dicee.static_funcs.load_model_ensemble(path_of_experiment_folder: str)  
→ Tuple[dicee.models.base_model.BaseKGE, Tuple[pandas.DataFrame, pandas.DataFrame]]
```

Construct Ensemble Of weights and initialize pytorch module from namespace arguments

- (1) Detect models under given path
- (2) Accumulate parameters of detected models
- (3) Normalize parameters
- (4) Insert (3) into model.

```
dicee.static_funcs.save_numpy_ndarray(*args, data: numpy.ndarray, file_path: str)
```

```
dicee.static_funcs.numpy_data_type_changer(train_set: numpy.ndarray, num: int)  
→ numpy.ndarray
```

Detect most efficient data type for a given triples :param train_set: :param num: :return:

```
dicee.static_funcs.save_checkpoint_model(model, path: str) → None
```

Store Pytorch model into disk

```
dicee.static_funcs.store(trained_model, model_name: str = 'model', full_storage_path: str = None,  
save_embeddings_as_csv=False) → None
```

```
dicee.static_funcs.add_noisy_triples(train_set: pandas.DataFrame, add_noise_rate: float)  
→ pandas.DataFrame
```

Add randomly constructed triples :param train_set: :param add_noise_rate: :return:

```
dicee.static_funcs.read_or_load_kg(args, cls)
```

```
dicee.static_funcs.intialize_model(args: Dict, verbose: int = 0)  
→ Tuple[dicee.models.base_model.BaseKGE, str]
```

Initialize a knowledge graph embedding model.

Parameters

- **args** – Dictionary containing model configuration including ‘model’ key.
- **verbose** – Verbosity level. If > 0, prints initialization message.

Returns

Tuple of (initialized model, form of labelling string).

Raises

ValueError – If the model name is not recognized.

`dicee.static_funcs.load_json(path: str) → Dict`

Load JSON file into a dictionary.

Parameters

`path` – Path to the JSON file.

Returns

Dictionary containing the JSON data.

Raises

- `FileNotFoundException` – If the file does not exist.
- `json.JSONDecodeError` – If the file contains invalid JSON.

`dicee.static_funcs.save_embeddings(embeddings: numpy.ndarray, indexes: List, path: str) → None`

Save embeddings to a CSV file.

Parameters

- `embeddings` – NumPy array of embeddings with shape (n_items, embedding_dim).
- `indexes` – List of index labels (entity/relation names).
- `path` – Output file path.

`dicee.static_funcs.vocab_to_parquet(vocab_to_idx, name, path_for_serialization, print_into)`

`dicee.static_funcs.create_experiment_folder(folder_name: str = 'Experiments') → str`

Create a timestamped experiment folder.

Parameters

`folder_name` – Base directory name for experiments.

Returns

Full path to the created experiment folder.

`dicee.static_funcs.continual_training_setup_executor(executor) → None`

`dicee.static_funcs.exponential_function(x: numpy.ndarray, lam: float, ascending_order=True) → torch.FloatTensor`

`dicee.static_funcs.load_numpy(path) → numpy.ndarray`

`dicee.static_funcs.evaluate(entity_to_idx, scores, easy_answers, hard_answers)`

@TODO: CD: Renamed this function Evaluate multi hop query answering on different query types

`dicee.static_funcs.download_file(url, destination_folder='')`

`dicee.static_funcs.download_files_from_url(base_url: str, destination_folder='') → None`

Parameters

- `base_url` (e.g. “<https://files.dice-research.org/projects/DiceEmbeddings/KINSHIP-Keci-dim128-epoch256-KvsAll>”)
- `destination_folder` (e.g. “`KINSHIP-Keci-dim128-epoch256-KvsAll`”)

`dicee.static_funcs.download_pretrained_model(url: str) → str`

`dicee.static_funcs.write_csv_from_model_parallel(path: str)`

Create

`dicee.static_funcs.from_pretrained_model_write_embeddings_into_csv(path: str) → None`

dicee.static_funcs_training

Training-related static functions.

This module provides backward compatibility by re-exporting evaluation functions from the new dicee.evaluation module, along with training utilities.

Deprecated since version Evaluation: functions have moved to `dicee.evaluation`. Use that module for new code. This module will continue to export training utilities.

Functions

<code>evaluate_lp</code> (→ Dict[str, float])	Evaluate link prediction with batched processing.
<code>evaluate_bpe_lp</code> (→ Dict[str, float])	Evaluate link prediction with BPE-encoded entities.
<code>make_iterable_verbose</code> (→ Iterable)	Wrap an iterable with tqdm progress bar if verbose is True.
<code>efficient_zero_grad</code> (→ None)	Efficiently zero gradients using parameter.grad = None.

Module Contents

`dicee.static_funcs_training.evaluate_lp(model, triple_idx, num_entities: int, er_vocab: Dict[Tuple, List], re_vocab: Dict[Tuple, List], info: str = 'Eval Starts', batch_size: int = 128, chunk_size: int = 1000) → Dict[str, float]`

Evaluate link prediction with batched processing.

Memory-efficient evaluation using chunked entity scoring.

Parameters

- `model` – The KGE model to evaluate.
- `triple_idx` – Integer-indexed triples as numpy array.
- `num_entities` – Total number of entities.
- `er_vocab` – Mapping (head_idx, rel_idx) -> list of tail indices.
- `re_vocab` – Mapping (rel_idx, tail_idx) -> list of head indices.
- `info` – Description to print.
- `batch_size` – Batch size for triple processing.
- `chunk_size` – Chunk size for entity scoring.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

`dicee.static_funcs_training.evaluate_bpe_lp(model, triple_idx: List[Tuple], all_bpe_shaped_entities, er_vocab: Dict[Tuple, List], re_vocab: Dict[Tuple, List], info: str = 'Eval Starts') → Dict[str, float]`

Evaluate link prediction with BPE-encoded entities.

Parameters

- `model` – The KGE model to evaluate.
- `triple_idx` – List of BPE-encoded triple tuples.
- `all_bpe_shaped_entities` – All entities with BPE representations.
- `er_vocab` – Mapping for tail filtering.

- **re_vocab** – Mapping for head filtering.
- **info** – Description to print.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

```
dicee.static_funcs_training.make_iterable_verbose(iterable_object: Iterable, verbose: bool,
desc: str = 'Default', position: int | None = None, leave: bool = True) → Iterable
```

Wrap an iterable with tqdm progress bar if verbose is True.

Parameters

- **iterable_object** – The iterable to potentially wrap.
- **verbose** – Whether to show progress bar.
- **desc** – Description for the progress bar.
- **position** – Position of the progress bar.
- **leave** – Whether to leave the progress bar after completion.

Returns

The original iterable or a tqdm-wrapped version.

```
dicee.static_funcs_training.efficient_zero_grad(model) → None
```

Efficiently zero gradients using parameter.grad = None.

This is more efficient than optimizer.zero_grad() as it avoids memory operations.

See: https://pytorch.org/tutorials/recipes/recipes/tuning_guide.html

Parameters

model – PyTorch model to zero gradients for.

dicee.static_preprocess_funcs

Attributes

`enable_log`

Functions

<code>timeit(func)</code>	
<code>preprocesses_input_args(args)</code>	Sanity Checking in input arguments
<code>create_constraints(→ Tuple[dict, dict, dict, dict])</code>	
<code>get_er_vocab(data)</code>	
<code>get_re_vocab(data)</code>	
<code>get_ee_vocab(data)</code>	
<code>mapping_from_first_two_cols_to_third(train_se</code>	

Module Contents

```
dicee.static_preprocess_funcs.enable_log = False
```

```
dicee.static_preprocess_funcs.timeit(func)
```

```
dicee.static_preprocess_funcs.preprocesses_input_args(args)
```

Sanity Checking in input arguments

```
dicee.static_preprocess_funcs.create_constraints(triples: numpy.ndarray)  
→ Tuple[dict, dict, dict, dict]
```

(1) Extract domains and ranges of relations

(2) Store a mapping from relations to entities that are outside of the domain and range. Create constraints entities based on the range of relations :param triples: :return:

```
dicee.static_preprocess_funcs.get_er_vocab(data)
```

```
dicee.static_preprocess_funcs.get_re_vocab(data)
```

```
dicee.static_preprocess_funcs.get_ee_vocab(data)
```

```
dicee.static_preprocess_funcs.mapping_from_first_two_cols_to_third(train_set_idx)
```

dicee.trainer

Submodules

dicee.trainer.dice_trainer

DICE Trainer module for knowledge graph embedding training.

Provides the DICE_Trainer class which supports multiple training backends including PyTorch Lightning, DDP, and custom CPU/GPU trainers.

Classes

DICE_Trainer

DICE_Trainer implement

Functions

```
load_term_mapping(→ polars.DataFrame)
```

Load term-to-index mapping from CSV file.

```
initialize_trainer(...)
```

Initialize the appropriate trainer based on configuration.

```
get_callbacks(→ List)
```

Create list of callbacks based on configuration.

Module Contents

```
dicee.trainer.dice_trainer.load_term_mapping(file_path: str) → polars.DataFrame
```

Load term-to-index mapping from CSV file.

Parameters

file_path – Base path without extension.

Returns

Polars DataFrame containing the mapping.

```
dicee.trainer.dice_trainer.initialize_trainer(args, callbacks: List)
```

→ dicee.trainer.torch_trainer.TorchTrainer | dicee.trainer.model_parallelism.TensorParallel | dicee.trainer.torch_trainer_ddp

Initialize the appropriate trainer based on configuration.

Parameters

- **args** – Configuration arguments containing trainer type.
- **callbacks** – List of training callbacks.

Returns

Initialized trainer instance.

Raises

AssertionError – If trainer is None after initialization.

`dicee.trainer.dice_trainer.get_callbacks(args) → List`

Create list of callbacks based on configuration.

Parameters

args – Configuration arguments.

Returns

List of callback instances.

`class dicee.trainer.dice_trainer.DICE_Trainer(args, is_continual_training: bool, storage_path, evaluator=None)`

DICE_Trainer implement

- 1- Pytorch Lightning trainer (<https://pytorch-lightning.readthedocs.io/en/stable/common/trainer.html>)
- 2- Multi-GPU Trainer(<https://pytorch.org/docs/stable/generated/torch.nn.parallel.DistributedDataParallel.html>)
- 3- CPU Trainer

args
is_continual_training:bool
storage_path:str
evaluator:
report:dict

report

args

`trainer = None`

`is_continual_training`

`storage_path`

`evaluator = None`

`form_of_labelling = None`

`continual_start(knowledge_graph)`

- (1) Initialize training.
- (2) Load model
- (3) Load trainer (3) Fit model

Parameter

returns

- *model*
- **form_of_labelling** (*str*)

initialize_trainer (*callbacks: List*)

→ lightning.Trainer | *dicee.trainer.model_parallelism.TensorParallel* | *dicee.trainer.torch_trainer.TorchTrainer* | *dicee.torch_trainer.DiceeTorchTrainer*

Initialize Trainer from input arguments

initialize_or_load_model ()

init_dataloader (*dataset: torch.utils.data.Dataset*) → torch.utils.data.DataLoader

init_dataset () → torch.utils.data.Dataset

start (*knowledge_graph: dicee.knowledge_graph.KG* | *numpy.memmap*)

→ Tuple[*dicee.models.base_model.BaseKGE*, *str*]

Start the training

(1) Initialize Trainer

(2) Initialize or load a pretrained KGE model

in DDP setup, we need to load the memory map of already read/index KG.

k_fold_cross_validation (*dataset*) → Tuple[*dicee.models.base_model.BaseKGE*, *str*]

Perform K-fold Cross-Validation

1. Obtain K train and test splits.

2. **For each split,**

2.1 initialize trainer and model 2.2. Train model with configuration provided in args. 2.3. Compute the mean reciprocal rank (MRR) score of the model on the test respective split.

3. Report the mean and average MRR .

Parameters

- **self**
- **dataset**

Returns

model

dicee.trainer.model_parallelism

Classes

TensorParallel

Abstract class for Trainer class for knowledge graph embedding models

Functions

```
extract_input_outputs(z[, device])
find_good_batch_size(train_loader,
tp_ensemble_model)
forward_backward_update_loss(→ float)
```

Module Contents

dicee.trainer.model_parallelism.**extract_input_outputs** (*z*: list, *device*=None)
dicee.trainer.model_parallelism.**find_good_batch_size** (*train_loader*, *tp_ensemble_model*)
dicee.trainer.model_parallelism.**forward_backward_update_loss** (*z*: Tuple, *ensemble_model*)
 → float

class dicee.trainer.model_parallelism.**TensorParallel** (*args*, *callbacks*)
 Bases: dicee.abtracts.AbstractTrainer
 Abstract class for Trainer class for knowledge graph embedding models

Parameter

args
 [str] ?
callbacks: list
 ?
fit(*args, **kwargs)
 Train model

dicee.trainer.torch_trainer

Classes

<i>TorchTrainer</i>	TorchTrainer for using single GPU or multi CPUs on a single node
---------------------	--

Module Contents

class dicee.trainer.torch_trainer.**TorchTrainer** (*args*, *callbacks*)
 Bases: dicee.abtracts.AbstractTrainer
 TorchTrainer for using single GPU or multi CPUs on a single node
 Arguments
 callbacks: list of Abstract callback instances
 loss_function = None
 optimizer = None

```
model = None
train_dataloaders = None
training_step = None
process
fit(*args, train_dataloaders, **kwargs) → None
```

Training starts

Arguments

kwargs:Tuple

empty dictionary

Return type

batch loss (float)

```
forward_backward_update(x_batch: torch.Tensor, y_batch: torch.Tensor) → torch.Tensor
```

Compute forward, loss, backward, and parameter update

Arguments

Return type

batch loss (float)

```
extract_input_outputs_set_device(batch: list) → Tuple
```

Construct inputs and outputs from a batch of inputs with outputs From a batch of inputs and put

Arguments

Return type

(tuple) mini-batch on select device

dicee.trainer.torch_trainer_ddp

Classes

TorchDDPTrainer
NodeTrainer

A Trainer based on torch.nn.parallel.DistributedDataParallel

Functions

make_iterable_verbose(→ Iterable)

Module Contents

```
dicee.trainer.torch_trainer_ddp.make_iterable_verbose(iterable_object, verbose,
desc='Default', position=None, leave=True) → Iterable
```

```

class dicee.trainer.torch_trainer_ddp.TorchDDPTrainer(args, callbacks)
Bases: dicee.abstracts.AbstractTrainer

A Trainer based on torch.nn.parallel.DistributedDataParallel

Arguments

entity_idxs
    mapping.

relation_idxs
    mapping.

form
    ?

store
    ?

label_smoothing_rate
    Using hard targets (0,1) drives weights to infinity. An outlier produces enormous gradients.

Return type
    torch.utils.data.Dataset

fit(*args, **kwargs)
    Train model

class dicee.trainer.torch_trainer_ddp.NodeTrainer(trainer, model: torch.nn.Module,
    train_dataset_loader: torch.utils.data.DataLoader, callbacks, num_epochs: int)

trainer
local_rank
global_rank
optimizer
train_dataset_loader
loss_func
callbacks
model
num_epochs

loss_history = []

ctx
scaler
extract_input_outputs(z: list)
train()
    Training loop for DDP

```

Classes

DICE_Trainer

DICE_Trainer implement

Package Contents

class dicee.trainer.DICE_Trainer(*args*, *is_continual_training*: bool, *storage_path*, *evaluator*=None)

DICE_Trainer implement

- 1- Pytorch Lightning trainer (<https://pytorch-lightning.readthedocs.io/en/stable/common/trainer.html>)
- 2- Multi-GPU Trainer(<https://pytorch.org/docs/stable/generated/torch.nn.parallel.DistributedDataParallel.html>)
- 3- CPU Trainer

args

is_continual_training:bool

storage_path:str

evaluator:

report:dict

report

args

trainer = None

is_continual_training

storage_path

evaluator = None

form_of_labelling = None

continual_start(*knowledge_graph*)

- (1) Initialize training.
- (2) Load model
- (3) Load trainer (3) Fit model

Parameter

returns

- *model*
- **form_of_labelling** (*str*)

initialize_trainer(*callbacks*: List)

→ lightning.Trainer | [dicee.trainer.model_parallelism.TensorParallel](#) | [dicee.trainer.torch_trainer.TorchTrainer](#) | [dicee.](#)

Initialize Trainer from input arguments

initialize_or_load_model()

```

init_dataloader (dataset: torch.utils.data.Dataset) → torch.utils.data.DataLoader

init_dataset () → torch.utils.data.Dataset

start (knowledge_graph: dicee.knowledge_graph.KG | numpy.memmap)
    → Tuple[dicee.models.base_model.BaseKGE, str]

Start the training
(1) Initialize Trainer
(2) Initialize or load a pretrained KGE model
in DDP setup, we need to load the memory map of already read/index KG.

k_fold_cross_validation (dataset) → Tuple[dicee.models.base_model.BaseKGE, str]

Perform K-fold Cross-Validation
1. Obtain K train and test splits.
2. For each split,
    2.1 initialize trainer and model 2.2. Train model with configuration provided in args. 2.3. Compute the mean reciprocal rank (MRR) score of the model on the test respective split.
3. Report the mean and average MRR .

Parameters
• self
• dataset

Returns
model

```

dicee.weight_averaging

Classes

<i>ASWA</i>	Adaptive stochastic weight averaging
<i>SWA</i>	Stochastic Weight Averaging callback.
<i>SWAG</i>	Stochastic Weight Averaging - Gaussian (SWAG).
<i>EMA</i>	Exponential Moving Average (EMA) callback.
<i>TWA</i>	Train with Weight Averaging (TWA) using subspace projection + averaging.

Module Contents

```
class dicee.weight_averaging.ASWA (num_epochs, path)
```

Bases: *dicee.abstracts.AbstractCallback*

Adaptive stochastic weight averaging ASWE keeps track of the validation performance and update s the ensemble model accordingly.

path

num_epochs

initial_eval_setting = None

```
epoch_count = 0
alphas = []
val_aswa = -1
on_fit_end(trainer, model)
    Call at the end of the training.
```

Parameter

trainer:

model:

rtype
None

```
static compute_mrr(trainer, model) → float
get_aswa_state_dict(model)
decide(running_model_state_dict, ensemble_state_dict, val_running_model,
       mrr_updated_ensemble_model)
    Perform Hard Update, software or rejection
```

Parameters

- running_model_state_dict
- ensemble_state_dict
- val_running_model
- mrr_updated_ensemble_model

```
on_train_epoch_end(trainer, model)
    Call at the end of each epoch during training.
```

Parameter

trainer:

model:

rtype
None

```
class dicee.weight_averaging.SWA(swa_start_epoch, swa_c_epochs: int = 1, lr_init: float = 0.1,
                                   swa_lr: float = 0.05, max_epochs: int = None)
```

Bases: [dicee.abstracts.AbstractCallback](#)

Stochastic Weight Averaging callback.

Initialize SWA callback.

swa_start_epoch: int
The epoch at which to start SWA.
swa_c_epochs: int
The number of epochs to use for SWA.

```

lr_init: float
    The initial learning rate.

swa_lr: float
    The learning rate to use during SWA.

max_epochs: int
    The maximum number of epochs. args.num_epochs

swa_start_epoch

swa_c_epochs = 1

swa_lr = 0.05

lr_init = 0.1

max_epochs = None

swa_model = None

swa_n = 0

current_epoch = -1

static moving_average(swa_model, running_model, alpha)
    Update SWA model with moving average of current model. Math: # SWA update: #  $\theta_{\text{swa}} \leftarrow (1 - \alpha) * \theta_{\text{swa}} + \alpha * \theta_1$  #  $\alpha = 1 / (n + 1)$ , where n = number of models already averaged # alpha is tracked via self.swa_n in code

on_train_epoch_start(trainer, model)
    Update learning rate according to SWA schedule.

on_train_epoch_end(trainer, model)
    Apply SWA averaging if conditions are met.

on_fit_end(trainer, model)
    Replace main model with SWA model at the end of training.

class dicee.weight_averaging.SWAG(swa_start_epoch, swa_c_epochs: int = 1, lr_init: float = 0.1,
    swa_lr: float = 0.05, max_epochs: int = None, max_num_models: int = 20,
    var_clamp: float = 1e-30)

Bases: dicee.abstracts.AbstractCallback

Stochastic Weight Averaging - Gaussian (SWAG). Parameters

swa_start_epoch
    [int] Epoch at which to start collecting weights.

swa_c_epochs
    [int] Interval of epochs between updates.

lr_init
    [float] Initial LR.

swa_lr
    [float] LR in SWA / GSWA phase.

max_epochs
    [int] Total number of epochs.

```

```

max_num_models
    [int] Number of models to keep for low-rank covariance approx.

var_clamp
    [float] Clamp low variance for stability.

swa_start_epoch
swa_c_epochs = 1

swa_lr = 0.05

lr_init = 0.1

max_epochs = None

max_num_models = 20

var_clamp = 1e-30

mean = None

sq_mean = None

deviations = []

gswa_n = 0

current_epoch = -1

get_mean_and_var()
    Return mean + variance (diagonal part).

sample(base_model, scale=0.5)
    Sample new model from SWAG posterior distribution.

