d3rlpy

Takuma Seno

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TUTORIALS

d3rlpy is a easy-to-use data-driven deep reinforcement learning library.

```
$ pip install d3rlpy
```

d3rlpy provides state-of-the-art data-driven deep reinforcement learning algorithms through out-of-the-box scikit-learn-style APIs. Unlike other RL libraries, the provided algorithms can achieve extremely powerful performance beyond the paper via several tweaks.

CHAPTER

ONE

GETTING STARTED

This tutorial is also available on Google Colaboratory

1.1 Install

First of all, let's install `d3rlpy` on your machine:

```
$ pip install d3rlpy
```

Note: `d3rlpy` supports Python 3.6+. Make sure which version you use.

Note: If you use GPU, please setup CUDA first.

1.2 Prepare Dataset

You can make your own dataset without any efforts. In this tutorial, let's use integrated datasets to start. If you want to make a new dataset, see *MDPDataset*.

d3rlpy provides suites of datasets for testing algorithms and research. See more documents at *Datasets*.

```
from d3rlpy.datasets import get_cartpole # CartPole-v0 dataset
from d3rlpy.datasets import get_pendulum # Pendulum-v0 dataset
from d3rlpy.datasets import get_pybullet # PyBullet task datasets
from d3rlpy.datasets import get_atari    # Atari 2600 task datasets
```

Here, we use the CartPole dataset to instantly check training results.

```
dataset, env = get_cartpole()
```

One interesting feature of d3rlpy is full compatibility with scikit-learn utilities. You can split `dataset` into a training dataset and a test dataset just like supervised learning as follows.

```
from sklearn.model_selection import train_test_split

train_episodes, test_episodes = train_test_split(dataset, test_size=0.2)
```

1.3 Setup Algorithm

There are many algorithms avaiable in d3rlpy. Since CartPole is the simple task, let's start from `DQN`, which is the Q-learnig algorithm proposed as the first deep reinforcement learning algorithm.

```
from d3rlpy.algos import DQN

# if you don't use GPU, set use_gpu=False instead.
dqn = DQN(use_gpu=True)
```

See more algorithms and configurations at *Algorithms*.

1.4 Setup Metrics

Collecting evaluation metrics is important to train algorithms properly. In d3rlpy, the metrics is computed through scikit-learn style scorer functions.

```
from d3rlpy.metrics.scorer import td_error_scorer
from d3rlpy.metrics.scorer import average_value_estimation_scorer

# calculate metrics with test dataset
td_error = td_error_scorer(dqn, test_episodes)
```

Since evaluating algorithms without access to environment is still difficult, the algorithm can be directly evaluated with `evaluate_on_environment` function if the environment is available to interact.

```
from d3rlpy.metrics.scorer import evaluate_on_environment

# set environment in scorer function
evaluate_scorer = evaluate_on_environment(env)

# evaluate algorithm on the environment
rewards = evaluate_scorer(dqn)
```

See more metrics and configurations at *Metrics*.

1.5 Start Training

Now, you have all to start data-driven training.

```
dqn.fit(train_episodes,
        eval_episodes=test_episodes,
        n_epochs=10,
        scorers={
            'td_error': td_error_scorer,
            'value_scale': average_value_estimation_scorer,
            'environment': evaluate_scorer
        })
```

Then, you will see training progress in the console like below:

```
augmentation=[]
batch_size=32
bootstrap=False
dynamics=None
encoder_params={}
eps=0.00015
gamma=0.99
learning_rate=6.25e-05
n_augmentations=1
n_critics=1
n_frames=1
q_func_type=mean
scaler=None
share_encoder=False
target_update_interval=8000.0
use_batch_norm=True
use_gpu=None
observation_shape=(4,)
action_size=2
100%|| 2490/2490 [00:24<00:00, 100.63it/s]
epoch=0 step=2490 value_loss=0.190237
epoch=0 step=2490 td_error=1.483964
epoch=0 step=2490 value_scale=1.241220
epoch=0 step=2490 environment=157.400000
100%|| 2490/2490 [00:24<00:00, 100.63it/s]
.
.
.
```

See more about logging at *Logging*.

Once the training is done, your algorithm is ready to make decisions.

```
observation = env.reset()

# return actions based on the greedy-policy
action = dqn.predict([observation])[0]

# estimate action-values
value = dqn.predict_value([observation], [action])[0]
```

1.6 Save and Load

d3rlpy provides several ways to save trained models.

```
# save full parameters
dqn.save_model('dqn.pt')

# load full parameters
dqn2 = DQN()
dqn2.load_model('dqn.pt')

# save the greedy-policy as TorchScript
dqn.save_policy('policy.pt')
```