    Math: # From SWAG, posterior is approximated as: #  $\theta \sim N(\text{mean}, \Sigma)$  # where  $\Sigma \approx \text{diag}(\text{var}) + (1/(K-1)) * D D^T$  # - mean = running average of weights # - var = elementwise variance (sq_mean - mean2) # - D = [dev_1, dev_2, ..., dev_K], deviations from mean (low-rank approx) # - K = number of collected models

    # Sampling step: # 1. theta_diag = mean + scale * std  $\odot \epsilon$ , where  $\epsilon \sim N(0, I)$  # 2. theta_lowrank = theta_diag + (D z) / sqrt(K-1), where z ~  $N(0, I_K)$  # Final sample = theta_lowrank

on_train_epoch_start(trainer, model)
    Update LR schedule (same as SWA).

on_train_epoch_end(trainer, model)
    Collect Gaussian stats at the end of epochs after swa_start.

on_fit_end(trainer, model)
    Set model weights to the collected SWAG mean at the end of training.

class dicee.weight_averaging.EMA(ema_start_epoch: int, decay: float = 0.999,
    max_epochs: int = None, ema_c_epochs: int = 1)
Bases: dicee.abstracts.AbstractCallback

Exponential Moving Average (EMA) callback.

Parameters

- ema_start_epoch (int) – Epoch to start EMA.

```

- **decay** (*float*) – EMA decay rate (typical: 0.99 - 0.9999) Math: $\theta_{\text{ema}} \leftarrow \text{decay} * \theta_{\text{ema}} + (1 - \text{decay}) * \theta$

- **max_epochs** (*int*) – Maximum number of epochs.

ema_start_epoch

decay = 0.999

max_epochs = None

ema_c_epochs = 1

ema_model = None

current_epoch = -1

static ema_update(*ema_model*, *running_model*, *decay*: *float*)

Update EMA model with exponential moving average of current model. Math: # EMA update: # $\theta_{\text{ema}} \leftarrow (1 - \alpha) * \theta_{\text{ema}} + \alpha * \theta$ # $\alpha = 1 - \text{decay}$, where decay is the EMA smoothing factor (typical 0.99 - 0.999) # alpha controls how much of the current model θ contributes to the EMA # decay is fixed in code
-> can be extended to scheduled

on_train_epoch_start(*trainer*, *model*)

Track current epoch.

on_train_epoch_end(*trainer*, *model*)

Update EMA if past start epoch.

on_fit_end(*trainer*, *model*)

Replace main model with EMA model at the end of training.

class dicee.weight_averaging.TWA(*twa_start_epoch*: *int*, *lr_init*: *float*, *num_samples*: *int* = 5, *reg_lambda*: *float* = 0.0, *max_epochs*: *int* = None, *twa_c_epochs*: *int* = 1)

Bases: *dicee.abstracts.AbstractCallback*

Train with Weight Averaging (TWA) using subspace projection + averaging.

Parameters

twa_start_epoch

[int] Epoch to start TWA.

lr_init

[float] Learning rate used for β updates.

num_samples

[int] Number of sampled weight snapshots to build projection subspace.

reg_lambda

[float] Regularization coefficient for β updates.

max_epochs

[int] Total number of training epochs.

twa_c_epochs

[int] Interval of epochs between TWA updates.

twa_start_epoch

num_samples = 5

```

reg_lambda = 0.0
max_epochs = None
lr_init
twa_c_epochs = 1
current_epoch = -1
weight_samples = []
twa_model = None
base_weights = None
P = None
beta = None
sample_weights(model)
    Collect sampled weights from the current model and maintain rolling buffer.

build_projection(weight_samples, k=None)
    Build projection subspace from collected weight samples. :param weight_samples: list of flat weight tensors [(D,), ...] :param k: number of basis vectors to keep. Defaults to min(N, D).

Returns
    (D,) base weight vector (average) P: (D, k) projection matrix with top-k basis directions

Return type
    mean_w

on_train_epoch_start(trainer, model)
    Track epoch.

on_train_epoch_end(trainer, model)
    Main TWA logic: build subspace and update in  $\beta$  space.

    # Math: # TWA weight update:  $w_{twa} = mean_w + P * beta$  #  $mean_w = (1/n) * \sum_i w_i$  (SWA baseline)
    #  $beta \leftarrow (1 - \eta * \lambda) * beta - \eta * P^T * g$  #  $g$  = gradient of training loss w.r.t. full model weights
    #  $\eta$  = learning rate,  $\lambda$  = ridge regularization #  $P$  = orthonormal basis spanning sampled checkpoints
    { $w_i$ }

on_fit_end(trainer, model)
    Replace with TWA model at the end.

```

14.2 Attributes

version

14.3 Classes

Execute

Executor class for training, retraining and evaluating KGE models.

continues on next page

Table 69 – continued from previous page

<i>KGE</i>	Knowledge Graph Embedding Class for interactive usage of pre-trained models
<i>QueryGenerator</i>	
<i>DICE_Trainer</i>	DICE_Trainer implement
<i>Evaluator</i>	Evaluator class for KGE models in various downstream tasks.

14.4 Package Contents

```
class dicee.Execute(args, continuous_training: bool = False)
```

Executor class for training, retraining and evaluating KGE models.

Handles the complete workflow: 1. Loading & Preprocessing & Serializing input data 2. Training & Validation & Testing 3. Storing all necessary information

args

Processed input arguments.

distributed

Whether distributed training is enabled.

rank

Process rank in distributed training.

world_size

Total number of processes.

local_rank

Local GPU rank.

trainer

Training handler instance.

trained_model

The trained model after training completes.

knowledge_graph

The loaded knowledge graph.

report

Dictionary storing training metrics and results.

evaluator

Model evaluation handler.

distributed

args

is_continual_training = *False*

trainer: *dicee.trainer.DICE_Trainer* | *None* = *None*

trained_model = *None*

knowledge_graph: *dicee.knowledge_graph.KG* | *None* = *None*

```

report: Dict
evaluator: dicee.evaluator.Evaluator | None = None
start_time: float | None = None
is_rank_zero() → bool
cleanup()
setup_executor() → None
    Set up storage directories for the experiment.
    Creates or reuses experiment directories based on configuration. Saves the configuration to a JSON file.
create_and_store_kg() → None
    Create knowledge graph and store as memory-mapped file.
    Only executed on rank 0 in distributed training. Skips if memmap already exists.
load_from_memmap() → None
    Load knowledge graph from memory-mapped file.
save_trained_model() → None
    Save a knowledge graph embedding model
    (1) Send model to eval mode and cpu.
    (2) Store the memory footprint of the model.
    (3) Save the model into disk.
    (4) Update the stats of KG again ?

```

Parameter

rtype

None

```

end(form_of_labelling: str) → dict
    End training
    (1) Store trained model.
    (2) Report runtimes.
    (3) Eval model if required.

```

Parameter

rtype

A dict containing information about the training and/or evaluation

```

write_report() → None
    Report training related information in a report.json file
start() → dict
    Start training
    # (1) Loading the Data # (2) Create an evaluator object. # (3) Create a trainer object. # (4) Start the training

```

Parameter

rtype

A dict containing information about the training and/or evaluation

```
class dicee.KGE(path=None, url=None, construct_ensemble=False, model_name=None)
Bases: dicee.abstracts.BaseInteractiveKGE, dicee.abstracts.
InteractiveQueryDecomposition, dicee.abstracts.BaseInteractiveTrainKGE
Knowledge Graph Embedding Class for interactive usage of pre-trained models

__str__()

to(device: str) → None

get_transductive_entity_embeddings(indices: torch.LongTensor | List[str], as_pytorch=False,
as_numpy=False, as_list=True) → torch.FloatTensor | numpy.ndarray | List[float]

create_vector_database(collection_name: str, distance: str, location: str = 'localhost',
port: int = 6333)

generate(h='', r='')

eval_lp_performance(dataset=List[Tuple[str, str, str]], filtered=True)

predict_missing_head_entity(relation: List[str] | str, tail_entity: List[str] | str, within=None,
batch_size=2, topk=1, return_indices=False) → Tuple
Given a relation and a tail entity, return top k ranked head entity.

argmax_{e in E} f(e,r,t), where r in R, t in E.
```

Parameter

relation: Union[List[str], str]

String representation of selected relations.

tail_entity: Union[List[str], str]

String representation of selected entities.

k: int

Highest ranked k entities.

Returns: Tuple

Highest K scores and entities

```
predict_missing_relations(head_entity: List[str] | str, tail_entity: List[str] | str, within=None,
batch_size=2, topk=1, return_indices=False) → Tuple
```

Given a head entity and a tail entity, return top k ranked relations.

argmax_{r in R} f(h,r,t), where h, t in E.

Parameter

head_entity: List[str]

String representation of selected entities.

tail_entity: List[str]

String representation of selected entities.

k: int

Highest ranked k entities.

Returns: Tuple

Highest K scores and entities

```
predict_missing_tail_entity(head_entity: List[str] | str, relation: List[str] | str,  
                           within: List[str] = None, batch_size=2, topk=1, return_indices=False) → torch.FloatTensor
```

Given a head entity and a relation, return top k ranked entities

argmax_{e in E} f(h,r,e), where h in E and r in R.

Parameter

head_entity: List[str]

String representation of selected entities.

tail_entity: List[str]

String representation of selected entities.

Returns: Tuple

scores

```
predict(*, h: List[str] | str = None, r: List[str] | str = None, t: List[str] | str = None, within=None,  
        logits=True) → torch.FloatTensor
```

Parameters

- **logits**
- **h**
- **r**
- **t**
- **within**

```
predict_topk(*, h: str | List[str] = None, r: str | List[str] = None, t: str | List[str] = None, topk: int = 10,  
            within: List[str] = None, batch_size: int = 1024)
```

Predict missing item in a given triple.

Returns

- If you query a single (h, r, ?) or (?, r, t) or (h, ?, t), returns List[(item, score)]
- If you query a batch of B, returns List of B such lists.

```
triple_score(h: List[str] | str = None, r: List[str] | str = None, t: List[str] | str = None, logits=False)  
→ torch.FloatTensor
```

Predict triple score

Parameter

head_entity: List[str]
String representation of selected entities.
relation: List[str]
String representation of selected relations.
tail_entity: List[str]
String representation of selected entities.
logits: bool
If logits is True, unnormalized score returned

Returns: Tuple

pytorch tensor of triple score

```
return_multi_hop_query_results(aggregated_query_for_all_entities, k: int, only_scores)
single_hop_query_answering(query: tuple, only_scores: bool = True, k: int = None)
answer_multi_hop_query(query_type: str = None, query: Tuple[str | Tuple[str, str], Ellipsis] = None,
queries: List[Tuple[str | Tuple[str, str], Ellipsis]] = None, tnorm: str = 'prod',
neg_norm: str = 'standard', lambda_: float = 0.0, k: int = 10, only_scores=False)
→ List[Tuple[str, torch.Tensor]]
# @TODO: Refactoring is needed # @TODO: Score computation for each query type should be done in a static function
```

Find an answer set for EPFO queries including negation and disjunction

Parameter

query_type: str The type of the query, e.g., “2p”.
query: Union[str, Tuple[str, Tuple[str, Tuple[str, str]]]] The query itself, either a string or a nested tuple.
queries: List of Tuple[Union[str, Tuple[str, str]], ...]
tnorm: str The t-norm operator.
neg_norm: str The negation norm.
lambda_: float lambda parameter for sugeno and yager negation norms
k: int The top-k substitutions for intermediate variables.

returns

- *List[Tuple[str, torch.Tensor]]*
- *Entities and corresponding scores sorted in the descening order of scores*

```
find_missing_triples(confidence: float, entities: List[str] = None, relations: List[str] = None,
topk: int = 10, at_most: int = sys.maxsize) → Set
```

Find missing triples

Iterative over a set of entities E and a set of relation R :

orall e in E and orall r in R f(e,r,x)

Return (e,r,x)
 otin G and f(e,r,x) > confidence
 confidence: float
 A threshold for an output of a sigmoid function given a triple.
 topk: int
 Highest ranked k item to select triples with f(e,r,x) > confidence .
 at_most: int
 Stop after finding at_most missing triples
 $\{(e,r,x) \mid f(e,r,x) > \text{confidence}\}$ land (e,r,x)
 otin G

predict_literals (*entity*: *List[str]* | *str* = *None*, *attribute*: *List[str]* | *str* = *None*,
denormalize_preds: *bool* = *True*) → *numpy.ndarray*

Predicts literal values for given entities and attributes.

Parameters

- **entity** (*Union[List[str], str]*) – Entity or list of entities to predict literals for.
- **attribute** (*Union[List[str], str]*) – Attribute or list of attributes to predict literals for.
- **denormalize_preds** (*bool*) – If True, denormalizes the predictions.

Returns

Predictions for the given entities and attributes.

Return type

numpy ndarray

```
class dicee.QueryGenerator(train_path, val_path: str, test_path: str, ent2id: Dict = None,
                           rel2id: Dict = None, seed: int = 1, gen_valid: bool = False, gen_test: bool = True)

  train_path
  val_path
  test_path
  gen_valid = False
  gen_test = True
  seed = 1
  max_ans_num = 1000000.0
  mode
  ent2id = None
  rel2id: Dict = None
  ent_in: Dict
```

```

ent_out: Dict
query_name_to_struct
list2tuple(list_data)
tuple2list(x: List | Tuple) → List | Tuple
    Convert a nested tuple to a nested list.

set_global_seed(seed: int)
    Set seed

construct_graph(paths: List[str]) → Tuple[Dict, Dict]
    Construct graph from triples Returns dicts with incoming and outgoing edges

fill_query(query_structure: List[str | List], ent_in: Dict, ent_out: Dict, answer: int) → bool
    Private method for fill_query logic.

achieve_answer(query: List[str | List], ent_in: Dict, ent_out: Dict) → set
    Private method for achieve_answer logic. @TODO: Document the code

write_links(ent_out, small_ent_out)

ground_queries(query_structure: List[str | List], ent_in: Dict, ent_out: Dict, small_ent_in: Dict,
    small_ent_out: Dict, gen_num: int, query_name: str)
    Generating queries and achieving answers

unmap(query_type, queries, tp_answers, fp_answers, fn_answers)

unmap_query(query_structure, query, id2ent, id2rel)

generate_queries(query_struct: List, gen_num: int, query_type: str)
    Passing incoming and outgoing edges to ground queries depending on mode [train valid or text] and getting
    queries and answers in return @ TODO: create a class for each single query struct

save_queries(query_type: str, gen_num: int, save_path: str)

abstractmethod load_queries(path)

get_queries(query_type: str, gen_num: int)

static save_queries_and_answers(path: str, data: List[Tuple[str, Tuple[collections.defaultdict]]])
    → None
    Save Queries into Disk

static load_queries_and_answers(path: str) → List[Tuple[str, Tuple[collections.defaultdict]]]
    Load Queries from Disk to Memory

class dicee.DICE_Trainer(args, is_continual_training: bool, storage_path, evaluator=None)

DICE_Trainer implement
    1- Pytorch Lightning trainer (https://pytorch-lightning.readthedocs.io/en/stable/common/trainer.html)
    2- Multi-GPU Trainer(https://pytorch.org/docs/stable/generated/torch.nn.parallel.DistributedDataParallel.html)
    3- CPU Trainer

    args
    is_continual_training:bool
    storage_path:str

```

```

evaluator:
report:dict

report

args

trainer = None

is_continual_training

storage_path

evaluator = None

form_of_labelling = None

continual_start (knowledge_graph)

```

- (1) Initialize training.
- (2) Load model
- (3) Load trainer (3) Fit model

Parameter

returns

- *model*
- **form_of_labelling** (*str*)

```

initialize_trainer (callbacks: List)
    → lightning.Trainer | dicee.trainer.model_parallelism.TensorParallel | dicee.trainer.torch_trainer.TorchTrainer | dicee.
Initialize Trainer from input arguments

```

```
initialize_or_load_model ()
```

```
init_dataloader (dataset: torch.utils.data.Dataset) → torch.utils.data.DataLoader
```

```
init_dataset () → torch.utils.data.Dataset
```

```

start (knowledge_graph: dicee.knowledge_graph.KG | numpy.memmap)
    → Tuple[dicee.models.base_model.BaseKGE, str]

```

Start the training

- (1) Initialize Trainer
- (2) Initialize or load a pretrained KGE model

in DDP setup, we need to load the memory map of already read/index KG.

```
k_fold_cross_validation (dataset) → Tuple[dicee.models.base_model.BaseKGE, str]
```

Perform K-fold Cross-Validation

1. Obtain K train and test splits.

2. **For each split,**

2.1 initialize trainer and model 2.2. Train model with configuration provided in args. 2.3. Compute the mean reciprocal rank (MRR) score of the model on the test respective split.

3. Report the mean and average MRR .

Parameters

- **self**
- **dataset**

Returns

model

```
class dicee.Evaluator(args, is_continual_training: bool = False)
```

Evaluator class for KGE models in various downstream tasks.

Orchestrates link prediction evaluation with different scoring techniques including standard evaluation and byte-pair encoding based evaluation.

er_vocab

Entity-relation to tail vocabulary for filtered ranking.

re_vocab

Relation-entity (tail) to head vocabulary.

ee_vocab

Entity-entity to relation vocabulary.

num_entities

Total number of entities in the knowledge graph.

num_relations

Total number of relations in the knowledge graph.

args

Configuration arguments.

report

Dictionary storing evaluation results.

during_training

Whether evaluation is happening during training.

Example

```
>>> from dicee.evaluation import Evaluator
>>> evaluator = Evaluator(args)
>>> results = evaluator.eval(dataset, model, 'EntityPrediction')
>>> print(f"Test MRR: {results['Test']['MRR']:.4f}")
```

```
re_vocab: Dict | None = None
er_vocab: Dict | None = None
ee_vocab: Dict | None = None
func_triple_to_bpe_representation = None
is_continual_training = False
```

```

num_entities: int | None = None
num_relations: int | None = None
domain_constraints_per_rel = None
range_constraints_per_rel = None
args
report: Dict
during_training = False
vocab_preparation(dataset) → None
    Prepare vocabularies from the dataset for evaluation.
    Resolves any future objects and saves vocabularies to disk.

Parameters
dataset – Knowledge graph dataset with vocabulary attributes.

eval(dataset, trained_model, form_of_labelling: str, during_training: bool = False) → Dict | None
Evaluate the trained model on the dataset.

Parameters

- dataset – Knowledge graph dataset (KG instance).
- trained_model – The trained KGE model.
- form_of_labelling – Type of labelling ('EntityPrediction' or 'RelationPrediction').
- during_training – Whether evaluation is during training.

Returns
Dictionary of evaluation metrics, or None if evaluation is skipped.

eval_rank_of_head_and_tail_entity(*train_set, valid_set=None, test_set=None, trained_model)
→ None
Evaluate with negative sampling scoring.

eval_rank_of_head_and_tail_byte_pair_encoded_entity(*train_set=None, valid_set=None,
test_set=None, ordered_bpe_entities, trained_model) → None
Evaluate with BPE-encoded entities and negative sampling.

eval_with_byte(*raw_train_set, raw_valid_set=None, raw_test_set=None, trained_model,
form_of_labelling) → None
Evaluate BytE model with generation.

eval_with_bpe_vs_all(*raw_train_set, raw_valid_set=None, raw_test_set=None, trained_model,
form_of_labelling) → None
Evaluate with BPE and KvsAll scoring.

eval_with_vs_all(*train_set, valid_set=None, test_set=None, trained_model, form_of_labelling)
→ None
Evaluate with KvsAll or 1vsAll scoring.

evaluate_lp_k_vs_all(model, triple_idx, info: str | None = None,
form_of_labelling: str | None = None) → Dict[str, float]
Filtered link prediction evaluation with KvsAll scoring.

Parameters

```

- **model** – The trained model to evaluate.
- **triple_idx** – Integer-indexed test triples.
- **info** – Description to print.
- **form_of_labelling** – ‘EntityPrediction’ or ‘RelationPrediction’.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

evaluate_lp_with_bytE (*model*, *triples*: *List[List[str]]*, *info*: *str* | *None* = *None*) → *Dict[str, float]*

Evaluate BytE model with text generation.

Parameters

- **model** – BytE model.
- **triples** – String triples.
- **info** – Description to print.

Returns

Dictionary with placeholder metrics (-1 values).

evaluate_lp_bpe_k_vs_all (*model*, *triples*: *List[List[str]]*, *info*: *str* | *None* = *None*, *form_of_labelling*: *str* | *None* = *None*) → *Dict[str, float]*

Evaluate BPE model with KvsAll scoring.

Parameters

- **model** – BPE-enabled model.
- **triples** – String triples.
- **info** – Description to print.
- **form_of_labelling** – Type of labelling.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

evaluate_lp (*model*, *triple_idx*, *info*: *str*) → *Dict[str, float]*

Evaluate link prediction with negative sampling.

Parameters

- **model** – The model to evaluate.
- **triple_idx** – Integer-indexed triples.
- **info** – Description to print.

Returns

Dictionary with H@1, H@3, H@10, and MRR metrics.

dummy_eval (*trained_model*, *form_of_labelling*: *str*) → *None*

Run evaluation from saved data (for continual training).

Parameters

- **trained_model** – The trained model.
- **form_of_labelling** – Type of labelling.

```
eval_with_data(dataset, trained_model, triple_idx: numpy.ndarray, form_of_labelling: str)
    → Dict[str, float]
```

Evaluate a trained model on a given dataset.

Parameters

- **dataset** – Knowledge graph dataset.
- **trained_model** – The trained model.
- **triple_idx** – Integer-indexed triples to evaluate.
- **form_of_labelling** – Type of labelling.

Returns

Dictionary with evaluation metrics.

Raises

ValueError – If scoring technique is invalid.

```
dicee.__version__ = '0.3.2'
```

Python Module Index

d

 dicee, 12
 dicee.__main__, 12
 dicee.abstracts, 12
 dicee.analyse_experiments, 19
 dicee.callbacks, 21
 dicee.config, 27
 dicee.dataset_classes, 31
 dicee.eval_static_funcs, 41
 dicee.evaluation, 44
 dicee.evaluation.ensemble, 45
 dicee.evaluation.evaluator, 46
 dicee.evaluation.link_prediction, 49
 dicee.evaluation.literal_prediction, 52
 dicee.evaluation.utils, 53
 dicee.evaluator, 64
 dicee.executer, 67
 dicee.knowledge_graph, 70
 dicee.knowledge_graph_embeddings, 72
 dicee.models, 76
 dicee.models.adopt, 76
 dicee.models.base_model, 85
 dicee.models.clifford, 94
 dicee.models.complex, 101
 dicee.models.dualE, 104
 dicee.models.ensemble, 105
 dicee.models.function_space, 106
 dicee.models.literal, 109
 dicee.models.octonion, 111
 dicee.models.pykeen_models, 114
 dicee.models.quaternion, 115
 dicee.models.real, 118
 dicee.models.static_funcs, 121
 dicee.models.transformers, 121
 dicee.query_generator, 180
 dicee.read_preprocess_save_load_kg, 182
 dicee.read_preprocess_save_load_kg.preprocess,
 182
 dicee.read_preprocess_save_load_kg.read_from_disk,
 183
 dicee.read_preprocess_save_load_kg.save_load_disk,
 183
 dicee.read_preprocess_save_load_kg.util,
 184
 dicee.sanity_checkers, 188
 dicee.scripts, 189
 dicee.scripts.index_serve, 189
 dicee.scripts.run, 190
 dicee.static_funcs, 190
 dicee.static_funcs_training, 195
 dicee.static_preprocess_funcs, 196
 dicee.trainer, 197
 dicee.trainer.dice_trainer, 197
 dicee.trainer.model_parallelism, 199
 dicee.trainer.torch_trainer, 200
 dicee.trainer.torch_trainer_ddp, 201
 dicee.weight_averaging, 204

Index

Non-alphabetical

`__call__()` (*dicee.models.base_model.IdentityClass method*), 94
`__call__()` (*dicee.models.ensemble.EnsembleKGE method*), 106
`__call__()` (*dicee.models.IdentityClass method*), 141, 155, 161
`__getitem__()` (*dicee.dataset_classes.AllvsAll method*), 35
`__getitem__()` (*dicee.dataset_classes.BPE_NegativeSamplingDataset method*), 32
`__getitem__()` (*dicee.dataset_classes.KvsAll method*), 35
`__getitem__()` (*dicee.dataset_classes.KvsSampleDataset method*), 38
`__getitem__()` (*dicee.dataset_classes.LiteralDataset method*), 40
`__getitem__()` (*dicee.dataset_classes.MultiClassClassificationDataset method*), 33
`__getitem__()` (*dicee.dataset_classes.MultiLabelDataset method*), 33
`__getitem__()` (*dicee.dataset_classes.NegSampleDataset method*), 38
`__getitem__()` (*dicee.dataset_classes.OnevsAllDataset method*), 34
`__getitem__()` (*dicee.dataset_classes.OnevsSample method*), 37
`__getitem__()` (*dicee.dataset_classes.TriplePredictionDataset method*), 39
`__iter__()` (*dicee.config.Namespace method*), 31
`__iter__()` (*dicee.knowledge_graph.KG method*), 72
`__iter__()` (*dicee.models.ensemble.EnsembleKGE method*), 105
`__len__()` (*dicee.dataset_classes.AllvsAll method*), 35
`__len__()` (*dicee.dataset_classes.BPE_NegativeSamplingDataset method*), 32
`__len__()` (*dicee.dataset_classes.KvsAll method*), 35
`__len__()` (*dicee.dataset_classes.KvsSampleDataset method*), 38
`__len__()` (*dicee.dataset_classes.LiteralDataset method*), 40
`__len__()` (*dicee.dataset_classes.MultiClassClassificationDataset method*), 33
`__len__()` (*dicee.dataset_classes.MultiLabelDataset method*), 33
`__len__()` (*dicee.dataset_classes.NegSampleDataset method*), 38
`__len__()` (*dicee.dataset_classes.OnevsAllDataset method*), 34
`__len__()` (*dicee.dataset_classes.OnevsSample method*), 36
`__len__()` (*dicee.dataset_classes.TriplePredictionDataset method*), 39
`__len__()` (*dicee.knowledge_graph.KG method*), 72
`__len__()` (*dicee.models.ensemble.EnsembleKGE method*), 105
`__setstate__()` (*dicee.models.ADOPT method*), 131
`__setstate__()` (*dicee.models.adopt.ADOPT method*), 80
`__str__()` (*dicee.KGE method*), 212
`__str__()` (*dicee.knowledge_graph_embeddings.KGE method*), 73
`__str__()` (*dicee.models.ensemble.EnsembleKGE method*), 106
`__version__` (*in module dicee*), 221

A

`AbstractCallback` (*class in dicee.abstracts*), 16
`AbstractPPECallback` (*class in dicee.abstracts*), 18
`AbstractTrainer` (*class in dicee.abstracts*), 13
`AccumulateEpochLossCallback` (*class in dicee.callbacks*), 21
`achieve_answer()` (*dicee.query_generator.QueryGenerator method*), 181
`achieve_answer()` (*dicee.QueryGenerator method*), 216
`AConEx` (*class in dicee.models*), 150
`AConEx` (*class in dicee.models.complex*), 102
`AConvO` (*class in dicee.models*), 163
`AConvO` (*class in dicee.models.octonion*), 113
`AConvQ` (*class in dicee.models*), 157
`AConvQ` (*class in dicee.models.quaternion*), 117
`adaptive_lr` (*dicee.config.Namespace attribute*), 31
`adaptive_swa` (*dicee.config.Namespace attribute*), 30
`add_new_entity_embeddings()` (*dicee.abstracts.BaseInteractiveKGE method*), 16
`add_noise_rate` (*dicee.config.Namespace attribute*), 28
`add_noise_rate` (*dicee.knowledge_graph.KG attribute*), 71
`add_noisy_triples()` (*in module dicee.static_funcs*), 193
`add_noisy_triples_into_training()` (*dicee.read_preprocess_save_load_kg.read_from_disk.ReadFromDisk method*), 183
`add_noisy_triples_into_training()` (*dicee.read_preprocess_save_load_kg.ReadFromDisk method*), 188
`add_reciprocal` (*dicee.knowledge_graph.KG attribute*), 71
`ADOPT` (*class in dicee.models*), 129
`ADOPT` (*class in dicee.models.adopt*), 78
`adopt()` (*in module dicee.models.adopt*), 81
`ALL_HITS_RANGE` (*in module dicee.evaluation*), 64
`ALL_HITS_RANGE` (*in module dicee.evaluation.utils*), 54

AllvsAll (*class in dicee.dataset_classes*), 35
 alphas (*dicee.abstracts.AbstractPPECallback attribute*), 18
 alphas (*dicee.weight_averaging.ASWA attribute*), 205
 analyse() (*in module dicee.analyse_experiments*), 20
 answer_multi_hop_query() (*dicee.KGE method*), 214
 answer_multi_hop_query() (*dicee.knowledge_graph_embeddings.KGE method*), 75
 app (*in module dicee.scripts.index_serve*), 189
 apply_coefficients() (*dicee.models.clifford.DeCaL method*), 100
 apply_coefficients() (*dicee.models.clifford.Keci method*), 96
 apply_coefficients() (*dicee.models.DeCaL method*), 169
 apply_coefficients() (*dicee.models.Keci method*), 165
 apply_reciprocal_or_noise() (*in module dicee.read_preprocess_save_load_kg.util*), 186
 apply_semantic_constraint (*dicee.abstracts.BaseInteractiveKGE attribute*), 15
 apply_unit_norm (*dicee.models.base_model.BaseKGE attribute*), 92
 apply_unit_norm (*dicee.models.BaseKGE attribute*), 139, 142, 148, 152, 159, 171, 175
 args (*dicee.DICE_Trainer attribute*), 217
 args (*dicee.evaluation.Evaluator attribute*), 56, 57
 args (*dicee.evaluation.evaluator.Evaluator attribute*), 46, 47
 args (*dicee.Evaluator attribute*), 218, 219
 args (*dicee.evaluator.Evaluator attribute*), 64, 65
 args (*dicee.Execute attribute*), 210
 args (*dicee.executor.Execute attribute*), 67, 68
 args (*dicee.models.base_model.BaseKGE attribute*), 91
 args (*dicee.models.base_model.IdentityClass attribute*), 94
 args (*dicee.models.BaseKGE attribute*), 139, 142, 148, 152, 158, 171, 174
 args (*dicee.models.ensemble.EnsembleKGE attribute*), 105
 args (*dicee.models.IdentityClass attribute*), 141, 155, 161
 args (*dicee.models.pykeen_models.PykeenKGE attribute*), 114
 args (*dicee.models.PykeenKGE attribute*), 173
 args (*dicee.trainer.DICE_Trainer attribute*), 203
 args (*dicee.trainer.dice_trainer.DICE_Trainer attribute*), 198
 ASWA (*class in dicee.weight_averaging*), 204
 awsa (*dicee.analyse_experiments.Experiment attribute*), 20
 attn (*dicee.models.Block attribute*), 144
 attn (*dicee.models.transformers.Block attribute*), 126
 attn_dropout (*dicee.models.transformers.SelfAttention attribute*), 125
 attributes (*dicee.abstracts.AbstractTrainer attribute*), 13
 auto_batch_finding (*dicee.config.Namespace attribute*), 30

B

backend (*dicee.config.Namespace attribute*), 29
 backend (*dicee.knowledge_graph.KG attribute*), 71
 base_weights (*dicee.weight_averaging.TWA attribute*), 209
 BaseInteractiveKGE (*class in dicee.abstracts*), 14
 BaseInteractiveTrainKGE (*class in dicee.abstracts*), 18
 BaseKGE (*class in dicee.models*), 138, 141, 147, 152, 158, 170, 174
 BaseKGE (*class in dicee.models.base_model*), 91
 BaseKGELightning (*class in dicee.models*), 132
 BaseKGELightning (*class in dicee.models.base_model*), 85
 batch_kronecker_product() (*dicee.callbacks.KronE static method*), 25
 batch_size (*dicee.analyse_experiments.Experiment attribute*), 20
 batch_size (*dicee.callbacks.PseudoLabellingCallback attribute*), 24
 batch_size (*dicee.config.Namespace attribute*), 28
 batches_per_epoch (*dicee.callbacks.LRScheduler attribute*), 27
 beta (*dicee.weight_averaging.TWA attribute*), 209
 bias (*dicee.models.CoKEConfig attribute*), 146, 147
 bias (*dicee.models.real.CoKEConfig attribute*), 120
 bias (*dicee.models.transformers.GPTConfig attribute*), 127
 bias (*dicee.models.transformers.LayerNorm attribute*), 124
 Block (*class in dicee.models*), 144
 Block (*class in dicee.models.transformers*), 126
 block_size (*dicee.config.Namespace attribute*), 30
 block_size (*dicee.dataset_classes.MultiClassClassificationDataset attribute*), 33
 block_size (*dicee.models.base_model.BaseKGE attribute*), 92
 block_size (*dicee.models.BaseKGE attribute*), 140, 143, 149, 153, 159, 172, 175
 block_size (*dicee.models.CoKEConfig attribute*), 146
 block_size (*dicee.models.real.CoKEConfig attribute*), 120

block_size (*dicee.models.transformers.GPTConfig* attribute), 126
 blocks (*dicee.models.CoKE* attribute), 147
 blocks (*dicee.models.real.CoKE* attribute), 121
 bn_conv1 (*dicee.models.AConvQ* attribute), 157
 bn_conv1 (*dicee.models.ConvQ* attribute), 157
 bn_conv1 (*dicee.models.quaternion.AConvQ* attribute), 118
 bn_conv1 (*dicee.models.quaternion.ConvQ* attribute), 117
 bn_conv2 (*dicee.models.AConvQ* attribute), 157
 bn_conv2 (*dicee.models.ConvQ* attribute), 157
 bn_conv2 (*dicee.models.quaternion.AConvQ* attribute), 118
 bn_conv2 (*dicee.models.quaternion.ConvQ* attribute), 117
 bn_conv2d (*dicee.models.AConEx* attribute), 150
 bn_conv2d (*dicee.models.AConvO* attribute), 163
 bn_conv2d (*dicee.models.complex.AConEx* attribute), 102
 bn_conv2d (*dicee.models.complex.ConEx* attribute), 102
 bn_conv2d (*dicee.models.ConEx* attribute), 150
 bn_conv2d (*dicee.models.ConvO* attribute), 163
 bn_conv2d (*dicee.models.octonion.AConvO* attribute), 114
 bn_conv2d (*dicee.models.octonion.ConvO* attribute), 113
 BPE_NegativeSamplingDataset (*class in dicee.dataset_classes*), 32
 build_chain_funcs () (*dicee.models.FMult2* method), 178
 build_chain_funcs () (*dicee.models.function_space.FMult2* method), 107
 build_func () (*dicee.models.FMult2* method), 178
 build_func () (*dicee.models.function_space.FMult2* method), 107
 build_projection () (*dicee.weight_averaging.TWA* method), 209
 Byte (*class in dicee.models.transformers*), 122
 byte_pair_encoding (*dicee.analyse_experiments.Experiment* attribute), 20
 byte_pair_encoding (*dicee.config.Namespace* attribute), 30
 byte_pair_encoding (*dicee.knowledge_graph.KG* attribute), 71
 byte_pair_encoding (*dicee.models.base_model.BaseKGE* attribute), 92
 byte_pair_encoding (*dicee.models.BaseKGE* attribute), 140, 143, 149, 153, 159, 172, 175

C

c_attn (*dicee.models.transformers.SelfAttention* attribute), 124
 c_fc (*dicee.models.transformers.MLP* attribute), 125
 c_proj (*dicee.models.transformers.MLP* attribute), 126
 c_proj (*dicee.models.transformers.SelfAttention* attribute), 125
 callbacks (*dicee.abstracts.AbstractTrainer* attribute), 13
 callbacks (*dicee.analyse_experiments.Experiment* attribute), 20
 callbacks (*dicee.config.Namespace* attribute), 28
 callbacks (*dicee.trainer.torch_trainer_ddp.NodeTrainer* attribute), 202
 causal (*dicee.models.CoKEConfig* attribute), 146, 147
 causal (*dicee.models.real.CoKEConfig* attribute), 120
 causal (*dicee.models.transformers.GPTConfig* attribute), 127
 causal (*dicee.models.transformers.SelfAttention* attribute), 125
 chain_func () (*dicee.models.FMult* method), 177
 chain_func () (*dicee.models.function_space.FMult* method), 106
 chain_func () (*dicee.models.function_space.GFMult* method), 107
 chain_func () (*dicee.models.GFMult* method), 177
 CKeci (*class in dicee.models*), 167
 CKeci (*class in dicee.models.clifford*), 98
 cl_pqr () (*dicee.models.clifford.DeCaL* method), 99
 cl_pqr () (*dicee.models.DeCaL* method), 168
 cleanup () (*dicee.Execute* method), 211
 cleanup () (*dicee.executer.Execute* method), 68
 clifford_multiplication () (*dicee.models.clifford.Keci* method), 96
 clifford_multiplication () (*dicee.models.Keci* method), 165
 clip_lambda (*dicee.models.ADOPT* attribute), 131
 clip_lambda (*dicee.models.adopt.ADOPT* attribute), 80
 CoKE (*class in dicee.models*), 147
 CoKE (*class in dicee.models.real*), 120
 coke_dropout (*dicee.models.CoKE* attribute), 147
 coke_dropout (*dicee.models.real.CoKE* attribute), 121
 CoKEConfig (*class in dicee.models*), 146
 CoKEConfig (*class in dicee.models.real*), 120
 collate_fn (*dicee.dataset_classes.AllvsAll* attribute), 35
 collate_fn (*dicee.dataset_classes.KvsAll* attribute), 34

collate_fn (*dicee.dataset_classes.KvsSampleDataset* attribute), 38
 collate_fn (*dicee.dataset_classes.MultiClassClassificationDataset* attribute), 33
 collate_fn (*dicee.dataset_classes.MultiLabelDataset* attribute), 33
 collate_fn (*dicee.dataset_classes.OnesVsAllDataset* attribute), 34
 collate_fn (*dicee.dataset_classes.OnesVsSample* attribute), 36
 collate_fn () (*dicee.dataset_classes.BPE_NegativeSamplingDataset* method), 32
 collate_fn () (*dicee.dataset_classes.TriplePredictionDataset* method), 39
 collection_name (*dicee.scripts.index_serve.NeuralSearcher* attribute), 189
 comp_func () (*dicee.models.function_space.LFMult* method), 109
 comp_func () (*dicee.models.LFM* method), 179
 ComplEx (*class in dicee.models*), 151
 ComplEx (*class in dicee.models.complex*), 103
 compute_convergence () (*in module dicee.callbacks*), 24
 compute_func () (*dicee.models.FMult* method), 177
 compute_func () (*dicee.models.FMult2* method), 178
 compute_func () (*dicee.models.function_space.FMult* method), 106
 compute_func () (*dicee.models.function_space.FMult2* method), 107
 compute_func () (*dicee.models.function_space.GFMult* method), 107
 compute_func () (*dicee.models.GFMult* method), 177
 compute_metrics_from_ranks () (*in module dicee.evaluation*), 62
 compute_metrics_from_ranks () (*in module dicee.evaluation.utils*), 54
 compute_metrics_from_ranks_simple () (*in module dicee.evaluation*), 63
 compute_metrics_from_ranks_simple () (*in module dicee.evaluation.utils*), 54
 compute_mrr () (*dicee.weight_averaging.ASWA* static method), 205
 compute_sigma_pp () (*dicee.models.clifford.DeCaL* method), 100
 compute_sigma_pp () (*dicee.models.clifford.Keci* method), 95
 compute_sigma_pp () (*dicee.models.DeCaL* method), 169
 compute_sigma_pp () (*dicee.models.Keci* method), 164
 compute_sigma_pq () (*dicee.models.clifford.DeCaL* method), 101
 compute_sigma_pq () (*dicee.models.clifford.Keci* method), 96
 compute_sigma_pq () (*dicee.models.DeCaL* method), 170
 compute_sigma_pq () (*dicee.models.Keci* method), 165
 compute_sigma_pr () (*dicee.models.clifford.DeCaL* method), 101
 compute_sigma_pr () (*dicee.models.DeCaL* method), 170
 compute_sigma_qq () (*dicee.models.clifford.DeCaL* method), 100
 compute_sigma_qq () (*dicee.models.clifford.Keci* method), 95
 compute_sigma_qq () (*dicee.models.DeCaL* method), 169
 compute_sigma_qq () (*dicee.models.Keci* method), 165
 compute_sigma_qr () (*dicee.models.clifford.DeCaL* method), 101
 compute_sigma_qr () (*dicee.models.DeCaL* method), 170
 compute_sigma_rr () (*dicee.models.clifford.DeCaL* method), 101
 compute_sigma_rr () (*dicee.models.DeCaL* method), 170
 compute_sigmas_multivect () (*dicee.models.clifford.DeCaL* method), 99
 compute_sigmas_multivect () (*dicee.models.DeCaL* method), 168
 compute_sigmas_single () (*dicee.models.clifford.DeCaL* method), 99
 compute_sigmas_single () (*dicee.models.DeCaL* method), 168
 ConEx (*class in dicee.models*), 150
 ConEx (*class in dicee.models.complex*), 102
 config (*dicee.models.CoKE* attribute), 147
 config (*dicee.models.real.CoKE* attribute), 121
 config (*dicee.models.transformers.BytE* attribute), 122
 config (*dicee.models.transformers.GPT* attribute), 127
 configs (*dicee.abstracts.BaseInteractiveKGE* attribute), 15
 configure_optimizers () (*dicee.models.base_model.BaseKGELightning* method), 89
 configure_optimizers () (*dicee.models.BaseKGELightning* method), 137
 configure_optimizers () (*dicee.models.transformers.GPT* method), 128
 construct_batch_selected_cl_multivector () (*dicee.models.clifford.Keci* method), 97
 construct_batch_selected_cl_multivector () (*dicee.models.Keci* method), 166
 construct_cl_multivector () (*dicee.models.clifford.DeCaL* method), 100
 construct_cl_multivector () (*dicee.models.clifford.Keci* method), 96
 construct_cl_multivector () (*dicee.models.DeCaL* method), 169
 construct_cl_multivector () (*dicee.models.Keci* method), 166
 construct_dataset () (*in module dicee.dataset_classes*), 31
 construct_ensemble (*dicee.abstracts.BaseInteractiveKGE* attribute), 14
 construct_graph () (*dicee.query_generator.QueryGenerator* method), 181
 construct_graph () (*dicee.QueryGenerator* method), 216
 construct_input_and_output () (*dicee.abstracts.BaseInteractiveKGE* method), 16
 construct_multi_coeff () (*dicee.models.function_space.LFMult* method), 108

construct_multi_coeff() (*dicee.models.LFMult method*), 179
 continual_learning (*dicee.config.Namespace attribute*), 30
 continual_start() (*dicee.DICE_Trainer method*), 217
 continual_start() (*dicee.executer.ContinuousExecute method*), 69
 continual_start() (*dicee.trainer.DICE_Trainer method*), 203
 continual_start() (*dicee.trainer.dice_trainer.DICE_Trainer method*), 198
 continual_training_setup_executor() (*in module dicee.static_funcs*), 194
 ContinuousExecute (*class in dicee.executer*), 69
 conv2d (*dicee.models.AConEx attribute*), 150
 conv2d (*dicee.models.AConvO attribute*), 163
 conv2d (*dicee.models.AConvQ attribute*), 157
 conv2d (*dicee.models.complex.AConEx attribute*), 102
 conv2d (*dicee.models.complex.ConEx attribute*), 102
 conv2d (*dicee.models.ConEx attribute*), 150
 conv2d (*dicee.models.ConvO attribute*), 163
 conv2d (*dicee.models.ConvQ attribute*), 157
 conv2d (*dicee.models.octonion.AConvO attribute*), 113
 conv2d (*dicee.models.octonion.ConvO attribute*), 113
 conv2d (*dicee.models.quaternion.AConvQ attribute*), 118
 conv2d (*dicee.models.quaternion.ConvQ attribute*), 117
 ConvO (*class in dicee.models*), 162
 ConvO (*class in dicee.models.octonion*), 112
 ConvQ (*class in dicee.models*), 157
 ConvQ (*class in dicee.models.quaternion*), 117
 count_triples() (*in module dicee.read_preprocess_save_load_kg.util*), 186
 create_and_store_kg() (*dicee.Execute method*), 211
 create_and_store_kg() (*dicee.executer.Execute method*), 68
 create_constraints() (*in module dicee.read_preprocess_save_load_kg.util*), 186
 create_constraints() (*in module dicee.static_preprocess_funcs*), 197
 create_experiment_folder() (*in module dicee.static_funcs*), 194
 create_hits_dict() (*in module dicee.evaluation*), 63
 create_hits_dict() (*in module dicee.evaluation.utils*), 55
 create_random_data() (*dicee.callbacks.PseudoLabellingCallback method*), 24
 create_reciprocal_triples() (*in module dicee.read_preprocess_save_load_kg.util*), 187
 create_reciprocal_triples() (*in module dicee.static_funcs*), 191
 create_vector_database() (*dicee.KGE method*), 212
 create_vector_database() (*dicee.knowledge_graph_embeddings.KGE method*), 73
 crop_block_size() (*dicee.models.transformers.GPT method*), 128
 ctx (*dicee.trainer.torch_trainer_ddp.NodeTrainer attribute*), 202
 current_epoch (*dicee.weight_averaging.EMA attribute*), 208
 current_epoch (*dicee.weight_averaging.SWA attribute*), 206
 current_epoch (*dicee.weight_averaging.SWAG attribute*), 207
 current_epoch (*dicee.weight_averaging.TWA attribute*), 209
 cycle_length (*dicee.callbacks.LRScheduler attribute*), 27

D

data_module (*dicee.callbacks.PseudoLabellingCallback attribute*), 24
 data_property_embeddings (*dicee.models.literal.LiteralEmbeddings attribute*), 110
 data_property_to_idx (*dicee.dataset_classes.LiteralDataset attribute*), 40
 dataset_dir (*dicee.config.Namespace attribute*), 28
 dataset_dir (*dicee.knowledge_graph.KG attribute*), 70, 71
 dataset_sanity_checking() (*in module dicee.read_preprocess_save_load_kg.util*), 187
 DeCaL (*class in dicee.models*), 167
 DeCaL (*class in dicee.models.clifford*), 98
 decay (*dicee.weight_averaging.EMA attribute*), 208
 decide() (*dicee.weight_averaging.ASWA method*), 205
 default_eval_model (*dicee.callbacks.PeriodicEvalCallback attribute*), 26
 DEFAULT_HITS_RANGE (*in module dicee.evaluation*), 63
 DEFAULT_HITS_RANGE (*in module dicee.evaluation.utils*), 54
 degree (*dicee.models.function_space.LFMult attribute*), 108
 degree (*dicee.models.LFMult attribute*), 178
 denormalize() (*dicee.dataset_classes.LiteralDataset static method*), 41
 describe() (*dicee.knowledge_graph.KG method*), 72
 description_of_input (*dicee.knowledge_graph.KG attribute*), 72
 deviations (*dicee.weight_averaging.SWAG attribute*), 207
 device (*dicee.models.literal.LiteralEmbeddings property*), 111
 DICE_Trainer (*class in dicee*), 216