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```
# save the greedy-policy as ONNX
dqn.save_policy('policy.onnx', as_onnx=True)
```

See more information at *Save and Load*.

CHAPTER

TWO

JUPYTER NOTEBOOKS

- CartPole
- Toy task (line tracer)
- Continuous Control with PyBullet
- Discrete Control with Atari

CHAPTER

THREE

API REFERENCE

3.1 Algorithms

d3rlpy provides state-of-the-art data-driven deep reinforcement learning algorithms as well as online algorithms for the base implementations.

3.1.1 Continuous control algorithms

d3rlpy.algos.BC	Behavior Cloning algorithm.
d3rlpy.algos.DDPG	Deep Deterministic Policy Gradients algorithm.
d3rlpy.algos.TD3	Twin Delayed Deep Deterministic Policy Gradients algorithm.
d3rlpy.algos.SAC	Soft Actor-Critic algorithm.
d3rlpy.algos.BCQ	Batch-Constrained Q-learning algorithm.
d3rlpy.algos.BEAR	Bootstrapping Error Accumulation Reduction algorithm.
d3rlpy.algos.CQL	Conservative Q-Learning algorithm.
d3rlpy.algos.AWR	Advantage-Weighted Regression algorithm.
d3rlpy.algos.AWAC	Advantage Weighted Actor-Critic algorithm.
d3rlpy.algos.PLAS	Policy in Latent Action Space algorithm.
d3rlpy.algos.PLASWithPerturbation	Policy in Latent Action Space algorithm with perturbation layer.

d3rlpy.algos.BC

class d3rlpy.algos.**BC**(**, learning_rate=0.001, optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, encoder_factory='default', batch_size=100, n_frames=1, use_gpu=False, scaler=None, augmentation=None, generator=None, impl=None, **kwargs*)

Behavior Cloning algorithm.

Behavior Cloning (BC) is to imitate actions in the dataset via a supervised learning approach. Since BC is only imitating action distributions, the performance will be close to the mean of the dataset even though BC mostly works better than online RL algorithms.

$$L(\theta) = \mathbb{E}_{a_t, s_t \sim D}[(a_t - \pi_\theta(s_t))^2]$$

Parameters

- **learning_rate** (*float*) – learing rate.

- **optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory.
- **encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory.
- **batch_size** (*int*) – mini-batch size.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **use_gpu** (*bool, int or d3rlpy.gpu.Device*) – flag to use GPU, device ID or device.
- **scaler** (*d3rlpy.preprocessing.Scaler or str*) – preprocessor. The available options are *['pixel', 'min_max', 'standard']*
- **augmentation** (*d3rlpy.augmentation.AugmentationPipeline or list(str)*) – augmentation pipeline.
- **generator** (*d3rlpy.algos.base.DataGenerator*) – dynamic dataset generator (e.g. model-based RL).
- **impl** (*d3rlpy.algos.torch.bc_impl.BCImpl*) – implemenation of the algorithm.

Methods

build_with_dataset (*dataset*)
Instantiate implementation object with MDPDataset object.

Parameters **dataset** (d3rlpy.dataset.MDPDataset) – dataset.

Return type None

build_with_env (*env*)
Instantiate implementation object with OpenAI Gym object.

Parameters **env** (*gym.core.Env*) – gym-like environment.

Return type None

create_impl (*observation_shape, action_size*)
Instantiate implementation objects with the dataset shapes.

This method will be used internally when *fit* method is called.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – dimension of action-space.

Return type None

fit (*episodes, n_epochs=1000, save_metrics=True, experiment_name=None, with_timestamp=True, logdir='d3rlpy_logs', verbose=True, show_progress=True, tensorboard=True, eval_episodes=None, save_interval=1, scorers=None, shuffle=True*)
Trains with the given dataset.

```
algo.fit(episodes)
```

Parameters

- **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes to train.

- **n_epochs** (*int*) – the number of epochs to train.
- **save_metrics** (*bool*) – flag to record metrics in files. If False, the log directory is not created and the model parameters are not saved during training.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be *{class name}_{timestamp}*.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)
- **eval_episodes** (*Optional[List[d3rlpy.dataset.Episode]]*) – list of episodes to test.
- **save_interval** (*int*) – interval to save parameters.
- **scorers** (*Optional[Dict[str, Callable[[Any, List[d3rlpy.dataset.Episode]], float]]]*) – list of scorer functions used with *eval_episodes*.
- **shuffle** (*bool*) – flag to shuffle transitions on each epoch.

Return type None

fit_online(*env, buffer, explorer=None, n_steps=1000000, n_steps_per_epoch=10000, update_interval=1, update_start_step=0, eval_env=None, eval_epsilon=0.0, save_metrics=True, experiment_name=None, with_timestamp=True, logdir='d3rlpy_logs', verbose=True, show_progress=True, tensorboard=True*)

Start training loop of online deep reinforcement learning.

Parameters

- **env** (*gym.core.Env*) – gym-like environment.
- **buffer** (*d3rlpy.online.buffers.Buffer*) – replay buffer.
- **explorer** (*Optional[d3rlpy.online.explorers.Explorer]*) – action explorer.
- **n_steps** (*int*) – the number of total steps to train.
- **n_steps_per_epoch** (*int*) – the number of steps per epoch.
- **update_interval** (*int*) – the number of steps per update.
- **update_start_step** (*int*) – the steps before starting updates.
- **eval_env** (*Optional[gym.core.Env]*) – gym-like environment. If None, evaluation is skipped.
- **eval_epsilon** (*float*) – ϵ-greedy factor during evaluation.
- **save_metrics** (*bool*) – flag to record metrics. If False, the log directory is not created and the model parameters are not saved.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be `{class name}_online_{timestamp}`.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.

- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

Return type None

classmethod from_json (*fname*, *use_gpu=False*)

Returns algorithm configured with json file.

The Json file should be the one saved during fitting.

```
from d3rlpy.algos import Algo

# create algorithm with saved configuration
algo = Algo.from_json('d3rlpy_logs/<path-to-json>/params.json')

# ready to load
algo.load_model('d3rlpy_logs/<path-to-model>/model_100.pt')

# ready to predict
algo.predict(...)
```

Parameters

- **fname** (*str*) – file path to *params.json*.
- **use_gpu** (*Optional[Union[bool, int, d3rlpy.gpu.Device]]*) – flag to use GPU, device ID or device.

Returns algorithm.

Return type d3rlpy.base.LearnableBase

get_params (*deep=True*)

Returns the all attributes.

This method returns the all attributes including ones in subclasses. Some of scikit-learn utilities will use this method.