```
DICE_Trainer (class in dicee.trainer), 203
DICE_Trainer (class in dicee.trainer.dice_trainer), 198
dicee
    module, 12
dicee.__main__
    module, 12
dicee.abstracts
    module, 12
dicee.analyse_experiments
    module, 19
dicee.callbacks
    module, 21
dicee.config
    module, 27
dicee.dataset_classes
    module, 31
dicee.eval_static_funcs
    module, 41
dicee.evaluation
    module, 44
dicee.evaluation.ensemble
    module, 45
dicee.evaluation.evaluator
    module, 46
dicee.evaluation.link_prediction
    module, 49
dicee.evaluation.literal_prediction
    module, 52
dicee.evaluation.utils
    module, 53
dicee.evaluator
    module, 64
dicee.executor
    module, 67
dicee.knowledge_graph
    module, 70
dicee.knowledge_graph_embeddings
    module, 72
dicee.models
    module, 76
dicee.models.adopt
    module, 76
dicee.models.base_model
    module, 85
dicee.models.clifford
    module, 94
dicee.models.complex
    module, 101
dicee.models.dualE
    module, 104
dicee.models.ensemble
    module, 105
dicee.models.function_space
    module, 106
dicee.models.literal
    module, 109
dicee.models.octonion
    module, 111
dicee.models.pykeen_models
    module, 114
dicee.models.quaternion
    module, 115
dicee.models.real
    module, 118
dicee.models.static_funcs
    module, 121
dicee.models.transformers
    module, 121
```

```

dicee.query_generator
    module, 180
dicee.read_preprocess_save_load_kg
    module, 182
dicee.read_preprocess_save_load_kg.preprocess
    module, 182
dicee.read_preprocess_save_load_kg.read_from_disk
    module, 183
dicee.read_preprocess_save_load_kg.save_load_disk
    module, 183
dicee.read_preprocess_save_load_kg.util
    module, 184
dicee.sanity_checkers
    module, 188
dicee.scripts
    module, 189
dicee.scripts.index_serve
    module, 189
dicee.scripts.run
    module, 190
dicee.static_funcs
    module, 190
dicee.static_funcs_training
    module, 195
dicee.static_preprocess_funcs
    module, 196
dicee.trainer
    module, 197
dicee.trainer.dice_trainer
    module, 197
dicee.trainer.model_parallelism
    module, 199
dicee.trainer.torch_trainer
    module, 200
dicee.trainer.torch_trainer_ddp
    module, 201
dicee.weight_averaging
    module, 204
discrete_points (dicee.models.FMult2 attribute), 177
discrete_points (dicee.models.function_space.FMult2 attribute), 107
dist_func (dicee.models.Pyke attribute), 146
dist_func (dicee.models.real.Pyke attribute), 119
DistMult (class in dicee.models), 145
DistMult (class in dicee.models.real), 118
distributed (dicee.Execute attribute), 210
distributed (dicee.executer.Execute attribute), 67, 68
domain_constraints_per_rel (dicee.evaluation.Evaluator attribute), 57
domain_constraints_per_rel (dicee.evaluation.evaluator.Evaluator attribute), 47
domain_constraints_per_rel (dicee.Evaluator attribute), 219
domain_constraints_per_rel (dicee.evaluator.Evaluator attribute), 65
download_file() (in module dicee.static_funcs), 194
download_files_from_url() (in module dicee.static_funcs), 194
download_pretrained_model() (in module dicee.static_funcs), 194
dropout (dicee.models.CoKEConfig attribute), 146
dropout (dicee.models.literal.LiteralEmbeddings attribute), 110
dropout (dicee.models.real.CoKEConfig attribute), 120
dropout (dicee.models.transformers.GPTConfig attribute), 127
dropout (dicee.models.transformers.MLP attribute), 126
dropout (dicee.models.transformers.SelfAttention attribute), 125
DualE (class in dicee.models), 179
DualE (class in dicee.models.dualE), 104
dummy_eval() (dicee.evaluation.Evaluator method), 58
dummy_eval() (dicee.evaluation.evaluator.Evaluator method), 49
dummy_eval() (dicee.Evaluator method), 220
dummy_eval() (dicee.evaluator.Evaluator method), 67
dummy_id (dicee.knowledge_graph.KG attribute), 72
during_training (dicee.evaluation.Evaluator attribute), 56, 57
during_training (dicee.evaluation.evaluator.Evaluator attribute), 47

```

`during_training` (*dicee.Evaluator attribute*), 218, 219
`during_training` (*dicee.evaluator.Evaluator attribute*), 64, 65

E

`ee_vocab` (*dicee.evaluation.Evaluator attribute*), 56
`ee_vocab` (*dicee.evaluation.evaluator.Evaluator attribute*), 46, 47
`ee_vocab` (*dicee.Evaluator attribute*), 218
`ee_vocab` (*dicee.evaluator.Evaluator attribute*), 64, 65
`efficient_zero_grad()` (in module *dicee.evaluation.utils*), 55
`efficient_zero_grad()` (in module *dicee.static_funcs_training*), 196
`EMA` (class in *dicee.weight_averaging*), 207
`ema` (*dicee.config.Namespace attribute*), 30
`ema_c_epochs` (*dicee.weight_averaging.EMA attribute*), 208
`ema_model` (*dicee.weight_averaging.EMA attribute*), 208
`ema_start_epoch` (*dicee.weight_averaging.EMA attribute*), 208
`ema_update()` (*dicee.weight_averaging.EMA static method*), 208
`embedding_dim` (*dicee.analyse_experiments.Experiment attribute*), 20
`embedding_dim` (*dicee.config.Namespace attribute*), 28
`embedding_dim` (*dicee.models.base_model.BaseKGE attribute*), 91
`embedding_dim` (*dicee.models.BaseKGE attribute*), 139, 142, 148, 152, 158, 171, 175
`embedding_dim` (*dicee.models.literal.LiteralEmbeddings attribute*), 110
`embedding_dims` (*dicee.models.literal.LiteralEmbeddings attribute*), 110
`enable_log` (in module *dicee.static_preprocess_funcs*), 196
`enc` (*dicee.knowledge_graph.KG attribute*), 71
`end()` (*dicee.Execute method*), 211
`end()` (*dicee.executer.Execute method*), 69
`EnsembleKGE` (class in *dicee.models.ensemble*), 105
`ent2id` (*dicee.query_generator.QueryGenerator attribute*), 181
`ent2id` (*dicee.QueryGenerator attribute*), 215
`ent_in` (*dicee.query_generator.QueryGenerator attribute*), 181
`ent_in` (*dicee.QueryGenerator attribute*), 215
`ent_out` (*dicee.query_generator.QueryGenerator attribute*), 181
`ent_out` (*dicee.QueryGenerator attribute*), 215
`entities_str` (*dicee.knowledge_graph.KG property*), 72
`entity_embeddings` (*dicee.models.AConvQ attribute*), 157
`entity_embeddings` (*dicee.models.clifford.DeCaL attribute*), 98
`entity_embeddings` (*dicee.models.ConvQ attribute*), 157
`entity_embeddings` (*dicee.models.DeCaL attribute*), 167
`entity_embeddings` (*dicee.models.DualE attribute*), 180
`entity_embeddings` (*dicee.models.dualE.DualE attribute*), 104
`entity_embeddings` (*dicee.models.FMult attribute*), 176
`entity_embeddings` (*dicee.models.FMult2 attribute*), 177
`entity_embeddings` (*dicee.models.function_space.FMult attribute*), 106
`entity_embeddings` (*dicee.models.function_space.FMult2 attribute*), 107
`entity_embeddings` (*dicee.models.function_space.GFMult attribute*), 107
`entity_embeddings` (*dicee.models.function_space.LFMult attribute*), 108
`entity_embeddings` (*dicee.models.function_space.LFMult1 attribute*), 108
`entity_embeddings` (*dicee.models.GFMult attribute*), 177
`entity_embeddings` (*dicee.models.LFMult attribute*), 178
`entity_embeddings` (*dicee.models.LFMult1 attribute*), 178
`entity_embeddings` (*dicee.models.literal.LiteralEmbeddings attribute*), 110
`entity_embeddings` (*dicee.models.pykeen_models.PykeenKGE attribute*), 114
`entity_embeddings` (*dicee.models.PykeenKGE attribute*), 173
`entity_embeddings` (*dicee.models.quaternion.AConvQ attribute*), 118
`entity_embeddings` (*dicee.models.quaternion.ConvQ attribute*), 117
`entity_to_idx` (*dicee.dataset_classes.LiteralDataset attribute*), 40
`entity_to_idx` (*dicee.knowledge_graph.KG attribute*), 70, 71
`entity_to_idx` (*dicee.scripts.index_serve.NeuralSearcher attribute*), 189
`epoch_count` (*dicee.abstracts.AbstractPPECallback attribute*), 18
`epoch_count` (*dicee.weight_averaging.ASWA attribute*), 204
`epoch_counter` (*dicee.callbacks.Eval attribute*), 24
`epoch_counter` (*dicee.callbacks.KGESaveCallback attribute*), 23
`epoch_counter` (*dicee.callbacks.PeriodicEvalCallback attribute*), 26
`epoch_ratio` (*dicee.callbacks.Eval attribute*), 24
`er_vocab` (*dicee.evaluation.Evaluator attribute*), 56
`er_vocab` (*dicee.evaluation.evaluator.Evaluator attribute*), 46, 47
`er_vocab` (*dicee.Evaluator attribute*), 218

er_vocab (*dicee.evaluator.Evaluator attribute*), 64, 65
 estimate_mfu () (*dicee.models.transformers.GPT method*), 128
 estimate_q () (*in module dicee.callbacks*), 24
 Eval (*class in dicee.callbacks*), 24
 eval () (*dicee.evaluation.Evaluator method*), 57
 eval () (*dicee.evaluation.evaluator.Evaluator method*), 47
 eval () (*dicee.Evaluator method*), 219
 eval () (*dicee.evaluator.Evaluator method*), 65
 eval () (*dicee.models.ensemble.EnsembleKGE method*), 105
 eval_at_epochs (*dicee.config.Namespace attribute*), 31
 eval_epochs (*dicee.callbacks.PeriodicEvalCallback attribute*), 26
 eval_every_n_epochs (*dicee.config.Namespace attribute*), 30
 eval_lp_performance () (*dicee.KGE method*), 212
 eval_lp_performance () (*dicee.knowledge_graph_embeddings.KGE method*), 73
 eval_model (*dicee.config.Namespace attribute*), 29
 eval_model (*dicee.knowledge_graph.KG attribute*), 71
 eval_rank_of_head_and_tail_byte_pair_encoded_entity () (*dicee.evaluation.Evaluator method*), 57
 eval_rank_of_head_and_tail_byte_pair_encoded_entity () (*dicee.evaluation.evaluator.Evaluator method*), 48
 eval_rank_of_head_and_tail_byte_pair_encoded_entity () (*dicee.Evaluator method*), 219
 eval_rank_of_head_and_tail_byte_pair_encoded_entity () (*dicee.evaluator.Evaluator method*), 65
 eval_rank_of_head_and_tail_entity () (*dicee.evaluation.Evaluator method*), 57
 eval_rank_of_head_and_tail_entity () (*dicee.evaluation.evaluator.Evaluator method*), 48
 eval_rank_of_head_and_tail_entity () (*dicee.Evaluator method*), 219
 eval_rank_of_head_and_tail_entity () (*dicee.evaluator.Evaluator method*), 65
 eval_with_bpe_vs_all () (*dicee.evaluation.Evaluator method*), 57
 eval_with_bpe_vs_all () (*dicee.evaluation.evaluator.Evaluator method*), 48
 eval_with_bpe_vs_all () (*dicee.Evaluator method*), 219
 eval_with_bpe_vs_all () (*dicee.evaluator.Evaluator method*), 65
 eval_with_byte () (*dicee.evaluation.Evaluator method*), 57
 eval_with_byte () (*dicee.evaluation.evaluator.Evaluator method*), 48
 eval_with_byte () (*dicee.Evaluator method*), 219
 eval_with_byte () (*dicee.evaluator.Evaluator method*), 65
 eval_with_data () (*dicee.evaluation.Evaluator method*), 58
 eval_with_data () (*dicee.evaluation.evaluator.Evaluator method*), 49
 eval_with_data () (*dicee.Evaluator method*), 220
 eval_with_data () (*dicee.evaluator.Evaluator method*), 67
 eval_with_vs_all () (*dicee.evaluation.Evaluator method*), 57
 eval_with_vs_all () (*dicee.evaluation.evaluator.Evaluator method*), 48
 eval_with_vs_all () (*dicee.Evaluator method*), 219
 eval_with_vs_all () (*dicee.evaluator.Evaluator method*), 66
 evaluate () (*in module dicee.static_funcs*), 194
 evaluate_bpe_lp () (*in module dicee.evaluation*), 61
 evaluate_bpe_lp () (*in module dicee.evaluation.link_prediction*), 51
 evaluate_bpe_lp () (*in module dicee.static_funcs_training*), 195
 evaluate_ensemble_link_prediction_performance () (*in module dicee.eval_static_funcs*), 44
 evaluate_ensemble_link_prediction_performance () (*in module dicee.evaluation*), 62
 evaluate_ensemble_link_prediction_performance () (*in module dicee.evaluation.ensemble*), 45
 evaluate_link_prediction_performance () (*in module dicee.eval_static_funcs*), 41
 evaluate_link_prediction_performance () (*in module dicee.evaluation*), 59
 evaluate_link_prediction_performance () (*in module dicee.evaluation.link_prediction*), 50
 evaluate_link_prediction_performance_with_bpe () (*in module dicee.eval_static_funcs*), 42
 evaluate_link_prediction_performance_with_bpe () (*in module dicee.evaluation*), 59
 evaluate_link_prediction_performance_with_bpe () (*in module dicee.evaluation.link_prediction*), 51
 evaluate_link_prediction_performance_with_bpe_reciprocals () (*in module dicee.eval_static_funcs*), 42
 evaluate_link_prediction_performance_with_bpe_reciprocals () (*in module dicee.evaluation*), 60
 evaluate_link_prediction_performance_with_bpe_reciprocals () (*in module dicee.evaluation.link_prediction*), 50
 evaluate_link_prediction_performance_with_reciprocals () (*in module dicee.eval_static_funcs*), 42
 evaluate_link_prediction_performance_with_reciprocals () (*in module dicee.evaluation*), 59
 evaluate_link_prediction_performance_with_reciprocals () (*in module dicee.evaluation.link_prediction*), 50
 evaluate_literal_prediction () (*in module dicee.eval_static_funcs*), 43
 evaluate_literal_prediction () (*in module dicee.evaluation*), 61
 evaluate_literal_prediction () (*in module dicee.evaluation.literal_prediction*), 52
 evaluate_lp () (*dicee.evaluation.Evaluator method*), 58
 evaluate_lp () (*dicee.evaluation.evaluator.Evaluator method*), 49
 evaluate_lp () (*dicee.Evaluator method*), 220
 evaluate_lp () (*dicee.evaluator.Evaluator method*), 66
 evaluate_lp () (*in module dicee.evaluation*), 60
 evaluate_lp () (*in module dicee.evaluation.link_prediction*), 51

```

evaluate_lp() (in module dicee.static_funcs_training), 195
evaluate_lp_bpe_k_vs_all() (dicee.evaluation.Evaluator method), 58
evaluate_lp_bpe_k_vs_all() (dicee.evaluation.evaluator.Evaluator method), 48
evaluate_lp_bpe_k_vs_all() (dicee.Evaluator method), 220
evaluate_lp_bpe_k_vs_all() (dicee.evaluator.Evaluator method), 66
evaluate_lp_bpe_k_vs_all() (in module dicee.eval_static_funcs), 42
evaluate_lp_bpe_k_vs_all() (in module dicee.evaluation), 60
evaluate_lp_bpe_k_vs_all() (in module dicee.evaluation.link_prediction), 52
evaluate_lp_k_vs_all() (dicee.evaluation.Evaluator method), 57
evaluate_lp_k_vs_all() (dicee.evaluation.evaluator.Evaluator method), 48
evaluate_lp_k_vs_all() (dicee.Evaluator method), 219
evaluate_lp_k_vs_all() (dicee.evaluator.Evaluator method), 66
evaluate_lp_with_byte() (dicee.evaluation.Evaluator method), 58
evaluate_lp_with_byte() (dicee.evaluation.evaluator.Evaluator method), 48
evaluate_lp_with_byte() (dicee.Evaluator method), 220
evaluate_lp_with_byte() (dicee.evaluator.Evaluator method), 66
Evaluator (class in dicee), 218
Evaluator (class in dicee.evaluation), 56
Evaluator (class in dicee.evaluation.evaluator), 46
Evaluator (class in dicee.evaluator), 64
evaluator (dicee.DICE_Trainer attribute), 217
evaluator (dicee.Execute attribute), 210, 211
evaluator (dicee.executer.Execute attribute), 68
evaluator (dicee.trainer.DICE_Trainer attribute), 203
evaluator (dicee.trainer.dice_trainer.DICE_Trainer attribute), 198
every_x_epoch (dicee.callbacks.KGESaveCallback attribute), 23
example_input_array (dicee.models.ensemble.EnsembleKGE property), 105
Execute (class in dicee), 210
Execute (class in dicee.executer), 67
exists() (dicee.knowledge_graph.KG method), 72
Experiment (class in dicee.analyse_experiments), 19
experiment_dir (dicee.callbacks.LRScheduler attribute), 27
experiment_dir (dicee.callbacks.PeriodicEvalCallback attribute), 26
explicit (dicee.models.QMult attribute), 156
explicit (dicee.models.quaternion.QMult attribute), 116
exponential_function() (in module dicee.static_funcs), 194
extract_input_outputs() (dicee.trainer.torch_trainer_ddp.NodeTrainer method), 202
extract_input_outputs() (in module dicee.trainer.model_parallelism), 200
extract_input_outputs_set_device() (dicee.trainer.torch_trainer.TorchTrainer method), 201

```

F

```

f (dicee.callbacks.KronE attribute), 25
fc (dicee.models.literal.LiteralEmbeddings attribute), 110
fc1 (dicee.models.AConEx attribute), 150
fc1 (dicee.models.AConvO attribute), 163
fc1 (dicee.models.AConvQ attribute), 157
fc1 (dicee.models.complex.AConEx attribute), 102
fc1 (dicee.models.complex.ConEx attribute), 102
fc1 (dicee.models.ConEx attribute), 150
fc1 (dicee.models.ConvO attribute), 163
fc1 (dicee.models.ConvQ attribute), 157
fc1 (dicee.models.octonion.AConvO attribute), 113
fc1 (dicee.models.octonion.ConvO attribute), 113
fc1 (dicee.models.quaternion.AConvQ attribute), 118
fc1 (dicee.models.quaternion.ConvQ attribute), 117
fc_num_input (dicee.models.AConEx attribute), 150
fc_num_input (dicee.models.AConvO attribute), 163
fc_num_input (dicee.models.AConvQ attribute), 157
fc_num_input (dicee.models.complex.AConEx attribute), 102
fc_num_input (dicee.models.complex.ConEx attribute), 102
fc_num_input (dicee.models.ConEx attribute), 150
fc_num_input (dicee.models.ConvO attribute), 163
fc_num_input (dicee.models.ConvQ attribute), 157
fc_num_input (dicee.models.octonion.AConvO attribute), 113
fc_num_input (dicee.models.octonion.ConvO attribute), 113
fc_num_input (dicee.models.quaternion.AConvQ attribute), 118
fc_num_input (dicee.models.quaternion.ConvQ attribute), 117

```

fc_out (*dicee.models.literal.LiteralEmbeddings* attribute), 110
 feature_map_dropout (*dicee.models.AConEx* attribute), 150
 feature_map_dropout (*dicee.models.AConvO* attribute), 163
 feature_map_dropout (*dicee.models.AConvQ* attribute), 157
 feature_map_dropout (*dicee.models.complex.AConEx* attribute), 102
 feature_map_dropout (*dicee.models.complex.ConEx* attribute), 102
 feature_map_dropout (*dicee.models.ConEx* attribute), 150
 feature_map_dropout (*dicee.models.ConvO* attribute), 163
 feature_map_dropout (*dicee.models.ConvQ* attribute), 157
 feature_map_dropout (*dicee.models.octonion.AConvO* attribute), 114
 feature_map_dropout (*dicee.models.octonion.ConvO* attribute), 113
 feature_map_dropout (*dicee.models.quaternion.AConvQ* attribute), 118
 feature_map_dropout (*dicee.models.quaternion.ConvQ* attribute), 117
 feature_map_dropout_rate (*dicee.config.Namespace* attribute), 30
 feature_map_dropout_rate (*dicee.models.base_model.BaseKGE* attribute), 92
 feature_map_dropout_rate (*dicee.models.BaseKGE* attribute), 139, 142, 148, 153, 159, 171, 175
 fetch_worker () (*in module dicee.read_preprocess_save_load_kg.util*), 186
 fill_query () (*dicee.query_generator.QueryGenerator* method), 181
 fill_query () (*dicee.QueryGenerator* method), 216
 find_good_batch_size () (*in module dicee.trainer.model_parallelism*), 200
 find_missing_triples () (*dicee.KGE* method), 214
 find_missing_triples () (*dicee.knowledge_graph_embeddings.KGE* method), 75
 fit () (*dicee.trainer.model_parallelism.TensorParallel* method), 200
 fit () (*dicee.trainer.torch_trainer_ddp.TorchDDPTrainer* method), 202
 fit () (*dicee.trainer.torch_trainer.TorchTrainer* method), 201
 flash (*dicee.models.transformers.SelfAttention* attribute), 125
 FMult (*class in dicee.models*), 176
 FMult (*class in dicee.models.function_space*), 106
 FMult2 (*class in dicee.models*), 177
 FMult2 (*class in dicee.models.function_space*), 107
 form_of_labelling (*dicee.DICE_Trainer* attribute), 217
 form_of_labelling (*dicee.trainer.DICE_Trainer* attribute), 203
 form_of_labelling (*dicee.trainer.dice_trainer.DICE_Trainer* attribute), 198
 forward () (*dicee.models.base_model.BaseKGE* method), 93
 forward () (*dicee.models.base_model.IdentityClass* static method), 94
 forward () (*dicee.models.BaseKGE* method), 140, 143, 149, 153, 160, 172, 176
 forward () (*dicee.models.Block* method), 145
 forward () (*dicee.models.IdentityClass* static method), 141, 155, 161
 forward () (*dicee.models.literal.LiteralEmbeddings* method), 111
 forward () (*dicee.models.transformers.Block* method), 126
 forward () (*dicee.models.transformers.BytE* method), 122
 forward () (*dicee.models.transformers.GPT* method), 128
 forward () (*dicee.models.transformers.LayerNorm* method), 124
 forward () (*dicee.models.transformers.MLP* method), 126
 forward () (*dicee.models.transformers.SelfAttention* method), 125
 forward_backward_update () (*dicee.trainer.torch_trainer.TorchTrainer* method), 201
 forward_backward_update_loss () (*in module dicee.trainer.model_parallelism*), 200
 forward_byte_pair_encoded_k_vs_all () (*dicee.models.base_model.BaseKGE* method), 92
 forward_byte_pair_encoded_k_vs_all () (*dicee.models.BaseKGE* method), 140, 143, 149, 153, 159, 172, 175
 forward_byte_pair_encoded_triple () (*dicee.models.base_model.BaseKGE* method), 92
 forward_byte_pair_encoded_triple () (*dicee.models.BaseKGE* method), 140, 143, 149, 153, 159, 172, 175
 forward_k_vs_all () (*dicee.models.AConEx* method), 150
 forward_k_vs_all () (*dicee.models.AConvO* method), 163
 forward_k_vs_all () (*dicee.models.AConvQ* method), 158
 forward_k_vs_all () (*dicee.models.base_model.BaseKGE* method), 93
 forward_k_vs_all () (*dicee.models.BaseKGE* method), 140, 143, 149, 154, 160, 173, 176
 forward_k_vs_all () (*dicee.models.clifford.DeCaL* method), 99
 forward_k_vs_all () (*dicee.models.clifford.Keci* method), 97
 forward_k_vs_all () (*dicee.models.CoKE* method), 147
 forward_k_vs_all () (*dicee.models.ComplEx* method), 152
 forward_k_vs_all () (*dicee.models.complex.AConEx* method), 103
 forward_k_vs_all () (*dicee.models.complex.ComplEx* method), 104
 forward_k_vs_all () (*dicee.models.complex.ConEx* method), 102
 forward_k_vs_all () (*dicee.models.ConEx* method), 150
 forward_k_vs_all () (*dicee.models.ConvO* method), 163
 forward_k_vs_all () (*dicee.models.ConvQ* method), 157
 forward_k_vs_all () (*dicee.models.DeCaL* method), 168
 forward_k_vs_all () (*dicee.models.DistMult* method), 145

```

forward_k_vs_all() (dicee.models.DualE method), 180
forward_k_vs_all() (dicee.models.dualE.DualE method), 105
forward_k_vs_all() (dicee.models.Keci method), 166
forward_k_vs_all() (dicee.models.octonion.AConvO method), 114
forward_k_vs_all() (dicee.models.octonion.ConvO method), 113
forward_k_vs_all() (dicee.models.octonion.OMult method), 112
forward_k_vs_all() (dicee.models.OMult method), 162
forward_k_vs_all() (dicee.models.pykeen_models.PykeenKGE method), 114
forward_k_vs_all() (dicee.models.PykeenKGE method), 173
forward_k_vs_all() (dicee.models.QMult method), 156
forward_k_vs_all() (dicee.models.quaternion.AConvQ method), 118
forward_k_vs_all() (dicee.models.quaternion.ConvQ method), 117
forward_k_vs_all() (dicee.models.quaternion.QMult method), 117
forward_k_vs_all() (dicee.models.real.CoKE method), 121
forward_k_vs_all() (dicee.models.real.DistMult method), 119
forward_k_vs_all() (dicee.models.real.Shallom method), 119
forward_k_vs_all() (dicee.models.real.TransE method), 119
forward_k_vs_all() (dicee.models.Shallom method), 145
forward_k_vs_all() (dicee.models.TransE method), 145
forward_k_vs_sample() (dicee.models.AConEx method), 151
forward_k_vs_sample() (dicee.models.base_model.BaseKGE method), 93
forward_k_vs_sample() (dicee.models.BaseKGE method), 140, 143, 149, 154, 160, 173, 176
forward_k_vs_sample() (dicee.models.clifford.Keci method), 97
forward_k_vs_sample() (dicee.models.CoKE method), 147
forward_k_vs_sample() (dicee.models.ComplEx method), 152
forward_k_vs_sample() (dicee.models.complex.AConEx method), 103
forward_k_vs_sample() (dicee.models.complex.ComplEx method), 104
forward_k_vs_sample() (dicee.models.complex.ConEx method), 102
forward_k_vs_sample() (dicee.models.ConEx method), 150
forward_k_vs_sample() (dicee.models.DistMult method), 145
forward_k_vs_sample() (dicee.models.Keci method), 166
forward_k_vs_sample() (dicee.models.pykeen_models.PykeenKGE method), 115
forward_k_vs_sample() (dicee.models.PykeenKGE method), 174
forward_k_vs_sample() (dicee.models.QMult method), 156
forward_k_vs_sample() (dicee.models.quaternion.QMult method), 117
forward_k_vs_sample() (dicee.models.real.CoKE method), 121
forward_k_vs_sample() (dicee.models.real.DistMult method), 119
forward_k_vs_with_explicit() (dicee.models.clifford.Keci method), 97
forward_k_vs_with_explicit() (dicee.models.Keci method), 166
forward_triples() (dicee.models.AConEx method), 151
forward_triples() (dicee.models.AConvO method), 163
forward_triples() (dicee.models.AConvQ method), 158
forward_triples() (dicee.models.base_model.BaseKGE method), 93
forward_triples() (dicee.models.BaseKGE method), 140, 143, 149, 154, 160, 172, 176
forward_triples() (dicee.models.clifford.DeCaL method), 99
forward_triples() (dicee.models.clifford.Keci method), 97
forward_triples() (dicee.models.complex.AConEx method), 103
forward_triples() (dicee.models.complex.ConEx method), 102
forward_triples() (dicee.models.ConEx method), 150
forward_triples() (dicee.models.ConvO method), 163
forward_triples() (dicee.models.ConvQ method), 157
forward_triples() (dicee.models.DeCaL method), 168
forward_triples() (dicee.models.DualE method), 180
forward_triples() (dicee.models.dualE.DualE method), 104
forward_triples() (dicee.models.FMult method), 177
forward_triples() (dicee.models.FMult2 method), 178
forward_triples() (dicee.models.function_space.FMult method), 106
forward_triples() (dicee.models.function_space.FMult2 method), 108
forward_triples() (dicee.models.function_space.GFMult method), 107
forward_triples() (dicee.models.function_space.LFMult method), 108
forward_triples() (dicee.models.function_space.LFMult1 method), 108
forward_triples() (dicee.models.GFMult method), 177
forward_triples() (dicee.models.Keci method), 167
forward_triples() (dicee.models.LFMult method), 178
forward_triples() (dicee.models.LFMult1 method), 178
forward_triples() (dicee.models.octonion.AConvO method), 114
forward_triples() (dicee.models.octonion.ConvO method), 113
forward_triples() (dicee.models.Pyke method), 146

```

```

forward_triples() (dicee.models.pykeen_models.PykeenKGE method), 115
forward_triples() (dicee.models.PykeenKGE method), 174
forward_triples() (dicee.models.quaternion.ACConvQ method), 118
forward_triples() (dicee.models.quaternion.ConvQ method), 117
forward_triples() (dicee.models.real.Pyke method), 119
forward_triples() (dicee.models.real.Shallom method), 119
forward_triples() (dicee.models.Shallom method), 145
freeze_entity_embeddings (dicee.models.literal.LiteralEmbeddings attribute), 110
frequency (dicee.callbacks.Perturb attribute), 26
from_pretrained() (dicee.models.transformers.GPT class method), 128
from_pretrained_model_write_embeddings_into_csv() (in module dicee.static_funcs), 194
full_storage_path (dicee.analyse_experiments.Experiment attribute), 20
func_triple_to_bpe_representation (dicee.evaluation.Evaluator attribute), 56
func_triple_to_bpe_representation (dicee.evaluation.evaluator.Evaluator attribute), 47
func_triple_to_bpe_representation (dicee.Evaluator attribute), 218
func_triple_to_bpe_representation (dicee.evaluator.Evaluator attribute), 65
func_triple_to_bpe_representation() (dicee.knowledge_graph.KG method), 72
function() (dicee.models.FMult2 method), 178
function() (dicee.models.function_space.FMult2 method), 107

```

G

```

gamma (dicee.models.FMult attribute), 177
gamma (dicee.models.function_space.FMult attribute), 106
gate_residual (dicee.models.literal.LiteralEmbeddings attribute), 110
gated_residual_proj (dicee.models.literal.LiteralEmbeddings attribute), 110
gelu (dicee.models.transformers.MLP attribute), 125
gen_test (dicee.query_generator.QueryGenerator attribute), 181
gen_test (dicee.QueryGenerator attribute), 215
gen_valid (dicee.query_generator.QueryGenerator attribute), 181
gen_valid (dicee.QueryGenerator attribute), 215
generate() (dicee.KGE method), 212
generate() (dicee.knowledge_graph_embeddings.KGE method), 73
generate() (dicee.models.transformers.BytE method), 123
generate_queries() (dicee.query_generator.QueryGenerator method), 181
generate_queries() (dicee.QueryGenerator method), 216
get_aswa_state_dict() (dicee.weight_averaging.ASWA method), 205
get_bpe_head_and_relation_representation() (dicee.models.base_model.BaseKGE method), 93
get_bpe_head_and_relation_representation() (dicee.models.BaseKGE method), 140, 144, 149, 154, 160, 173, 176
get_bpe_token_representation() (dicee.abtracts.BaseInteractiveKGE method), 15
get_callbacks() (in module dicee.trainer.dice_trainer), 198
get_default_arguments() (in module dicee.analyse_experiments), 19
get_default_arguments() (in module dicee.scripts.index_serve), 189
get_default_arguments() (in module dicee.scripts.run), 190
get_ee_vocab() (in module dicee.read_preprocess_save_load_kg.util), 186
get_ee_vocab() (in module dicee.static_funcs), 192
get_ee_vocab() (in module dicee.static_preprocess_funcs), 197
get_embeddings() (dicee.models.base_model.BaseKGE method), 93
get_embeddings() (dicee.models.BaseKGE method), 141, 144, 149, 154, 160, 173, 176
get_embeddings() (dicee.models.ensemble.EnsembleKGE method), 106
get_embeddings() (dicee.models.real.Shallom method), 119
get_embeddings() (dicee.models.Shallom method), 145
get_entity_embeddings() (dicee.abtracts.BaseInteractiveKGE method), 16
get_entity_index() (dicee.abtracts.BaseInteractiveKGE method), 15
get_er_vocab() (in module dicee.read_preprocess_save_load_kg.util), 186
get_er_vocab() (in module dicee.static_funcs), 191
get_er_vocab() (in module dicee.static_preprocess_funcs), 197
get_eval_report() (dicee.abtracts.BaseInteractiveKGE method), 15
get_head_relation_representation() (dicee.models.base_model.BaseKGE method), 93
get_head_relation_representation() (dicee.models.BaseKGE method), 140, 143, 149, 154, 160, 173, 176
get_kronecker_triple_representation() (dicee.callbacks.KronE method), 25
get_mean_and_var() (dicee.weight_averaging.SWAG method), 207
get_num_params() (dicee.models.transformers.GPT method), 127
get_padded_bpe_triple_representation() (dicee.abtracts.BaseInteractiveKGE method), 15
get_queries() (dicee.query_generator.QueryGenerator method), 182
get_queries() (dicee.QueryGenerator method), 216
get_re_vocab() (in module dicee.read_preprocess_save_load_kg.util), 186
get_re_vocab() (in module dicee.static_funcs), 192

```

get_re_vocab() (*in module dicee.static_preprocess_funcs*), 197
 get_relation_embeddings() (*dicee.abstracts.BaseInteractiveKGE method*), 16
 get_relation_index() (*dicee.abstracts.BaseInteractiveKGE method*), 15
 get_sentence_representation() (*dicee.models.base_model.BaseKGE method*), 93
 get_sentence_representation() (*dicee.models.BaseKGE method*), 140, 144, 149, 154, 160, 173, 176
 get_transductive_entity_embeddings() (*dicee.KGE method*), 212
 get_transductive_entity_embeddings() (*dicee.knowledge_graph_embeddings.KGE method*), 73
 get_triple_representation() (*dicee.models.base_model.BaseKGE method*), 93
 get_triple_representation() (*dicee.models.BaseKGE method*), 140, 143, 149, 154, 160, 173, 176
 GFMult (*class in dicee.models*), 177
 GFMult (*class in dicee.models.function_space*), 107
 global_rank (*dicee.abstracts.AbstractTrainer attribute*), 13
 global_rank (*dicee.trainer.torch_trainer_ddp.NodeTrainer attribute*), 202
 GPT (*class in dicee.models.transformers*), 127
 GPTConfig (*class in dicee.models.transformers*), 126
 gpus (*dicee.config.Namespace attribute*), 28
 gradient_accumulation_steps (*dicee.config.Namespace attribute*), 29
 ground_queries() (*dicee.query_generator.QueryGenerator method*), 181
 ground_queries() (*dicee.QueryGenerator method*), 216
 gswa_n (*dicee.weight_averaging.SWAG attribute*), 207

H

hidden_dim (*dicee.models.literal.LiteralEmbeddings attribute*), 110
 hidden_dropout (*dicee.models.base_model.BaseKGE attribute*), 92
 hidden_dropout (*dicee.models.BaseKGE attribute*), 140, 143, 148, 153, 159, 172, 175
 hidden_dropout_rate (*dicee.config.Namespace attribute*), 30
 hidden_dropout_rate (*dicee.models.base_model.BaseKGE attribute*), 92
 hidden_dropout_rate (*dicee.models.BaseKGE attribute*), 139, 142, 148, 153, 159, 171, 175
 hidden_normalizer (*dicee.models.base_model.BaseKGE attribute*), 92
 hidden_normalizer (*dicee.models.BaseKGE attribute*), 139, 143, 148, 153, 159, 172, 175

I

IdentityClass (*class in dicee.models*), 141, 154, 160
 IdentityClass (*class in dicee.models.base_model*), 93
 idx_entity_to_bpe_shaped (*dicee.knowledge_graph.KG attribute*), 71
 index() (*in module dicee.scripts.index_serve*), 189
 index_triple() (*dicee.abstracts.BaseInteractiveKGE method*), 15
 init_dataloader() (*dicee.DICE_Trainer method*), 217
 init_dataloader() (*dicee.trainer.DICE_Trainer method*), 203
 init_dataloader() (*dicee.trainer.dice_trainer.DICE_Trainer method*), 199
 init_dataset() (*dicee.DICE_Trainer method*), 217
 init_dataset() (*dicee.trainer.DICE_Trainer method*), 204
 init_dataset() (*dicee.trainer.dice_trainer.DICE_Trainer method*), 199
 init_param (*dicee.config.Namespace attribute*), 29
 init_params_with_sanity_checking() (*dicee.models.base_model.BaseKGE method*), 93
 init_params_with_sanity_checking() (*dicee.models.BaseKGE method*), 140, 143, 149, 153, 159, 172, 176
 initial_eval_setting (*dicee.weight_averaging.ASWA attribute*), 204
 initialize_or_load_model() (*dicee.DICE_Trainer method*), 217
 initialize_or_load_model() (*dicee.trainer.DICE_Trainer method*), 203
 initialize_or_load_model() (*dicee.trainer.dice_trainer.DICE_Trainer method*), 199
 initialize_trainer() (*dicee.DICE_Trainer method*), 217
 initialize_trainer() (*dicee.trainer.DICE_Trainer method*), 203
 initialize_trainer() (*dicee.trainer.dice_trainer.DICE_Trainer method*), 199
 initialize_trainer() (*in module dicee.trainer.dice_trainer*), 197
 input_dp_ent_real (*dicee.models.base_model.BaseKGE attribute*), 92
 input_dp_ent_real (*dicee.models.BaseKGE attribute*), 140, 143, 148, 153, 159, 172, 175
 input_dp_rel_real (*dicee.models.base_model.BaseKGE attribute*), 92
 input_dp_rel_real (*dicee.models.BaseKGE attribute*), 140, 143, 148, 153, 159, 172, 175
 input_dropout_rate (*dicee.config.Namespace attribute*), 30
 input_dropout_rate (*dicee.models.base_model.BaseKGE attribute*), 92
 input_dropout_rate (*dicee.models.BaseKGE attribute*), 139, 142, 148, 153, 159, 171, 175
 InteractiveQueryDecomposition (*class in dicee.abstracts*), 16
 initialize_model() (*in module dicee.static_funcs*), 193
 is_continual_training (*dicee.DICE_Trainer attribute*), 217
 is_continual_training (*dicee.evaluation.Evaluator attribute*), 56
 is_continual_training (*dicee.evaluation.evaluator.Evaluator attribute*), 47
 is_continual_training (*dicee.Evaluator attribute*), 218

is_continual_training (*dicee.evaluator.Evaluator attribute*), 65
 is_continual_training (*dicee.Execute attribute*), 210
 is_continual_training (*dicee.executer.Execute attribute*), 68
 is_continual_training (*dicee.trainer.DICE_Trainer attribute*), 203
 is_continual_training (*dicee.trainer.dice_trainer.DICE_Trainer attribute*), 198
 is_global_zero (*dicee.abstracts.AbstractTrainer attribute*), 13
 is_rank_zero() (*dicee.Execute method*), 211
 is_rank_zero() (*dicee.executer.Execute method*), 68
 is_seen() (*dicee.abtracts.BaseInteractiveKGE method*), 15
 is_sparql_endpoint_alive() (*in module dicee.sanity_checkers*), 188

K

k (*dicee.models.FMult attribute*), 176
 k (*dicee.models.FMult2 attribute*), 177
 k (*dicee.models.function_space.FMult attribute*), 106
 k (*dicee.models.function_space.FMult2 attribute*), 107
 k (*dicee.models.function_space.GFMult attribute*), 107
 k (*dicee.models.GFMult attribute*), 177
 k_fold_cross_validation() (*dicee.DICE_Trainer method*), 217
 k_fold_cross_validation() (*dicee.trainer.DICE_Trainer method*), 204
 k_fold_cross_validation() (*dicee.trainer.dice_trainer.DICE_Trainer method*), 199
 k_vs_all_score() (*dicee.models.clifford.Keci method*), 97
 k_vs_all_score() (*dicee.models.ComplEx static method*), 151
 k_vs_all_score() (*dicee.models.complex.ComplEx static method*), 103
 k_vs_all_score() (*dicee.models.DistMult method*), 145
 k_vs_all_score() (*dicee.models.Keci method*), 166
 k_vs_all_score() (*dicee.models.octonion.OMult method*), 112
 k_vs_all_score() (*dicee.models.OMult method*), 162
 k_vs_all_score() (*dicee.models.QMult method*), 156
 k_vs_all_score() (*dicee.models.quaternion.QMult method*), 117
 k_vs_all_score() (*dicee.models.real.DistMult method*), 119
 Keci (*class in dicee.models*), 164
 Keci (*class in dicee.models.clifford*), 94
 kernel_size (*dicee.config.Namespace attribute*), 30
 kernel_size (*dicee.models.base_model.BaseKGE attribute*), 92
 kernel_size (*dicee.models.BaseKGE attribute*), 139, 142, 148, 153, 159, 171, 175
 KG (*class in dicee.knowledge_graph*), 70
 kg (*dicee.callbacks.PseudoLabellingCallback attribute*), 24
 kg (*dicee.read_preprocess_save_load_kg.LoadSaveToDisk attribute*), 188
 kg (*dicee.read_preprocess_save_load_kg.PreprocessKG attribute*), 187
 kg (*dicee.read_preprocess_save_load_kg.preprocess.PreprocessKG attribute*), 182
 kg (*dicee.read_preprocess_save_load_kg.read_from_disk.ReadFromDisk attribute*), 183
 kg (*dicee.read_preprocess_save_load_kg.ReadFromDisk attribute*), 188
 kg (*dicee.read_preprocess_save_load_kg.save_load_disk.LoadSaveToDisk attribute*), 183
 KGE (*class in dicee*), 212
 KGE (*class in dicee.knowledge_graph_embeddings*), 73
 KGESaveCallback (*class in dicee.callbacks*), 22
 knowledge_graph (*dicee.Execute attribute*), 210
 knowledge_graph (*dicee.executer.Execute attribute*), 68
 KronE (*class in dicee.callbacks*), 25
 KvsAll (*class in dicee.dataset_classes*), 34
 kvsall_score() (*dicee.models.DualE method*), 180
 kvsall_score() (*dicee.models.dualE.DualE method*), 104
 KvsSampleDataset (*class in dicee.dataset_classes*), 37

L

label_smoothing_rate (*dicee.config.Namespace attribute*), 29
 label_smoothing_rate (*dicee.dataset_classes.AllvsAll attribute*), 35
 label_smoothing_rate (*dicee.dataset_classes.KvsAll attribute*), 34
 label_smoothing_rate (*dicee.dataset_classes.KvsSampleDataset attribute*), 38
 label_smoothing_rate (*dicee.dataset_classes.OnevsSample attribute*), 36
 label_smoothing_rate (*dicee.dataset_classes.TriplePredictionDataset attribute*), 39
 labels (*dicee.dataset_classes.NegSampleDataset attribute*), 38
 layer_norm (*dicee.models.literal.LiteralEmbeddings attribute*), 111
 LayerNorm (*class in dicee.models.transformers*), 124
 learning_rate (*dicee.models.base_model.BaseKGE attribute*), 92
 learning_rate (*dicee.models.BaseKGE attribute*), 139, 142, 148, 152, 159, 171, 175