```
params = algo.get_params(deep=True)

# the returned values can be used to instantiate the new object.
algo2 = AlgoBase(**params)
```

Parameters deep (*bool*) – flag to deeply copy objects such as *impl*.

Returns attribute values in dictionary.

Return type Dict[str, Any]

load_model (*fname*)

Load neural network parameters.

```
algo.load_model('model.pt')
```

Parameters fname (*str*) – source file path.

Return type None

predict (*x*)
Returns greedy actions.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

actions = algo.predict(x)
# actions.shape == (100, action size) for continuous control
# actions.shape == (100,) for discrete control
```

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations

Returns greedy actions

Return type numpy.ndarray

predict_value (*x, action, with_std=False*)
value prediction is not supported by BC algorithms.

Parameters

- **x** (*Union[numpy.ndarray, List[Any]]*) –
- **action** (*Union[numpy.ndarray, List[Any]]*) –
- **with_std** (*bool*) –

Return type numpy.ndarray

sample_action (*x*)
sampling action is not supported by BC algorithm.

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) –

Return type None

save_model (*fname*)
Saves neural network parameters.

```
algo.save_model('model.pt')
```

Parameters **fname** (*str*) – destination file path.

Return type None

save_policy (*fname, as_onnx=False*)
Save the greedy-policy computational graph as TorchScript or ONNX.

```
# save as TorchScript
algo.save_policy('policy.pt')

# save as ONNX
algo.save_policy('policy.onnx', as_onnx=True)
```

The artifacts saved with this method will work without d3rlpy. This method is especially useful to deploy the learned policy to production environments or embedding systems.

See also

- https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html (for Python).

- https://pytorch.org/tutorials/advanced/cpp_export.html (for C++).
- https://onnx.ai (for ONNX)

Parameters

- **fname** (*str*) – destination file path.
- **as_onnx** (*bool*) – flag to save as ONNX format.

Return type None

set_params(***params*)

Sets the given arguments to the attributes if they exist.

This method sets the given values to the attributes including ones in subclasses. If the values that don't exist as attributes are passed, they are ignored. Some of scikit-learn utilities will use this method.

```
algo.set_params(batch_size=100)
```

Parameters **params** (*Any*) – arbitrary inputs to set as attributes.

Returns itself.

Return type d3rlpy.base.LearnableBase

update(*epoch*, *total_step*, *batch*)

Update parameters with mini-batch of data.

Parameters

- **epoch** (*int*) – the current number of epochs.
- **total_step** (*int*) – the current number of total iterations.
- **batch** (d3rlpy.dataset.TransitionMiniBatch) – mini-batch data.

Returns loss values.

Return type list

Attributes

action_size

Action size.

Returns action size.

Return type Optional[int]

batch_size

Batch size to train.

Returns batch size.

Return type int

gamma

Discount factor.

Returns discount factor.

Return type float

impl
Implementation object.

Returns implementation object.

Return type Optional[ImplBase]

n_frames
Number of frames to stack.

This is only for image observation.

Returns number of frames to stack.

Return type int

n_steps
N-step TD backup.

Returns N-step TD backup.

Return type int

observation_shape
Observation shape.

Returns observation shape.

Return type Optional[Sequence[int]]

scaler
Preprocessing scaler.

Returns preprocessing scaler.

Return type Optional[Scaler]

d3rlpy.algos.DDPG

class d3rlpy.algos.**DDPG**(***, *actor_learning_rate=0.0003*, *critic_learning_rate=0.0003*, *actor_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>*, *critic_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>*, *actor_encoder_factory='default'*, *critic_encoder_factory='default'*, *q_func_factory='mean'*, *batch_size=100*, *n_frames=1*, *n_steps=1*, *gamma=0.99*, *tau=0.005*, *n_critics=1*, *bootstrap=False*, *share_encoder=False*, *use_gpu=False*, *scaler=None*, *augmentation=None*, *generator=None*, *impl=None*, ***kwargs*)

Deep Deterministic Policy Gradients algorithm.

DDPG is an actor-critic algorithm that trains a Q function parametrized with θ and a policy function parametrized with ϕ.

$$L(\theta) = \mathbb{E}_{s_t, a_t, r_{t+1}, s_{t+1} \sim D}[(r_{t+1} + \gamma Q_{\theta'}(s_{t+1}, \pi_{\phi'}(s_{t+1})) - Q_\theta(s_t, a_t))^2]$$

$$J(\phi) = \mathbb{E}_{s_t \sim D}[Q_\theta(s_t, \pi_\phi(s_t))]$$

where θ' and ϕ are the target network parameters. There target network parameters are updated every iteration.

$$\theta' \leftarrow \tau\theta + (1 - \tau)\theta'$$
$$\phi' \leftarrow \tau\phi + (1 - \tau)\phi'$$

References

- Silver et al., Deterministic policy gradient algorithms.
- Lillicrap et al., Continuous control with deep reinforcement learning.