```

length (dicee.dataset_classes.NegSampleDataset attribute), 38
length (dicee.dataset_classes.TriplePredictionDataset attribute), 39
level (dicee.callbacks.Perturb attribute), 26
LFMult (class in dicee.models), 178
LFMult (class in dicee.models.function_space), 108
LFMult1 (class in dicee.models), 178
LFMult1 (class in dicee.models.function_space), 108
linear () (dicee.models.function_space.LFMult method), 108
linear () (dicee.models.LFMult method), 179
list2tuple () (dicee.query_generator.QueryGenerator method), 181
list2tuple () (dicee.QueryGenerator method), 216
LiteralDataset (class in dicee.dataset_classes), 39
LiteralEmbeddings (class in dicee.models.literal), 109
lm_head (dicee.models.transformers.BytE attribute), 122
lm_head (dicee.models.transformers.GPT attribute), 127
ln_1 (dicee.models.Block attribute), 144
ln_1 (dicee.models.transformers.Block attribute), 126
ln_2 (dicee.models.Block attribute), 145
ln_2 (dicee.models.transformers.Block attribute), 126
ln_f (dicee.models.CoKE attribute), 147
ln_f (dicee.models.real.CoKE attribute), 121
load () (dicee.read_preprocess_save_load_kg.LoadSaveToDisk method), 188
load () (dicee.read_preprocess_save_load_kg.save_load_disk.LoadSaveToDisk method), 183
load_and_validate_literal_data () (dicee.dataset_classes.LiteralDataset static method), 40
load_from_memmap () (dicee.Execute method), 211
load_from_memmap () (dicee.executer.Execute method), 68
load_json () (in module dicee.static_funcs), 194
load_model () (in module dicee.static_funcs), 193
load_model_ensemble () (in module dicee.static_funcs), 193
load_numpy () (in module dicee.static_funcs), 194
load_numpy_ndarray () (in module dicee.read_preprocess_save_load_kg.util), 187
load_pickle () (in module dicee.read_preprocess_save_load_kg.util), 187
load_pickle () (in module dicee.static_funcs), 192
load_queries () (dicee.query_generator.QueryGenerator method), 182
load_queries () (dicee.QueryGenerator method), 216
load_queries_and_answers () (dicee.query_generator.QueryGenerator static method), 182
load_queries_and_answers () (dicee.QueryGenerator static method), 216
load_state_dict () (dicee.models.ensemble.EnsembleKGE method), 106
load_term_mapping () (in module dicee.static_funcs), 192
load_term_mapping () (in module dicee.trainer.dice_trainer), 197
load_with_pandas () (in module dicee.read_preprocess_save_load_kg.util), 186
loader_backend (dicee.dataset_classes.LiteralDataset attribute), 40
LoadSaveToDisk (class in dicee.read_preprocess_save_load_kg), 188
LoadSaveToDisk (class in dicee.read_preprocess_save_load_kg.save_load_disk), 183
local_rank (dicee.abstracts.AbstractTrainer attribute), 13
local_rank (dicee.Execute attribute), 210
local_rank (dicee.executer.Execute attribute), 68
local_rank (dicee.trainer.torch_trainer_ddp.NodeTrainer attribute), 202
loss (dicee.models.base_model.BaseKGE attribute), 92
loss (dicee.models.BaseKGE attribute), 139, 142, 148, 153, 159, 172, 175
loss_func (dicee.trainer.torch_trainer_ddp.NodeTrainer attribute), 202
loss_function (dicee.trainer.torch_trainer.TorchTrainer attribute), 200
loss_function () (dicee.models.base_model.BaseKGELightning method), 87
loss_function () (dicee.models.BaseKGELightning method), 134
loss_function () (dicee.models.transformers.BytE method), 122
loss_history (dicee.models.base_model.BaseKGE attribute), 92
loss_history (dicee.models.BaseKGE attribute), 140, 143, 149, 153, 159, 172, 175
loss_history (dicee.models.pykeen_models.PykeenKGE attribute), 114
loss_history (dicee.models.PykeenKGE attribute), 173
loss_history (dicee.trainer.torch_trainer_ddp.NodeTrainer attribute), 202
lr (dicee.analyse_experiments.Experiment attribute), 20
lr (dicee.config.Namespace attribute), 28
lr_init (dicee.weight_averaging.SWA attribute), 206
lr_init (dicee.weight_averaging.SWAG attribute), 207
lr_init (dicee.weight_averaging.TWA attribute), 209
lr_lambda (dicee.callbacks.LRScheduler attribute), 27
LRScheduler (class in dicee.callbacks), 26

```

M

`m` (`dicee.models.function_space.LFMult attribute`), 108
`m` (`dicee.models.LFMult attribute`), 178
`main()` (`in module dicee.scripts.index_serve`), 190
`main()` (`in module dicee.scripts.run`), 190
`make_iterable_verbose()` (`in module dicee.evaluation`), 63
`make_iterable_verbose()` (`in module dicee.evaluation.utils`), 54
`make_iterable_verbose()` (`in module dicee.static_funcs_training`), 196
`make_iterable_verbose()` (`in module dicee.trainer.torch_trainer_ddp`), 201
`mapping_from_first_two_cols_to_third()` (`in module dicee.static_preprocess_funcs`), 197
`margin` (`dicee.models.Pyke attribute`), 146
`margin` (`dicee.models.real.Pyke attribute`), 119
`margin` (`dicee.models.real.TransE attribute`), 119
`margin` (`dicee.models.TransE attribute`), 145
`mask_emb` (`dicee.models.CoKE attribute`), 147
`mask_emb` (`dicee.models.real.CoKE attribute`), 121
`max_ans_num` (`dicee.query_generator.QueryGenerator attribute`), 181
`max_ans_num` (`dicee.QueryGenerator attribute`), 215
`max_epochs` (`dicee.callbacks.KGESaveCallback attribute`), 23
`max_epochs` (`dicee.callbacks.PeriodicEvalCallback attribute`), 26
`max_epochs` (`dicee.weight_averaging.EMA attribute`), 208
`max_epochs` (`dicee.weight_averaging.SWA attribute`), 206
`max_epochs` (`dicee.weight_averaging.SWAG attribute`), 207
`max_epochs` (`dicee.weight_averaging.TWA attribute`), 209
`max_length_subword_tokens` (`dicee.knowledge_graph.KG attribute`), 72
`max_length_subword_tokens` (`dicee.models.base_model.BaseKGE attribute`), 92
`max_length_subword_tokens` (`dicee.models.BaseKGE attribute`), 140, 143, 149, 153, 159, 172, 175
`max_num_models` (`dicee.weight_averaging.SWAG attribute`), 207
`max_num_of_classes` (`dicee.dataset_classes.KvsSampleDataset attribute`), 38
`mean` (`dicee.weight_averaging.SWAG attribute`), 207
`mem_of_model()` (`dicee.models.base_model.BaseKGELightning method`), 86
`mem_of_model()` (`dicee.models.BaseKGELightning method`), 133
`mem_of_model()` (`dicee.models.ensemble.EnsembleKGE method`), 106
`method` (`dicee.callbacks.Perturb attribute`), 26
`MLP` (`class in dicee.models.transformers`), 125
`mlp` (`dicee.models.Block attribute`), 145
`mlp` (`dicee.models.transformers.Block attribute`), 126
`mode` (`dicee.query_generator.QueryGenerator attribute`), 181
`mode` (`dicee.QueryGenerator attribute`), 215
`model` (`dicee.config.Namespace attribute`), 28
`model` (`dicee.models.pykeen_models.PykeenKGE attribute`), 114
`model` (`dicee.models.PykeenKGE attribute`), 173
`model` (`dicee.trainer.torch_trainer_ddp.NodeTrainer attribute`), 202
`model` (`dicee.trainer.torch_trainer.TorchTrainer attribute`), 200
`model_kwarg` (`dicee.models.pykeen_models.PykeenKGE attribute`), 114
`model_kwarg` (`dicee.models.PykeenKGE attribute`), 173
`model_name` (`dicee.analyse_experiments.Experiment attribute`), 19
`MODEL_REGISTRY` (`in module dicee.static_funcs`), 191
`module`
 `dicee`, 12
 `dicee.__main__`, 12
 `dicee.abstracts`, 12
 `dicee.analyse_experiments`, 19
 `dicee.callbacks`, 21
 `dicee.config`, 27
 `dicee.dataset_classes`, 31
 `dicee.eval_static_funcs`, 41
 `dicee.evaluation`, 44
 `dicee.evaluation.ensemble`, 45
 `dicee.evaluation.evaluator`, 46
 `dicee.evaluation.link_prediction`, 49
 `dicee.evaluation.literal_prediction`, 52
 `dicee.evaluation.utils`, 53
 `dicee.evaluator`, 64
 `dicee.executer`, 67
 `dicee.knowledge_graph`, 70
 `dicee.knowledge_graph_embeddings`, 72
 `dicee.models`, 76

```

dicee.models.adopt, 76
dicee.models.base_model, 85
dicee.models.clifford, 94
dicee.models.complex, 101
dicee.models.dualE, 104
dicee.models.ensemble, 105
dicee.models.function_space, 106
dicee.models.literal, 109
dicee.models.octonion, 111
dicee.models.pykeen_models, 114
dicee.models.quaternion, 115
dicee.models.real, 118
dicee.models.static_funcs, 121
dicee.models.transformers, 121
dicee.query_generator, 180
dicee.read_preprocess_save_load_kg, 182
dicee.read_preprocess_save_load_kg.preprocess, 182
dicee.read_preprocess_save_load_kg.read_from_disk, 183
dicee.read_preprocess_save_load_kg.save_load_disk, 183
dicee.read_preprocess_save_load_kg.util, 184
dicee.sanity_checkers, 188
dicee.scripts, 189
dicee.scripts.index_serve, 189
dicee.scripts.run, 190
dicee.static_funcs, 190
dicee.static_funcs_training, 195
dicee.static_preprocess_funcs, 196
dicee.trainer, 197
dicee.trainer.dice_trainer, 197
dicee.trainer.model_parallelism, 199
dicee.trainer.torch_trainer, 200
dicee.trainer.torch_trainer_ddp, 201
dicee.weight_averaging, 204
modules() (dicee.models.ensemble.EnsembleKGE method), 105
moving_average() (dicee.weight_averaging.SWA static method), 206
MultiClassClassificationDataset (class in dicee.dataset_classes), 33
MultiLabelDataset (class in dicee.dataset_classes), 32

```

N