Parameters

- **actor_learning_rate** (*float*) – learning rate for policy function.
- **critic_learning_rate** (*float*) – learning rate for Q function.
- **actor_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the actor.
- **critic_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the critic.
- **actor_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the actor.
- **critic_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the critic.
- **q_func_factory** (*d3rlpy.models.q_functions.QFunctionFactory or str*) – Q function factory.
- **batch_size** (*int*) – mini-batch size.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **n_steps** (*int*) – N-step TD calculation.
- **gamma** (*float*) – discount factor.
- **tau** (*float*) – target network synchronization coefficiency.
- **n_critics** (*int*) – the number of Q functions for ensemble.
- **bootstrap** (*bool*) – flag to bootstrap Q functions.
- **share_encoder** (*bool*) – flag to share encoder network.
- **use_gpu** (*bool, int or d3rlpy.gpu.Device*) – flag to use GPU, device ID or device.
- **scaler** (*d3rlpy.preprocessing.Scaler or str*) – preprocessor. The available options are *['pixel', 'min_max', 'standard']*
- **augmentation** (*d3rlpy.augmentation.AugmentationPipeline or list(str)*) – augmentation pipeline.
- **generator** (*d3rlpy.algos.base.DataGenerator*) – dynamic dataset generator (e.g. model-based RL).
- **impl** (*d3rlpy.algos.torch.ddpg_impl.DDPGImpl*) – algorithm implementation.

Methods

build_with_dataset(*dataset*)

Instantiate implementation object with MDPDataset object.

Parameters **dataset** (d3rlpy.dataset.MDPDataset) – dataset.

Return type None

build_with_env(*env*)

Instantiate implementation object with OpenAI Gym object.

Parameters **env** (*gym.core.Env*) – gym-like environment.

Return type None

create_impl(*observation_shape*, *action_size*)

Instantiate implementation objects with the dataset shapes.

This method will be used internally when *fit* method is called.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – dimension of action-space.

Return type None

fit(*episodes*, *n_epochs=1000*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*, *eval_episodes=None*, *save_interval=1*, *scorers=None*, *shuffle=True*)

Trains with the given dataset.

```
algo.fit(episodes)
```

Parameters

- **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes to train.
- **n_epochs** (*int*) – the number of epochs to train.
- **save_metrics** (*bool*) – flag to record metrics in files. If False, the log directory is not created and the model parameters are not saved during training.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be *{class name}_{timestamp}*.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)
- **eval_episodes** (*Optional[List[d3rlpy.dataset.Episode]]*) – list of episodes to test.
- **save_interval** (*int*) – interval to save parameters.

- **scorers** (*Optional[Dict[str, Callable[[Any, List[d3rlpy.dataset.Episode]], float]]]*) – list of scorer functions used with *eval_episodes*.
- **shuffle** (*bool*) – flag to shuffle transitions on each epoch.

Return type None

fit_online(*env*, *buffer*, *explorer=None*, *n_steps=1000000*, *n_steps_per_epoch=10000*, *update_interval=1*, *update_start_step=0*, *eval_env=None*, *eval_epsilon=0.0*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*)
Start training loop of online deep reinforcement learning.

Parameters

- **env** (*gym.core.Env*) – gym-like environment.
- **buffer** (*d3rlpy.online.buffers.Buffer*) – replay buffer.
- **explorer** (*Optional[d3rlpy.online.explorers.Explorer]*) – action explorer.
- **n_steps** (*int*) – the number of total steps to train.
- **n_steps_per_epoch** (*int*) – the number of steps per epoch.
- **update_interval** (*int*) – the number of steps per update.
- **update_start_step** (*int*) – the steps before starting updates.
- **eval_env** (*Optional[gym.core.Env]*) – gym-like environment. If None, evaluation is skipped.
- **eval_epsilon** (*float*) – ϵ-greedy factor during evaluation.
- **save_metrics** (*bool*) – flag to record metrics. If False, the log directory is not created and the model parameters are not saved.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be `{class name}_online_{timestamp}`.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

Return type None

classmethod from_json(*fname*, *use_gpu=False*)
Returns algorithm configured with json file.

The Json file should be the one saved during fitting.

```
from d3rlpy.algos import Algo

# create algorithm with saved configuration
algo = Algo.from_json('d3rlpy_logs/<path-to-json>/params.json')
```

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```
# ready to load
algo.load_model('d3rlpy_logs/<path-to-model>/model_100.pt')

# ready to predict
algo.predict(...)
```

Parameters

- **fname** (*str*) – file path to *params.json*.
- **use_gpu** (*Optional[Union[bool, int, d3rlpy.gpu.Device]]*) – flag to use GPU, device ID or device.

Returns algorithm.

Return type d3rlpy.base.LearnableBase

get_params (*deep=True*)

Returns the all attributes.

This method returns the all attributes including ones in subclasses. Some of scikit-learn utilities will use this method.

```
params = algo.get_params(deep=True)

# the returned values can be used to instantiate the new object.
algo2 = AlgoBase(**params)
```

Parameters **deep** (*bool*) – flag to deeply copy objects such as *impl*.

Returns attribute values in dictionary.

Return type Dict[str, Any]

load_model (*fname*)

Load neural network parameters.

```
algo.load_model('model.pt')
```

Parameters **fname** (*str*) – source file path.

Return type None

predict (*x*)

Returns greedy actions.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

actions = algo.predict(x)
# actions.shape == (100, action size) for continuous control
# actions.shape == (100,) for discrete control
```

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations

Returns greedy actions

Return type numpy.ndarray

predict_value (*x*, *action*, *with_std=False*)
Returns predicted action-values.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

# for continuous control
# 100 actions with shape of (2,)
actions = np.random.random((100, 2))

# for discrete control
# 100 actions in integer values
actions = np.random.randint(2, size=100)

values = algo.predict_value(x, actions)
# values.shape == (100,)

values, stds = algo.predict_value(x, actions, with_std=True)
# stds.shape  == (100,)
```

Parameters

- **x** (*Union[numpy.ndarray, List[Any]]*) – observations
- **action** (*Union[numpy.ndarray, List[Any]]*) – actions
- **with_std** (*bool*) – flag to return standard deviation of ensemble estimation. This deviation reflects uncertainty for the given observations. This uncertainty will be more accurate if you enable `bootstrap` flag and increase `n_critics` value.

Returns predicted action-values

Return type Union[numpy.ndarray, Tuple[numpy.ndarray, numpy.ndarray]]

sample_action (*x*)
Returns sampled actions.

The sampled actions are identical to the output of *predict* method if the policy is deterministic.

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations.

Returns sampled actions.

Return type numpy.ndarray

save_model (*fname*)
Saves neural network parameters.

```
algo.save_model('model.pt')
```

Parameters **fname** (*str*) – destination file path.

Return type None

save_policy (*fname*, *as_onnx=False*)
Save the greedy-policy computational graph as TorchScript or ONNX.

```
# save as TorchScript
algo.save_policy('policy.pt')
```

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```
# save as ONNX
algo.save_policy('policy.onnx', as_onnx=True)
```

The artifacts saved with this method will work without d3rlpy. This method is especially useful to deploy the learned policy to production environments or embedding systems.

See also

- https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html (for Python).
- https://pytorch.org/tutorials/advanced/cpp_export.html (for C++).
- https://onnx.ai (for ONNX)

Parameters

- **fname** (*str*) – destination file path.
- **as_onnx** (*bool*) – flag to save as ONNX format.

Return type None

set_params (***params*)

Sets the given arguments to the attributes if they exist.

This method sets the given values to the attributes including ones in subclasses. If the values that don't exist as attributes are passed, they are ignored. Some of scikit-learn utilities will use this method.

```
algo.set_params(batch_size=100)
```

Parameters **params** (*Any*) – arbitrary inputs to set as attributes.

Returns itself.

Return type d3rlpy.base.LearnableBase

update (*epoch, total_step, batch*)

Update parameters with mini-batch of data.

Parameters

- **epoch** (*int*) – the current number of epochs.
- **total_step** (*int*) – the current number of total iterations.
- **batch** (d3rlpy.dataset.TransitionMiniBatch) – mini-batch data.

Returns loss values.

Return type list

Attributes

action_size
Action size.

Returns action size.

Return type Optional[int]

batch_size
Batch size to train.

Returns batch size.

Return type int

gamma
Discount factor.

Returns discount factor.

Return type float

impl
Implementation object.

Returns implementation object.

Return type Optional[ImplBase]

n_frames
Number of frames to stack.

This is only for image observation.

Returns number of frames to stack.

Return type int

n_steps
N-step TD backup.

Returns N-step TD backup.

Return type int

observation_shape
Observation shape.

Returns observation shape.

Return type Optional[Sequence[int]]

scaler
Preprocessing scaler.

Returns preprocessing scaler.

Return type Optional[Scaler]

d3rlpy.algos.TD3

class d3rlpy.algos.**TD3**(**, actor_learning_rate=0.0003, critic_learning_rate=0.0003, actor_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, critic_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, actor_encoder_factory='default', critic_encoder_factory='default', q_func_factory='mean', batch_size=100, n_frames=1, n_steps=1, gamma=0.99, tau=0.005, n_critics=2, bootstrap=False, share_encoder=False, target_smoothing_sigma=0.2, target_smoothing_clip=0.5, update_actor_interval=2, use_gpu=False, scaler=None, augmentation=None, generator=None, impl=None, **kwargs*)

Twin Delayed Deep Deterministic Policy Gradients algorithm.

TD3 is an improved DDPG-based algorithm. Major differences from DDPG are as follows.

- TD3 has twin Q functions to reduce overestimation bias at TD learning. The number of Q functions can be designated by *n_critics*.
- TD3 adds noise to target value estimation to avoid overfitting with the deterministic policy.
- TD3 updates the policy function after several Q function updates in order to reduce variance of action-value estimation. The interval of the policy function update can be designated by *update_actor_interval*.

$$L(\theta_i) = \mathbb{E}_{s_t, a_t, r_{t+1}, s_{t+1} \sim D}[(r_{t+1} + \gamma \min_j Q_{\theta_j'}(s_{t+1}, \pi_{\phi'}(s_{t+1}) + \epsilon) - Q_{\theta_i}(s_t, a_t))^2]$$

$$J(\phi) = \mathbb{E}_{s_t \sim D}[\min_i Q_{\theta_i}(s_t, \pi_\phi(s_t))]$$

where $\epsilon \sim clip(N(0, \sigma), -c, c)$

References

- Fujimoto et al., Addressing Function Approximation Error in Actor-Critic Methods.

Parameters

- **actor_learning_rate** (*float*) – learning rate for a policy function.
- **critic_learning_rate** (*float*) – learning rate for Q functions.
- **actor_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the actor.
- **critic_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the critic.
- **actor_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the actor.
- **critic_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the critic.
- **q_func_factory** (*d3rlpy.models.q_functions.QFunctionFactory or str*) – Q function factory.
- **batch_size** (*int*) – mini-batch size.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **n_steps** (*int*) – N-step TD calculation.
- **gamma** (*float*) – discount factor.