```

n (dicee.models.FMult2 attribute), 177
n (dicee.models.function_space.FMult2 attribute), 107
n_embd (dicee.models.CoKEConfig attribute), 146
n_embd (dicee.models.real.CoKEConfig attribute), 120
n_embd (dicee.models.transformers.GPTConfig attribute), 127
n_embd (dicee.models.transformers.SelfAttention attribute), 125
n_epochs_eval_model (dicee.callbacks.PeriodicEvalCallback attribute), 26
n_epochs_eval_model (dicee.config.Namespace attribute), 31
n_head (dicee.models.CoKEConfig attribute), 146
n_head (dicee.models.real.CoKEConfig attribute), 120
n_head (dicee.models.transformers.GPTConfig attribute), 127
n_head (dicee.models.transformers.SelfAttention attribute), 125
n_layer (dicee.models.CoKEConfig attribute), 146
n_layer (dicee.models.real.CoKEConfig attribute), 120
n_layer (dicee.models.transformers.GPTConfig attribute), 127
n_layers (dicee.models.FMult2 attribute), 177
n_layers (dicee.models.function_space.FMult2 attribute), 107
name (dicee.abtracts.BaseInteractiveKGE property), 15
name (dicee.models.AConEx attribute), 150
name (dicee.models.ACovO attribute), 163
name (dicee.models.ACovQ attribute), 157
name (dicee.models.CKeci attribute), 167
name (dicee.models.clifford.CKeci attribute), 98
name (dicee.models.clifford.DeCaL attribute), 98
name (dicee.models.clifford.Keci attribute), 95
name (dicee.models.CoKE attribute), 147
name (dicee.models.ComplEx attribute), 151
name (dicee.models.complex.AConEx attribute), 102

```

name (*dicee.models.complex.ComplEx attribute*), 103
 name (*dicee.models.complex.ConEx attribute*), 102
 name (*dicee.models.ConEx attribute*), 150
 name (*dicee.models.ConvO attribute*), 163
 name (*dicee.models.ConvQ attribute*), 157
 name (*dicee.models.DeCaL attribute*), 167
 name (*dicee.models.DistMult attribute*), 145
 name (*dicee.models.DualE attribute*), 179
 name (*dicee.models.dualE.DualE attribute*), 104
 name (*dicee.models.ensemble.EnsembleKGE attribute*), 105
 name (*dicee.models.FMult attribute*), 176
 name (*dicee.models.FMult2 attribute*), 177
 name (*dicee.models.function_space.FMult attribute*), 106
 name (*dicee.models.function_space.FMult2 attribute*), 107
 name (*dicee.models.function_space.GFMult attribute*), 107
 name (*dicee.models.function_space.LFMult attribute*), 108
 name (*dicee.models.function_space.LFMult1 attribute*), 108
 name (*dicee.models.GFMult attribute*), 177
 name (*dicee.models.Keci attribute*), 164
 name (*dicee.models.LFMult attribute*), 178
 name (*dicee.models.LFMult1 attribute*), 178
 name (*dicee.models.octonion.AConvO attribute*), 113
 name (*dicee.models.octonion.ConvO attribute*), 113
 name (*dicee.models.octonion.OMult attribute*), 112
 name (*dicee.models.OMult attribute*), 162
 name (*dicee.models.Pyke attribute*), 146
 name (*dicee.models.pykeen_models.PykeenKGE attribute*), 114
 name (*dicee.models.PykeenKGE attribute*), 173
 name (*dicee.models.QMult attribute*), 156
 name (*dicee.models.quaternion.AConvQ attribute*), 118
 name (*dicee.models.quaternion.ConvQ attribute*), 117
 name (*dicee.models.quaternion.QMult attribute*), 116
 name (*dicee.models.real.CoKE attribute*), 120
 name (*dicee.models.real.DistMult attribute*), 118
 name (*dicee.models.real.Pyke attribute*), 119
 name (*dicee.models.real.Shallom attribute*), 119
 name (*dicee.models.real.TransE attribute*), 119
 name (*dicee.models.Shallom attribute*), 145
 name (*dicee.models.TransE attribute*), 145
 name (*dicee.models.transformers.BytE attribute*), 122
 named_children () (*dicee.models.ensemble.EnsembleKGE method*), 105
 Namespace (*class in dicee.config*), 28
 neg_ratio (*dicee.config.Namespace attribute*), 29
 neg_ratio (*dicee.dataset_classes.BPE_NegativeSamplingDataset attribute*), 32
 neg_ratio (*dicee.dataset_classes.KvsSampleDataset attribute*), 37
 neg_sample_ratio (*dicee.dataset_classes.NegSampleDataset attribute*), 38
 neg_sample_ratio (*dicee.dataset_classes.OnevsSample attribute*), 36
 neg_sample_ratio (*dicee.dataset_classes.TriplePredictionDataset attribute*), 39
 negnorm () (*dicee.abstracts.InteractiveQueryDecomposition method*), 16
 NegSampleDataset (*class in dicee.dataset_classes*), 38
 neural_searcher (*in module dicee.scripts.index_serve*), 189
 NeuralSearcher (*class in dicee.scripts.index_serve*), 189
 NodeTrainer (*class in dicee.trainer.torch_trainer_ddp*), 202
 norm_fc1 (*dicee.models.AConEx attribute*), 150
 norm_fc1 (*dicee.models.AConvO attribute*), 163
 norm_fc1 (*dicee.models.complex.AConEx attribute*), 102
 norm_fc1 (*dicee.models.complex.ConEx attribute*), 102
 norm_fc1 (*dicee.models.ConEx attribute*), 150
 norm_fc1 (*dicee.models.ConvO attribute*), 163
 norm_fc1 (*dicee.models.octonion.AConvO attribute*), 114
 norm_fc1 (*dicee.models.octonion.ConvO attribute*), 113
 normalization (*dicee.analyse_experiments.Experiment attribute*), 20
 normalization (*dicee.config.Namespace attribute*), 29
 normalization (*dicee.dataset_classes.LiteralDataset attribute*), 39
 normalization_params (*dicee.dataset_classes.LiteralDataset attribute*), 39, 40
 normalization_type (*dicee.dataset_classes.LiteralDataset attribute*), 40
 normalize_head_entity_embeddings (*dicee.models.base_model.BaseKGE attribute*), 92
 normalize_head_entity_embeddings (*dicee.models.BaseKGE attribute*), 139, 143, 148, 153, 159, 172, 175

normalize_relation_embeddings (*dicee.models.base_model.BaseKGE* attribute), 92
 normalize_relation_embeddings (*dicee.models.BaseKGE* attribute), 139, 143, 148, 153, 159, 172, 175
 normalize_tail_entity_embeddings (*dicee.models.base_model.BaseKGE* attribute), 92
 normalize_tail_entity_embeddings (*dicee.models.BaseKGE* attribute), 139, 143, 148, 153, 159, 172, 175
 normalizer_class (*dicee.models.base_model.BaseKGE* attribute), 92
 normalizer_class (*dicee.models.BaseKGE* attribute), 139, 143, 148, 153, 159, 172, 175
 num_bpe_entities (*dicee.dataset_classes.BPE_NegativeSamplingDataset* attribute), 32
 num_bpe_entities (*dicee.knowledge_graph.KG* attribute), 71
 num_core (*dicee.config.Namespace* attribute), 29
 num_data_properties (*dicee.dataset_classes.LiteralDataset* attribute), 40
 num_datapoints (*dicee.dataset_classes.BPE_NegativeSamplingDataset* attribute), 32
 num_datapoints (*dicee.dataset_classes.MultiLabelDataset* attribute), 33
 num_ent (*dicee.models.DualE* attribute), 180
 num_ent (*dicee.models.dualE.DualE* attribute), 104
 num_entities (*dicee.dataset_classes.KvsSampleDataset* attribute), 38
 num_entities (*dicee.dataset_classes.LiteralDataset* attribute), 40
 num_entities (*dicee.dataset_classes.NegSampleDataset* attribute), 38
 num_entities (*dicee.dataset_classes.OnevsSample* attribute), 36
 num_entities (*dicee.dataset_classes.TriplePredictionDataset* attribute), 39
 num_entities (*dicee.evaluation.Evaluator* attribute), 56
 num_entities (*dicee.evaluation.evaluator.Evaluator* attribute), 46, 47
 num_entities (*dicee.Evaluator* attribute), 218
 num_entities (*dicee.evaluator.Evaluator* attribute), 64, 65
 num_entities (*dicee.knowledge_graph.KG* attribute), 70, 71
 num_entities (*dicee.models.base_model.BaseKGE* attribute), 92
 num_entities (*dicee.models.BaseKGE* attribute), 139, 142, 148, 152, 158, 171, 175
 num_epochs (*dicee.abstracts.AbstractPPECallback* attribute), 18
 num_epochs (*dicee.analyse_experiments.Experiment* attribute), 20
 num_epochs (*dicee.config.Namespace* attribute), 28
 num_epochs (*dicee.trainer.torch_trainer_ddp.NodeTrainer* attribute), 202
 num_epochs (*dicee.weight_averaging.ASWA* attribute), 204
 num_folds_for_cv (*dicee.config.Namespace* attribute), 29
 num_of_data_points (*dicee.dataset_classes.MultiClassClassificationDataset* attribute), 33
 num_of_data_properties (*dicee.models.literal.LiteralEmbeddings* attribute), 110
 num_of_epochs (*dicee.callbacks.PseudoLabellingCallback* attribute), 24
 num_of_output_channels (*dicee.config.Namespace* attribute), 30
 num_of_output_channels (*dicee.models.base_model.BaseKGE* attribute), 92
 num_of_output_channels (*dicee.models.BaseKGE* attribute), 139, 142, 148, 153, 159, 172, 175
 num_params (*dicee.analyse_experiments.Experiment* attribute), 20
 num_relations (*dicee.dataset_classes.NegSampleDataset* attribute), 38
 num_relations (*dicee.dataset_classes.OnevsSample* attribute), 36
 num_relations (*dicee.dataset_classes.TriplePredictionDataset* attribute), 39
 num_relations (*dicee.evaluation.Evaluator* attribute), 56
 num_relations (*dicee.evaluation.evaluator.Evaluator* attribute), 46, 47
 num_relations (*dicee.Evaluator* attribute), 218, 219
 num_relations (*dicee.evaluator.Evaluator* attribute), 64, 65
 num_relations (*dicee.knowledge_graph.KG* attribute), 70, 71
 num_relations (*dicee.models.base_model.BaseKGE* attribute), 92
 num_relations (*dicee.models.BaseKGE* attribute), 139, 142, 148, 152, 158, 171, 175
 num_sample (*dicee.models.FMult* attribute), 176
 num_sample (*dicee.models.function_space.FMult* attribute), 106
 num_sample (*dicee.models.function_space.GFMult* attribute), 107
 num_sample (*dicee.models.GFMult* attribute), 177
 num_samples (*dicee.weight_averaging.TWA* attribute), 208
 num_tokens (*dicee.knowledge_graph.KG* attribute), 71
 num_tokens (*dicee.models.base_model.BaseKGE* attribute), 92
 num_tokens (*dicee.models.BaseKGE* attribute), 139, 142, 148, 152, 158, 171, 175
 numpy_data_type_changer () (*in module dicee.static_funcs*), 193

O

octonion_mul () (*in module dicee.models*), 161
 octonion_mul () (*in module dicee.models.octonion*), 111
 octonion_mul_norm () (*in module dicee.models*), 161
 octonion_mul_norm () (*in module dicee.models.octonion*), 111
 octonion_normalizer () (*dicee.models.AConvO* static method), 163
 octonion_normalizer () (*dicee.models.ConvO* static method), 163
 octonion_normalizer () (*dicee.models.octonion.AConvO* static method), 114

octonion_normalizer() (dicee.models.octonion.ConvO static method), 113
 octonion_normalizer() (dicee.models.octonion.OMult static method), 112
 octonion_normalizer() (dicee.models.OMult static method), 162
 OMult (class in dicee.models), 161
 OMult (class in dicee.models.octonion), 111
 on_epoch_end() (dicee.callbacks.KGESaveCallback method), 23
 on_epoch_end() (dicee.callbacks.PseudoLabellingCallback method), 24
 on_fit_end() (dicee.abstracts.AbstractCallback method), 17
 on_fit_end() (dicee.abstracts.AbstractPPECallback method), 18
 on_fit_end() (dicee.abstracts.AbstractTrainer method), 13
 on_fit_end() (dicee.callbacks.AccumulateEpochLossCallback method), 21
 on_fit_end() (dicee.callbacks.Eval method), 24
 on_fit_end() (dicee.callbacks.KGESaveCallback method), 23
 on_fit_end() (dicee.callbacks.LRScheduler method), 27
 on_fit_end() (dicee.callbacks.PeriodicEvalCallback method), 26
 on_fit_end() (dicee.callbacks.PrintCallback method), 22
 on_fit_end() (dicee.weight_averaging.ASWA method), 205
 on_fit_end() (dicee.weight_averaging.EMA method), 208
 on_fit_end() (dicee.weight_averaging.SWA method), 206
 on_fit_end() (dicee.weight_averaging.SWAG method), 207
 on_fit_end() (dicee.weight_averaging.TWA method), 209
 on_fit_start() (dicee.abstracts.AbstractCallback method), 17
 on_fit_start() (dicee.abstracts.AbstractPPECallback method), 18
 on_fit_start() (dicee.abstracts.AbstractTrainer method), 13
 on_fit_start() (dicee.callbacks.Eval method), 24
 on_fit_start() (dicee.callbacks.KGESaveCallback method), 23
 on_fit_start() (dicee.callbacks.KronE method), 25
 on_fit_start() (dicee.callbacks.PrintCallback method), 22
 on_init_end() (dicee.abstracts.AbstractCallback method), 17
 on_init_start() (dicee.abstracts.AbstractCallback method), 16
 on_train_batch_end() (dicee.abstracts.AbstractCallback method), 17
 on_train_batch_end() (dicee.abstracts.AbstractTrainer method), 14
 on_train_batch_end() (dicee.callbacks.Eval method), 25
 on_train_batch_end() (dicee.callbacks.KGESaveCallback method), 23
 on_train_batch_end() (dicee.callbacks.LRScheduler method), 27
 on_train_batch_end() (dicee.callbacks.PrintCallback method), 22
 on_train_batch_start() (dicee.callbacks.Perturb method), 26
 on_train_epoch_end() (dicee.abstracts.AbstractCallback method), 17
 on_train_epoch_end() (dicee.abstracts.AbstractTrainer method), 14
 on_train_epoch_end() (dicee.callbacks.Eval method), 25
 on_train_epoch_end() (dicee.callbacks.KGESaveCallback method), 23
 on_train_epoch_end() (dicee.callbacks.PeriodicEvalCallback method), 26
 on_train_epoch_end() (dicee.callbacks.PrintCallback method), 22
 on_train_epoch_end() (dicee.models.base_model.BaseKGELightning method), 87
 on_train_epoch_end() (dicee.models.BaseKGELightning method), 134
 on_train_epoch_end() (dicee.weight_averaging.ASWA method), 205
 on_train_epoch_end() (dicee.weight_averaging.EMA method), 208
 on_train_epoch_end() (dicee.weight_averaging.SWA method), 206
 on_train_epoch_end() (dicee.weight_averaging.SWAG method), 207
 on_train_epoch_end() (dicee.weight_averaging.TWA method), 209
 on_train_epoch_start() (dicee.abstracts.AbstractTrainer method), 13
 on_train_epoch_start() (dicee.weight_averaging.EMA method), 208
 on_train_epoch_start() (dicee.weight_averaging.SWA method), 206
 on_train_epoch_start() (dicee.weight_averaging.SWAG method), 207
 on_train_epoch_start() (dicee.weight_averaging.TWA method), 209
 on_train_start() (dicee.callbacks.LRScheduler method), 27
 OnevsAllDataset (class in dicee.dataset_classes), 33
 OnevsSample (class in dicee.dataset_classes), 35
 optim (dicee.config.Namespace attribute), 28
 optimizer (dicee.trainer.torch_trainer_ddp.NodeTrainer attribute), 202
 optimizer (dicee.trainer.torch_trainer.TorchTrainer attribute), 200
 optimizer_name (dicee.models.base_model.BaseKGE attribute), 92
 optimizer_name (dicee.models.BaseKGE attribute), 139, 142, 148, 153, 159, 171, 175
 ordered_bpe_entities (dicee.dataset_classes.BPE_NegativeSamplingDataset attribute), 32
 ordered_bpe_entities (dicee.knowledge_graph.KG attribute), 72
 ordered_shaped_bpe_tokens (dicee.knowledge_graph.KG attribute), 71

P

p (*dicee.config.Namespace attribute*), 30
p (*dicee.models.clifford.DeCaL attribute*), 98
p (*dicee.models.clifford.Keci attribute*), 95
p (*dicee.models.DeCaL attribute*), 168
p (*dicee.models.Keci attribute*), 164
p (*dicee.weight_averaging.TWA attribute*), 209
padding (*dicee.knowledge_graph.KG attribute*), 72
pandas_dataframe_indexer () (in module *dicee.read_preprocess_save_load_kg.util*), 185
param_init (*dicee.models.base_model.BaseKGE attribute*), 92
param_init (*dicee.models.BaseKGE attribute*), 139, 143, 148, 153, 159, 172, 175
parameters () (*dicee.abstracts.BaseInteractiveKGE method*), 16
parameters () (*dicee.models.ensemble.EnsembleKGE method*), 105
path (*dicee.abstracts.AbstractPPECallback attribute*), 18
path (*dicee.callbacks.AccumulateEpochLossCallback attribute*), 21
path (*dicee.callbacks.Eval attribute*), 24
path (*dicee.callbacks.KGESaveCallback attribute*), 23
path (*dicee.weight_averaging.ASWA attribute*), 204
path_dataset_folder (*dicee.analyse_experiments.Experiment attribute*), 20
path_for_deserialization (*dicee.knowledge_graph.KG attribute*), 71
path_for_serialization (*dicee.knowledge_graph.KG attribute*), 71
path_single_kg (*dicee.config.Namespace attribute*), 28
path_single_kg (*dicee.knowledge_graph.KG attribute*), 71
path_to_store_single_run (*dicee.config.Namespace attribute*), 28
PeriodicEvalCallback (*class in dicee.callbacks*), 26
Perturb (*class in dicee.callbacks*), 25
polars_dataframe_indexer () (in module *dicee.read_preprocess_save_load_kg.util*), 184
poly_NN () (*dicee.models.function_space.LFMult method*), 108
poly_NN () (*dicee.models.LFMult method*), 179
polynomial () (*dicee.models.function_space.LFMult method*), 109
polynomial () (*dicee.models.LFMult method*), 179
pop () (*dicee.models.function_space.LFMult method*), 109
pop () (*dicee.models.LFMult method*), 179
pos_emb (*dicee.models.CoKE attribute*), 147
pos_emb (*dicee.models.real.CoKE attribute*), 121
pq (*dicee.analyse_experiments.Experiment attribute*), 20
predict () (*dicee.KGE method*), 213
predict () (*dicee.knowledge_graph_embeddings.KGE method*), 74
predict_dataloader () (*dicee.models.base_model.BaseKGELightning method*), 88
predict_dataloader () (*dicee.models.BaseKGELightning method*), 136
predict_literals () (*dicee.KGE method*), 215
predict_literals () (*dicee.knowledge_graph_embeddings.KGE method*), 76
predict_missing_head_entity () (*dicee.KGE method*), 212
predict_missing_head_entity () (*dicee.knowledge_graph_embeddings.KGE method*), 73
predict_missing_relations () (*dicee.KGE method*), 212
predict_missing_relations () (*dicee.knowledge_graph_embeddings.KGE method*), 73
predict_missing_tail_entity () (*dicee.KGE method*), 213
predict_missing_tail_entity () (*dicee.knowledge_graph_embeddings.KGE method*), 74
predict_topk () (*dicee.KGE method*), 213
predict_topk () (*dicee.knowledge_graph_embeddings.KGE method*), 74
preprocess_with_byte_pair_encoding () (*dicee.read_preprocess_save_load_kg.PreprocessKG method*), 187
preprocess_with_byte_pair_encoding () (*dicee.read_preprocess_save_load_kg.preprocess.PreprocessKG method*), 182
preprocess_with_byte_pair_encoding_with_padding () (*dicee.read_preprocess_save_load_kg.PreprocessKG method*), 187
preprocess_with_byte_pair_encoding_with_padding () (*dicee.read_preprocess_save_load_kg.preprocess.PreprocessKG method*), 182
preprocess_with_pandas () (*dicee.read_preprocess_save_load_kg.PreprocessKG method*), 187
preprocess_with_pandas () (*dicee.read_preprocess_save_load_kg.preprocess.PreprocessKG method*), 182
preprocess_with_polars () (*dicee.read_preprocess_save_load_kg.PreprocessKG method*), 187
preprocess_with_polars () (*dicee.read_preprocess_save_load_kg.preprocess.PreprocessKG method*), 182
preprocesses_input_args () (in module *dicee.static_preprocess_funcs*), 196
PreprocessKG (*class in dicee.read_preprocess_save_load_kg*), 187
PreprocessKG (*class in dicee.read_preprocess_save_load_kg.preprocess*), 182
PrintCallback (*class in dicee.callbacks*), 21
process (*dicee.trainer.torch_trainer.TorchTrainer attribute*), 201
PseudoLabellingCallback (*class in dicee.callbacks*), 23
Pyke (*class in dicee.models*), 146
Pyke (*class in dicee.models.real*), 119
pykeen_model_kwarg (*dicee.config.Namespace attribute*), 30
PykeenKGE (*class in dicee.models*), 173

`PykeenKGE` (*class in dicee.models.pykeen_models*), 114

Q

`q` (*dicee.config.Namespace attribute*), 30
`q` (*dicee.models.clifford.DeCaL attribute*), 99
`q` (*dicee.models.clifford.Keci attribute*), 95
`q` (*dicee.models.DeCaL attribute*), 168
`q` (*dicee.models.Keci attribute*), 164
`qdant_client` (*dicee.scripts.index_serve.NeuralSearcher attribute*), 189
`QMult` (*class in dicee.models*), 155
`QMult` (*class in dicee.models.quaternion*), 115
`quaternion_mul()` (*in module dicee.models*), 152
`quaternion_mul()` (*in module dicee.models.static_funcs*), 121
`quaternion_mul_with_unit_norm()` (*in module dicee.models*), 155
`quaternion_mul_with_unit_norm()` (*in module dicee.models.quaternion*), 115
`quaternion_multiplication_followed_by_inner_product()` (*dicee.models.QMult method*), 156
`quaternion_multiplication_followed_by_inner_product()` (*dicee.models.quaternion.QMult method*), 116
`quaternion_normalizer()` (*dicee.models.QMult static method*), 156
`quaternion_normalizer()` (*dicee.models.quaternion.QMult static method*), 116
`queries` (*dicee.scripts.index_serve.StringListRequest attribute*), 190
`query_name_to_struct` (*dicee.query_generator.QueryGenerator attribute*), 181
`query_name_to_struct` (*dicee.QueryGenerator attribute*), 216
`QueryGenerator` (*class in dicee*), 215
`QueryGenerator` (*class in dicee.query_generator*), 181

R

`r` (*dicee.models.clifford.DeCaL attribute*), 99
`r` (*dicee.models.clifford.Keci attribute*), 95
`r` (*dicee.models.DeCaL attribute*), 168
`r` (*dicee.models.Keci attribute*), 164
`random_seed` (*dicee.config.Namespace attribute*), 29
`range_constraints_per_rel` (*dicee.evaluation.Evaluator attribute*), 57
`range_constraints_per_rel` (*dicee.evaluation.evaluator.Evaluator attribute*), 47
`range_constraints_per_rel` (*dicee.Evaluator attribute*), 219
`range_constraints_per_rel` (*dicee.evaluator.Evaluator attribute*), 65
`rank` (*dicee.Execute attribute*), 210
`rank` (*dicee.executer.Execute attribute*), 67
`ratio` (*dicee.callbacks.Perturb attribute*), 26
`raw_test_set` (*dicee.knowledge_graph.KG attribute*), 71
`raw_train_set` (*dicee.knowledge_graph.KG attribute*), 71
`raw_valid_set` (*dicee.knowledge_graph.KG attribute*), 71
`re` (*dicee.models.clifford.DeCaL attribute*), 99
`re` (*dicee.models.DeCaL attribute*), 168
`re_vocab` (*dicee.evaluation.Evaluator attribute*), 56
`re_vocab` (*dicee.evaluation.evaluator.Evaluator attribute*), 46, 47
`re_vocab` (*dicee.Evaluator attribute*), 218
`re_vocab` (*dicee.evaluator.Evaluator attribute*), 64
`read_from_disk()` (*in module dicee.read_preprocess_save_load_kg.util*), 186
`read_from_triple_store_with_pandas()` (*in module dicee.read_preprocess_save_load_kg.util*), 186
`read_from_triple_store_with_polars()` (*in module dicee.read_preprocess_save_load_kg.util*), 186
`read_only_few` (*dicee.config.Namespace attribute*), 29
`read_only_few` (*dicee.knowledge_graph.KG attribute*), 71
`read_or_load_kg()` (*in module dicee.static_funcs*), 193
`read_with_pandas()` (*in module dicee.read_preprocess_save_load_kg.util*), 186
`read_with_polars()` (*in module dicee.read_preprocess_save_load_kg.util*), 186
`ReadFromDisk` (*class in dicee.read_preprocess_save_load_kg*), 188
`ReadFromDisk` (*class in dicee.read_preprocess_save_load_kg.read_from_disk*), 183
`reducer` (*dicee.scripts.index_serve.StringListRequest attribute*), 190
`reg_lambda` (*dicee.weight_averaging.TWA attribute*), 208
`rel2id` (*dicee.query_generator.QueryGenerator attribute*), 181
`rel2id` (*dicee.QueryGenerator attribute*), 215
`relation_embeddings` (*dicee.models.AConvQ attribute*), 157
`relation_embeddings` (*dicee.models.clifford.DeCaL attribute*), 98
`relation_embeddings` (*dicee.models.ConvQ attribute*), 157
`relation_embeddings` (*dicee.models.DeCaL attribute*), 168
`relation_embeddings` (*dicee.models.DualE attribute*), 180
`relation_embeddings` (*dicee.models.dualE.DualE attribute*), 104