- **tau** (*float*) – target network synchronization coefficiency.
- **n_critics** (*int*) – the number of Q functions for ensemble.
- **bootstrap** (*bool*) – flag to bootstrap Q functions.
- **share_encoder** (*bool*) – flag to share encoder network.
- **target_smoothing_sigma** (*float*) – standard deviation for target noise.
- **target_smoothing_clip** (*float*) – clipping range for target noise.
- **update_actor_interval** (*int*) – interval to update policy function described as *delayed policy update* in the paper.
- **use_gpu** (*bool, int or d3rlpy.gpu.Device*) – flag to use GPU, device ID or device.
- **scaler** (*d3rlpy.preprocessing.Scaler or str*) – preprocessor. The available options are *['pixel', 'min_max', 'standard']*
- **augmentation** (*d3rlpy.augmentation.AugmentationPipeline or list(str)*) – augmentation pipeline.
- **generator** (*d3rlpy.algos.base.DataGenerator*) – dynamic dataset generator (e.g. model-based RL).
- **impl** (*d3rlpy.algos.torch.td3_impl.TD3Impl*) – algorithm implementation.

Methods

build_with_dataset (*dataset*)
Instantiate implementation object with MDPDataset object.

Parameters **dataset** (d3rlpy.dataset.MDPDataset) – dataset.

Return type None

build_with_env (*env*)
Instantiate implementation object with OpenAI Gym object.

Parameters **env** (*gym.core.Env*) – gym-like environment.

Return type None

create_impl (*observation_shape, action_size*)
Instantiate implementation objects with the dataset shapes.

This method will be used internally when *fit* method is called.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – dimension of action-space.

Return type None

fit (*episodes, n_epochs=1000, save_metrics=True, experiment_name=None, with_timestamp=True, logdir='d3rlpy_logs', verbose=True, show_progress=True, tensorboard=True, eval_episodes=None, save_interval=1, scorers=None, shuffle=True*)
Trains with the given dataset.

```
algo.fit(episodes)
```

Parameters

- **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes to train.
- **n_epochs** (*int*) – the number of epochs to train.
- **save_metrics** (*bool*) – flag to record metrics in files. If False, the log directory is not created and the model parameters are not saved during training.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be *{class name}_{timestamp}*.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)
- **eval_episodes** (*Optional[List[d3rlpy.dataset.Episode]]*) – list of episodes to test.
- **save_interval** (*int*) – interval to save parameters.
- **scorers** (*Optional[Dict[str, Callable[[Any, List[d3rlpy.dataset.Episode]], float]]]*) – list of scorer functions used with *eval_episodes*.
- **shuffle** (*bool*) – flag to shuffle transitions on each epoch.

Return type None

fit_online(*env*, *buffer*, *explorer=None*, *n_steps=1000000*, *n_steps_per_epoch=10000*, *update_interval=1*, *update_start_step=0*, *eval_env=None*, *eval_epsilon=0.0*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*)

Start training loop of online deep reinforcement learning.

Parameters

- **env** (*gym.core.Env*) – gym-like environment.
- **buffer** (*d3rlpy.online.buffers.Buffer*) – replay buffer.
- **explorer** (*Optional[d3rlpy.online.explorers.Explorer]*) – action explorer.
- **n_steps** (*int*) – the number of total steps to train.
- **n_steps_per_epoch** (*int*) – the number of steps per epoch.
- **update_interval** (*int*) – the number of steps per update.
- **update_start_step** (*int*) – the steps before starting updates.
- **eval_env** (*Optional[gym.core.Env]*) – gym-like environment. If None, evaluation is skipped.
- **eval_epsilon** (*float*) – ϵ-greedy factor during evaluation.
- **save_metrics** (*bool*) – flag to record metrics. If False, the log directory is not created and the model parameters are not saved.

- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be `{class name}_online_{timestamp}`.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

Return type None

classmethod from_json (*fname, use_gpu=False*)

Returns algorithm configured with json file.

The Json file should be the one saved during fitting.

```
from d3rlpy.algos import Algo

# create algorithm with saved configuration
algo = Algo.from_json('d3rlpy_logs/<path-to-json>/params.json')

# ready to load
algo.load_model('d3rlpy_logs/<path-to-model>/model_100.pt')

# ready to predict
algo.predict(...)
```

Parameters

- **fname** (*str*) – file path to *params.json*.
- **use_gpu** (*Optional[Union[bool, int, d3rlpy.gpu.Device]]*) – flag to use GPU, device ID or device.

Returns algorithm.

Return type d3rlpy.base.LearnableBase

get_params (*deep=True*)

Returns the all attributes.

This method returns the all attributes including ones in subclasses. Some of scikit-learn utilities will use this method.

```
params = algo.get_params(deep=True)

# the returned values can be used to instantiate the new object.
algo2 = AlgoBase(**params)
```

Parameters deep (*bool*) – flag to deeply copy objects such as *impl*.

Returns attribute values in dictionary.

Return type Dict[str, Any]

load_model (*fname*)

Load neural network parameters.

```
algo.load_model('model.pt')
```

Parameters **fname** (*str*) – source file path.