```

relation_embeddings (dicee.models.FMult attribute), 176
relation_embeddings (dicee.models.FMult2 attribute), 178
relation_embeddings (dicee.models.function_space.FMult attribute), 106
relation_embeddings (dicee.models.function_space.FMult2 attribute), 107
relation_embeddings (dicee.models.function_space.GFMult attribute), 107
relation_embeddings (dicee.models.function_space.LFMult attribute), 108
relation_embeddings (dicee.models.function_space.LFMultI attribute), 108
relation_embeddings (dicee.models.GFMult attribute), 177
relation_embeddings (dicee.models.LFMult attribute), 178
relation_embeddings (dicee.models.LFMultI attribute), 178
relation_embeddings (dicee.models.pykeen_models.PykeenKGE attribute), 114
relation_embeddings (dicee.models.PykeenKGE attribute), 173
relation_embeddings (dicee.models.quaternion.AConvQ attribute), 118
relation_embeddings (dicee.models.quaternion.ConvQ attribute), 117
relation_to_idx (dicee.knowledge_graph.KG attribute), 71
relations_str (dicee.knowledge_graph.KG property), 72
reload_dataset () (in module dicee.dataset_classes), 31
report (dicee.DICE_Trainer attribute), 217
report (dicee.evaluation.Evaluator attribute), 56, 57
report (dicee.evaluation.evaluator.Evaluator attribute), 47
report (dicee.Evaluator attribute), 218, 219
report (dicee.evaluator.Evaluator attribute), 64, 65
report (dicee.Execute attribute), 210
report (dicee.executor.Execute attribute), 68
report (dicee.trainer.DICE_Trainer attribute), 203
report (dicee.trainer.dice_trainer.DICE_Trainer attribute), 198
reports (dicee.callbacks.Eval attribute), 24
reports (dicee.callbacks.PeriodicEvalCallback attribute), 26
requires_grad_for_interactions (dicee.models.CKeci attribute), 167
requires_grad_for_interactions (dicee.models.clifford.CKeci attribute), 98
requires_grad_for_interactions (dicee.models.clifford.Keci attribute), 95
requires_grad_for_interactions (dicee.models.Keci attribute), 164
resid_dropout (dicee.models.transformers.SelfAttention attribute), 125
residual_convolution () (dicee.models.AConEx method), 150
residual_convolution () (dicee.models.AConvO method), 163
residual_convolution () (dicee.models.AConvQ method), 158
residual_convolution () (dicee.models.complex.AConEx method), 103
residual_convolution () (dicee.models.complex.ConEx method), 102
residual_convolution () (dicee.models.ConEx method), 150
residual_convolution () (dicee.models.ConvO method), 163
residual_convolution () (dicee.models.ConvQ method), 157
residual_convolution () (dicee.models.octonion.AConvO method), 114
residual_convolution () (dicee.models.octonion.ConvO method), 113
residual_convolution () (dicee.models.quaternion.AConvQ method), 118
residual_convolution () (dicee.models.quaternion.ConvQ method), 117
retrieve_embedding () (dicee.scripts.index_serve.NeuralSearcher method), 189
retrieve_embeddings () (in module dicee.scripts.index_serve), 190
return_multi_hop_query_results () (dicee.KGE method), 214
return_multi_hop_query_results () (dicee.knowledge_graph_embeddings.KGE method), 75
root () (in module dicee.scripts.index_serve), 190
roots (dicee.models.FMult attribute), 177
roots (dicee.models.function_space.FMult attribute), 106
roots (dicee.models.function_space.GFMult attribute), 107
roots (dicee.models.GFMult attribute), 177
runtime (dicee.analyse_experiments.Experiment attribute), 20

```

S

```

sample () (dicee.weight_averaging.SWAG method), 207
sample_counter (dicee.abstracts.AbstractPPECallback attribute), 18
sample_entity () (dicee.abstracts.BaseInteractiveKGE method), 15
sample_relation () (dicee.abstracts.BaseInteractiveKGE method), 15
sample_triples_ratio (dicee.config.Namespace attribute), 29
sample_triples_ratio (dicee.knowledge_graph.KG attribute), 71
sample_weights () (dicee.weight_averaging.TWA method), 209
sampling_ratio (dicee.dataset_classes.LiteralDataset attribute), 40
sanity_check_callback_args () (in module dicee.sanity_checkers), 188
sanity_checking_with_arguments () (in module dicee.sanity_checkers), 188

```

```

save() (dicee.abstracts.BaseInteractiveKGE method), 15
save() (dicee.read_preprocess_save_load_kg.LoadSaveToDisk method), 188
save() (dicee.read_preprocess_save_load_kg.save_load_disk.LoadSaveToDisk method), 183
save_checkpoint() (dicee.abstracts.AbstractTrainer static method), 14
save_checkpoint_model() (in module dicee.static_funcs), 193
save_embeddings() (in module dicee.static_funcs), 194
save_embeddings_as_csv(dicee.config.Namespace attribute), 28
save_every_n_epochs(dicee.config.Namespace attribute), 30
save_experiment() (dicee.analyse_experiments.Experiment method), 20
save_model_at_every_epoch(dicee.config.Namespace attribute), 29
save_model_every_n_epoch(dicee.callbacks.PeriodicEvalCallback attribute), 26
save_numpy_ndarray() (in module dicee.read_preprocess_save_load_kg.util), 186
save_numpy_ndarray() (in module dicee.static_funcs), 193
save_pickle() (in module dicee.read_preprocess_save_load_kg.util), 187
save_pickle() (in module dicee.static_funcs), 192
save_queries() (dicee.query_generator.QueryGenerator method), 182
save_queries() (dicee.QueryGenerator method), 216
save_queries_and_answers() (dicee.query_generator.QueryGenerator static method), 182
save_queries_and_answers() (dicee.QueryGenerator static method), 216
save_trained_model() (dicee.Execute method), 211
save_trained_model() (dicee.executer.Execute method), 68
scalar_batch_NN() (dicee.models.function_space.LFMult method), 108
scalar_batch_NN() (dicee.models.LFMult method), 179
scaler (dicee.callbacks.Perturb attribute), 26
scaler (dicee.trainer.torch_trainer_ddp.NodeTrainer attribute), 202
scheduler (dicee.callbacks.LRScheduler attribute), 27
score() (dicee.models.clifford.Keci method), 97
score() (dicee.models.CoKE method), 147
score() (dicee.models.ComplEx static method), 151
score() (dicee.models.complex.ComplEx static method), 103
score() (dicee.models.DistMult method), 145
score() (dicee.models.Keci method), 166
score() (dicee.models.octonion.OMult method), 112
score() (dicee.models.OMult method), 162
score() (dicee.models.QMult method), 156
score() (dicee.models.quaternion.QMult method), 117
score() (dicee.models.real.CoKE method), 121
score() (dicee.models.real.DistMult method), 119
score() (dicee.models.real.TransE method), 119
score() (dicee.models.TransE method), 145
score_func (dicee.models.FMult2 attribute), 177
score_func (dicee.models.function_space.FMult2 attribute), 107
scoring_technique (dicee.analyse_experiments.Experiment attribute), 20
scoring_technique (dicee.config.Namespace attribute), 29
search() (dicee.scripts.index_serve.NeuralSearcher method), 189
search_embeddings() (in module dicee.scripts.index_serve), 190
search_embeddings_batch() (in module dicee.scripts.index_serve), 190
seed (dicee.query_generator.QueryGenerator attribute), 181
seed (dicee.QueryGenerator attribute), 215
select_model() (in module dicee.static_funcs), 193
selected_optimizer (dicee.models.base_model.BaseKGE attribute), 92
selected_optimizer (dicee.models.BaseKGE attribute), 139, 142, 148, 153, 159, 172, 175
SelfAttention (class in dicee.models.transformers), 124
separator (dicee.config.Namespace attribute), 29
separator (dicee.knowledge_graph.KG attribute), 71
sequential_vocabulary_construction() (dicee.read_preprocess_save_load_kg.PreprocessKG method), 187
sequential_vocabulary_construction() (dicee.read_preprocess_save_load_kg.preprocess.PreprocessKG method), 182
serve() (in module dicee.scripts.index_serve), 190
set_global_seed() (dicee.query_generator.QueryGenerator method), 181
set_global_seed() (dicee.QueryGenerator method), 216
set_model_eval_mode() (dicee.abstracts.BaseInteractiveKGE method), 15
set_model_train_mode() (dicee.abstracts.BaseInteractiveKGE method), 15
setup_executor() (dicee.Execute method), 211
setup_executor() (dicee.executer.Execute method), 68
Shallom (class in dicee.models), 145
Shallom (class in dicee.models.real), 119
shallom (dicee.models.real.Shallom attribute), 119
shallom (dicee.models.Shallom attribute), 145

```

```

single_hop_query_answering() (dicee.KGE method), 214
single_hop_query_answering() (dicee.knowledge_graph_embeddings.KGE method), 75
snapshot_dir (dicee.callbacks.LRScheduler attribute), 27
snapshot_loss (dicee.callbacks.LRScheduler attribute), 27
sparql_endpoint (dicee.config.Namespace attribute), 28
sparql_endpoint (dicee.knowledge_graph.KG attribute), 71
sq_mean (dicee.weight_averaging.SWAG attribute), 207
start () (dicee.DICE_Trainer method), 217
start () (dicee.Execute method), 211
start () (dicee.executer.Execute method), 69
start () (dicee.read_preprocess_save_load_kg.PreprocessKG method), 187
start () (dicee.read_preprocess_save_load_kg.preprocess.PreprocessKG method), 182
start () (dicee.read_preprocess_save_load_kg.read_from_disk.ReadFromDisk method), 183
start () (dicee.read_preprocess_save_load_kg.ReadFromDisk method), 188
start () (dicee.trainer.DICE_Trainer method), 204
start () (dicee.trainer.dice_trainer.DICE_Trainer method), 199
start_time (dicee.callbacks.PrintCallback attribute), 22
start_time (dicee.Execute attribute), 211
start_time (dicee.executer.Execute attribute), 68
state_dict () (dicee.models.ensemble.EnsembleKGE method), 105
step() (dicee.models.ADOPT method), 131
step() (dicee.models.adopt.ADOPT method), 80
step() (dicee.models.ensemble.EnsembleKGE method), 106
step_count (dicee.callbacks.LRScheduler attribute), 27
storage_path (dicee.config.Namespace attribute), 28
storage_path (dicee.DICE_Trainer attribute), 217
storage_path (dicee.trainer.DICE_Trainer attribute), 203
storage_path (dicee.trainer.dice_trainer.DICE_Trainer attribute), 198
store() (in module dicee.static_funcs), 193
store_ensemble() (dicee.abstracts.AbstractPPECallback method), 18
strategy (dicee.abstracts.AbstractTrainer attribute), 13
StringListRequest (class in dicee.scripts.index_serve), 190
SWA (class in dicee.weight_averaging), 205
swa (dicee.config.Namespace attribute), 30
swa_c_epochs (dicee.config.Namespace attribute), 31
swa_c_epochs (dicee.weight_averaging.SWA attribute), 206
swa_c_epochs (dicee.weight_averaging.SWAG attribute), 207
swa_l1 (dicee.weight_averaging.SWA attribute), 206
swa_l1 (dicee.weight_averaging.SWAG attribute), 207
swa_model (dicee.weight_averaging.SWA attribute), 206
swa_n (dicee.weight_averaging.SWA attribute), 206
swa_start_epoch (dicee.config.Namespace attribute), 31
swa_start_epoch (dicee.weight_averaging.SWA attribute), 206
swa_start_epoch (dicee.weight_averaging.SWAG attribute), 207
SWAG (class in dicee.weight_averaging), 206
swag (dicee.config.Namespace attribute), 30

```

T

```

T() (dicee.models.DualE method), 180
T() (dicee.models.dualE.DualE method), 105
t_conorm() (dicee.abstracts.InteractiveQueryDecomposition method), 16
t_norm() (dicee.abstracts.InteractiveQueryDecomposition method), 16
target_dim (dicee.dataset_classes.AllvsAll attribute), 35
target_dim (dicee.dataset_classes.MultiLabelDataset attribute), 33
target_dim (dicee.dataset_classes.OnevsAllDataset attribute), 34
target_dim (dicee.knowledge_graph.KG attribute), 72
temperature (dicee.models.transformers.BytE attribute), 122
tensor_t_norm() (dicee.abstracts.InteractiveQueryDecomposition method), 16
TensorParallel (class in dicee.trainer.model_parallelism), 200
test_dataloader() (dicee.models.base_model.BaseKGELightning method), 87
test_dataloader() (dicee.models.BaseKGELightning method), 135
test_epoch_end() (dicee.models.base_model.BaseKGELightning method), 87
test_epoch_end() (dicee.models.BaseKGELightning method), 135
test_h1 (dicee.analyse_experiments.Experiment attribute), 20
test_h3 (dicee.analyse_experiments.Experiment attribute), 20
test_h10 (dicee.analyse_experiments.Experiment attribute), 20
test_mrr (dicee.analyse_experiments.Experiment attribute), 20

```

test_path (*dicee.query_generator.QueryGenerator* attribute), 181
 test_path (*dicee.QueryGenerator* attribute), 215
 test_set (*dicee.knowledge_graph.KG* attribute), 70, 71
 timeit () (in module *dicee.read_preprocess_save_load_kg.util*), 186
 timeit () (in module *dicee.static_funcs*), 192
 timeit () (in module *dicee.static_preprocess_funcs*), 196
 to () (*dicee.KGE* method), 212
 to () (*dicee.knowledge_graph_embeddings.KGE* method), 73
 to () (*dicee.models.ensemble.EnsembleKGE* method), 105
 to_df () (*dicee.analyse_experiments.Experiment* method), 20
 topk (*dicee.models.transformers.BytE* attribute), 122
 topk (*dicee.scripts.index_serve.NeuralSearcher* attribute), 189
 torch_ordered_shaped_bpe_entities (*dicee.dataset_classes.MultiLabelDataset* attribute), 33
 TorchDDPTrainer (*class* in *dicee.trainer.torch_trainer_ddp*), 201
 TorchTrainer (*class* in *dicee.trainer.torch_trainer*), 200
 total_epochs (*dicee.callbacks.LRScheduler* attribute), 27
 total_steps (*dicee.callbacks.LRScheduler* attribute), 27
 train () (*dicee.abstracts.BaseInteractiveTrainKGE* method), 19
 train () (*dicee.trainer.torch_trainer_ddp.NodeTrainer* method), 202
 train_data (*dicee.dataset_classes.AllvsAll* attribute), 35
 train_data (*dicee.dataset_classes.KvsAll* attribute), 34
 train_data (*dicee.dataset_classes.KvsSampleDataset* attribute), 37
 train_data (*dicee.dataset_classes.MultiClassClassificationDataset* attribute), 33
 train_data (*dicee.dataset_classes.OnevsAllDataset* attribute), 34
 train_data (*dicee.dataset_classes.OnevsSample* attribute), 36
 train_dataloader () (*dicee.models.base_model.BaseKGELighting* method), 89
 train_dataloader () (*dicee.models.BaseKGELighting* method), 136
 train_dataloaders (*dicee.trainer.torch_trainer.TorchTrainer* attribute), 201
 train_dataset_loader (*dicee.trainer.torch_trainer_dlp.NodeTrainer* attribute), 202
 train_file_path (*dicee.dataset_classes.LiteralDataset* attribute), 39, 40
 train_h1 (*dicee.analyse_experiments.Experiment* attribute), 20
 train_h3 (*dicee.analyse_experiments.Experiment* attribute), 20
 train_h10 (*dicee.analyse_experiments.Experiment* attribute), 20
 train_indices_target (*dicee.dataset_classes.MultiLabelDataset* attribute), 33
 train_k_vs_all () (*dicee.abstracts.BaseInteractiveTrainKGE* method), 18
 train_literals () (*dicee.abstracts.BaseInteractiveTrainKGE* method), 19
 train_mode (*dicee.models.ensemble.EnsembleKGE* attribute), 105
 train_mrr (*dicee.analyse_experiments.Experiment* attribute), 20
 train_path (*dicee.query_generator.QueryGenerator* attribute), 181
 train_path (*dicee.QueryGenerator* attribute), 215
 train_set (*dicee.dataset_classes.BPE_NegativeSamplingDataset* attribute), 32
 train_set (*dicee.dataset_classes.MultiLabelDataset* attribute), 33
 train_set (*dicee.dataset_classes.NegSampleDataset* attribute), 38
 train_set (*dicee.dataset_classes.TriplePredictionDataset* attribute), 39
 train_set (*dicee.knowledge_graph.KG* attribute), 70, 71
 train_set_target (*dicee.knowledge_graph.KG* attribute), 72
 train_target (*dicee.dataset_classes.AllvsAll* attribute), 35
 train_target (*dicee.dataset_classes.KvsAll* attribute), 34
 train_target (*dicee.dataset_classes.KvsSampleDataset* attribute), 37
 train_target_indices (*dicee.knowledge_graph.KG* attribute), 72
 train_triples (*dicee.dataset_classes.NegSampleDataset* attribute), 38
 train_triples () (*dicee.abstracts.BaseInteractiveTrainKGE* method), 18
 trained_model (*dicee.Execute* attribute), 210
 trained_model (*dicee.executer.Execute* attribute), 68
 trainer (*dicee.config.Namespace* attribute), 29
 trainer (*dicee.DICE_Trainer* attribute), 217
 trainer (*dicee.Execute* attribute), 210
 trainer (*dicee.executer.Execute* attribute), 68
 trainer (*dicee.trainer.DICE_Trainer* attribute), 203
 trainer (*dicee.trainer.dice_trainer.DICE_Trainer* attribute), 198
 trainer (*dicee.trainer.torch_trainer_ddp.NodeTrainer* attribute), 202
 training_step (*dicee.trainer.torch_trainer.TorchTrainer* attribute), 201
 training_step () (*dicee.models.base_model.BaseKGELighting* method), 86
 training_step () (*dicee.models.BaseKGELighting* method), 133
 training_step () (*dicee.models.transformers.BytE* method), 123
 training_step_outputs (*dicee.models.base_model.BaseKGELighting* attribute), 86
 training_step_outputs (*dicee.models.BaseKGELighting* attribute), 133
 training_technique (*dicee.knowledge_graph.KG* attribute), 71

TransE (*class in dicee.models*), 145
TransE (*class in dicee.models.real*), 119
transformer (*dicee.models.transformers.BytE attribute*), 122
transformer (*dicee.models.transformers.GPT attribute*), 127
trapezoid() (*dicee.models.FMult2 method*), 178
trapezoid() (*dicee.models.function_space.FMult2 method*), 107
tri_score() (*dicee.models.function_space.LFMult method*), 109
tri_score() (*dicee.models.function_space.LFMult1 method*), 108
tri_score() (*dicee.models.LFMult method*), 179
tri_score() (*dicee.models.LFMult1 method*), 178
triple_score() (*dicee.KGE method*), 213
triple_score() (*dicee.knowledge_graph_embeddings.KGE method*), 74
TriplePredictionDataset (*class in dicee.dataset_classes*), 38
tuple2list () (*dicee.query_generator.QueryGenerator method*), 181
tuple2list () (*dicee.QueryGenerator method*), 216
TWA (*class in dicee.weight_averaging*), 208
twa (*dicee.config.Namespace attribute*), 30
twa_c_epochs (*dicee.weight_averaging.TWA attribute*), 209
twa_model (*dicee.weight_averaging.TWA attribute*), 209
twa_start_epoch (*dicee.weight_averaging.TWA attribute*), 208

U

unlabelled_size (*dicee.callbacks.PseudoLabellingCallback attribute*), 24
unmap () (*dicee.query_generator.QueryGenerator method*), 181
unmap () (*dicee.QueryGenerator method*), 216
unmap_query () (*dicee.query_generator.QueryGenerator method*), 181
unmap_query () (*dicee.QueryGenerator method*), 216
update_hits () (*in module dicee.evaluation*), 63
update_hits () (*in module dicee.evaluation.utils*), 54

V

val_aswa (*dicee.weight_averaging.ASWA attribute*), 205
val_dataloader () (*dicee.models.base_model.BaseKGELightning method*), 88
val_dataloader () (*dicee.models.BaseKGELightning method*), 135
val_h1 (*dicee.analyse_experiments.Experiment attribute*), 20
val_h3 (*dicee.analyse_experiments.Experiment attribute*), 20
val_h10 (*dicee.analyse_experiments.Experiment attribute*), 20
val_mrr (*dicee.analyse_experiments.Experiment attribute*), 20
val_path (*dicee.query_generator.QueryGenerator attribute*), 181
val_path (*dicee.QueryGenerator attribute*), 215
VALID_SCORING_TECHNIQUES (*in module dicee.evaluation.evaluator*), 46
valid_set (*dicee.knowledge_graph.KG attribute*), 70, 71
validate_knowledge_graph () (*in module dicee.sanity_checkers*), 188
var_clamp (*dicee.weight_averaging.SWAG attribute*), 207
vocab_preparation () (*dicee.evaluation.Evaluator method*), 57
vocab_preparation () (*dicee.evaluation.evaluator.Evaluator method*), 47
vocab_preparation () (*dicee.Evaluator method*), 219
vocab_preparation () (*dicee.evaluator.Evaluator method*), 65
vocab_size (*dicee.models.CoKEConfig attribute*), 146
vocab_size (*dicee.models.real.CoKEConfig attribute*), 120
vocab_size (*dicee.models.transformers.GPTConfig attribute*), 126
vocab_to_parquet () (*in module dicee.static_funcs*), 194
vtp_score() (*dicee.models.function_space.LFMult method*), 109
vtp_score() (*dicee.models.function_space.LFMult1 method*), 108
vtp_score() (*dicee.models.LFMult method*), 179
vtp_score() (*dicee.models.LFMult1 method*), 178

W

warmup_steps (*dicee.callbacks.LRScheduler attribute*), 27
weight (*dicee.models.transformers.LayerNorm attribute*), 124
weight_decay (*dicee.config.Namespace attribute*), 29
weight_decay (*dicee.models.base_model.BaseKGE attribute*), 92
weight_decay (*dicee.models.BaseKGE attribute*), 139, 142, 148, 153, 159, 172, 175
weight_samples (*dicee.weight_averaging.TWA attribute*), 209
weights (*dicee.models.FMult attribute*), 177
weights (*dicee.models.function_space.FMult attribute*), 106

weights (*dicee.models.function_space.GFMult attribute*), 107
weights (*dicee.models.GFMult attribute*), 177
world_size (*dicee.Execute attribute*), 210
world_size (*dicee.executer.Execute attribute*), 68
write_csv_from_model_parallel () (in module *dicee.static_funcs*), 194
write_links () (*dicee.query_generator.QueryGenerator method*), 181
write_links () (*dicee.QueryGenerator method*), 216
write_report () (*dicee.Execute method*), 211
write_report () (*dicee.executer.Execute method*), 69

X

x_values (*dicee.models.function_space.LFMult attribute*), 108
x_values (*dicee.models.LFMult attribute*), 178