Return type None

predict (*x*)
Returns greedy actions.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

actions = algo.predict(x)
# actions.shape == (100, action size) for continuous control
# actions.shape == (100,) for discrete control
```

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations

Returns greedy actions

Return type numpy.ndarray

predict_value (*x, action, with_std=False*)
Returns predicted action-values.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

# for continuous control
# 100 actions with shape of (2,)
actions = np.random.random((100, 2))

# for discrete control
# 100 actions in integer values
actions = np.random.randint(2, size=100)

values = algo.predict_value(x, actions)
# values.shape == (100,)

values, stds = algo.predict_value(x, actions, with_std=True)
# stds.shape  == (100,)
```

Parameters

- **x** (*Union[numpy.ndarray, List[Any]]*) – observations
- **action** (*Union[numpy.ndarray, List[Any]]*) – actions
- **with_std** (*bool*) – flag to return standard deviation of ensemble estimation. This deviation reflects uncertainty for the given observations. This uncertainty will be more accurate if you enable `bootstrap` flag and increase `n_critics` value.

Returns predicted action-values

Return type Union[numpy.ndarray, Tuple[numpy.ndarray, numpy.ndarray]]

sample_action (*x*)
Returns sampled actions.

The sampled actions are identical to the output of *predict* method if the policy is deterministic.

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations.

Returns sampled actions.

Return type numpy.ndarray

save_model (*fname*)

Saves neural network parameters.

```
algo.save_model('model.pt')
```

Parameters **fname** (*str*) – destination file path.

Return type None

save_policy (*fname*, *as_onnx=False*)

Save the greedy-policy computational graph as TorchScript or ONNX.

```
# save as TorchScript
algo.save_policy('policy.pt')

# save as ONNX
algo.save_policy('policy.onnx', as_onnx=True)
```

The artifacts saved with this method will work without d3rlpy. This method is especially useful to deploy the learned policy to production environments or embedding systems.

See also

- https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html (for Python).
- https://pytorch.org/tutorials/advanced/cpp_export.html (for C++).
- https://onnx.ai (for ONNX)

Parameters

- **fname** (*str*) – destination file path.
- **as_onnx** (*bool*) – flag to save as ONNX format.

Return type None

set_params (***params*)

Sets the given arguments to the attributes if they exist.

This method sets the given values to the attributes including ones in subclasses. If the values that don't exist as attributes are passed, they are ignored. Some of scikit-learn utilities will use this method.

```
algo.set_params(batch_size=100)
```

Parameters **params** (*Any*) – arbitrary inputs to set as attributes.

Returns itself.

Return type d3rlpy.base.LearnableBase

update (*epoch*, *total_step*, *batch*)

Update parameters with mini-batch of data.

Parameters

- **epoch** (*int*) – the current number of epochs.
- **total_step** (*int*) – the current number of total iterations.
- **batch** (`d3rlpy.dataset.TransitionMiniBatch`) – mini-batch data.

Returns loss values.

Return type list

Attributes

action_size
Action size.

Returns action size.

Return type Optional[int]

batch_size
Batch size to train.

Returns batch size.

Return type int

gamma
Discount factor.

Returns discount factor.

Return type float

impl
Implementation object.

Returns implementation object.

Return type Optional[ImplBase]

n_frames
Number of frames to stack.

This is only for image observation.

Returns number of frames to stack.

Return type int

n_steps
N-step TD backup.

Returns N-step TD backup.

Return type int

observation_shape
Observation shape.

Returns observation shape.

Return type Optional[Sequence[int]]

scaler
Preprocessing scaler.

Returns preprocessing scaler.

Return type Optional[Scaler]

d3rlpy.algos.SAC

class d3rlpy.algos.**SAC**(**, actor_learning_rate=0.0003, critic_learning_rate=0.0003, temp_learning_rate=0.0003, actor_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, critic_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, temp_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, actor_encoder_factory='default', critic_encoder_factory='default', q_func_factory='mean', batch_size=100, n_frames=1, n_steps=1, gamma=0.99, tau=0.005, n_critics=2, bootstrap=False, share_encoder=False, update_actor_interval=1, initial_temperature=1.0, use_gpu=False, scaler=None, augmentation=None, generator=None, impl=None, **kwargs*)

Soft Actor-Critic algorithm.

SAC is a DDPG-based maximum entropy RL algorithm, which produces state-of-the-art performance in online RL settings. SAC leverages twin Q functions proposed in TD3. Additionally, *delayed policy update* in TD3 is also implemented, which is not done in the paper.

$$L(\theta_i) = \mathbb{E}_{s_t,a_t,r_{t+1},s_{t+1}\sim D,a_{t+1}\sim\pi_\phi(\cdot|s_{t+1})}[(y - Q_{\theta_i}(s_t, a_t))^2]$$

$$y = r_{t+1} + \gamma(\min_j Q_{\theta_j}(s_{t+1}, a_{t+1}) - \alpha\log(\pi_\phi(a_{t+1}|s_{t+1})))$$

$$J(\phi) = \mathbb{E}_{s_t\sim D,a_t\sim\pi_\phi(\cdot|s_t)}[\alpha\log(\pi_\phi(a_t|s_t)) - \min_i Q_{\theta_i}(s_t, \pi_\phi(a_t|s_t))]$$

The temperature parameter α is also automatically adjustable.

$$J(\alpha) = \mathbb{E}_{s_t\sim D,a_t\sim\pi_\phi\cdot|s_t)}[-\alpha(\log(\pi_\phi(a_t|s_t)) + H)]$$

where H is a target entropy, which is defined as $\dim a$.

References

- Haarnoja et al., Soft Actor-Critic: Off-Policy Maximum Entropy Deep Reinforcement Learning with a Stochastic Actor.
- Haarnoja et al., Soft Actor-Critic Algorithms and Applications.

Parameters

- **actor_learning_rate** (`float`) – learning rate for policy function.
- **critic_learning_rate** (`float`) – learning rate for Q functions.
- **temp_learning_rate** (`float`) – learning rate for temperature parameter.
- **actor_optim_factory** (`d3rlpy.models.optimizers.OptimizerFactory`) – optimizer factory for the actor.
- **critic_optim_factory** (`d3rlpy.models.optimizers.OptimizerFactory`) – optimizer factory for the critic.
- **temp_optim_factory** (`d3rlpy.models.optimizers.OptimizerFactory`) – optimizer factory for the temperature.

- **actor_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the actor.
- **critic_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the critic.
- **q_func_factory** (*d3rlpy.models.q_functions.QFunctionFactory or str*) – Q function factory.
- **batch_size** (*int*) – mini-batch size.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **n_steps** (*int*) – N-step TD calculation.
- **gamma** (*float*) – discount factor.
- **tau** (*float*) – target network synchronization coefficiency.
- **n_critics** (*int*) – the number of Q functions for ensemble.
- **bootstrap** (*bool*) – flag to bootstrap Q functions.
- **share_encoder** (*bool*) – flag to share encoder network.
- **update_actor_interval** (*int*) – interval to update policy function.
- **initial_temperature** (*float*) – initial temperature value.
- **use_gpu** (*bool, int or d3rlpy.gpu.Device*) – flag to use GPU, device ID or device.
- **scaler** (*d3rlpy.preprocessing.Scaler or str*) – preprocessor. The available options are *['pixel', 'min_max', 'standard']*
- **augmentation** (*d3rlpy.augmentation.AugmentationPipeline or list(str)*) – augmentation pipeline.
- **generator** (*d3rlpy.algos.base.DataGenerator*) – dynamic dataset generator (e.g. model-based RL).
- **impl** (*d3rlpy.algos.torch.sac_impl.SACImpl*) – algorithm implementation.

Methods

build_with_dataset(*dataset*)
Instantiate implementation object with MDPDataset object.

Parameters **dataset** (d3rlpy.dataset.MDPDataset) – dataset.

Return type None

build_with_env(*env*)
Instantiate implementation object with OpenAI Gym object.

Parameters **env** (*gym.core.Env*) – gym-like environment.

Return type None

create_impl(*observation_shape*, *action_size*)
Instantiate implementation objects with the dataset shapes.

This method will be used internally when *fit* method is called.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – dimension of action-space.

Return type None

fit(*episodes*, *n_epochs=1000*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*, *eval_episodes=None*, *save_interval=1*, *scorers=None*, *shuffle=True*)
Trains with the given dataset.

```
algo.fit(episodes)
```

Parameters

- **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes to train.
- **n_epochs** (*int*) – the number of epochs to train.
- **save_metrics** (*bool*) – flag to record metrics in files. If False, the log directory is not created and the model parameters are not saved during training.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be *{class name}_{timestamp}*.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)
- **eval_episodes** (*Optional[List[d3rlpy.dataset.Episode]]*) – list of episodes to test.
- **save_interval** (*int*) – interval to save parameters.
- **scorers** (*Optional[Dict[str, Callable[[Any, List[d3rlpy.dataset.Episode]], float]]]*) – list of scorer functions used with *eval_episodes*.
- **shuffle** (*bool*) – flag to shuffle transitions on each epoch.

Return type None

fit_online(*env*, *buffer*, *explorer=None*, *n_steps=1000000*, *n_steps_per_epoch=10000*, *update_interval=1*, *update_start_step=0*, *eval_env=None*, *eval_epsilon=0.0*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*)
Start training loop of online deep reinforcement learning.

Parameters

- **env** (*gym.core.Env*) – gym-like environment.
- **buffer** (*d3rlpy.online.buffers.Buffer*) – replay buffer.
- **explorer** (*Optional[d3rlpy.online.explorers.Explorer]*) – action explorer.
- **n_steps** (*int*) – the number of total steps to train.

- **n_steps_per_epoch** (*int*) – the number of steps per epoch.
- **update_interval** (*int*) – the number of steps per update.
- **update_start_step** (*int*) – the steps before starting updates.
- **eval_env** (*Optional[gym.core.Env]*) – gym-like environment. If None, evaluation is skipped.
- **eval_epsilon** (*float*) – ϵ-greedy factor during evaluation.
- **save_metrics** (*bool*) – flag to record metrics. If False, the log directory is not created and the model parameters are not saved.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be `{class name}_online_{timestamp}`.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

Return type None

classmethod from_json(*fname*, *use_gpu=False*)

Returns algorithm configured with json file.

The Json file should be the one saved during fitting.

```
from d3rlpy.algos import Algo

# create algorithm with saved configuration
algo = Algo.from_json('d3rlpy_logs/<path-to-json>/params.json')

# ready to load
algo.load_model('d3rlpy_logs/<path-to-model>/model_100.pt')

# ready to predict
algo.predict(...)
```

Parameters

- **fname** (*str*) – file path to *params.json*.
- **use_gpu** (*Optional[Union[bool, int, d3rlpy.gpu.Device]]*) – flag to use GPU, device ID or device.

Returns algorithm.

Return type d3rlpy.base.LearnableBase

get_params(*deep=True*)

Returns the all attributes.

This method returns the all attributes including ones in subclasses. Some of scikit-learn utilities will use this method.

```
params = algo.get_params(deep=True)

# the returned values can be used to instantiate the new object.
algo2 = AlgoBase(**params)
```

Parameters **deep** (*bool*) – flag to deeply copy objects such as *impl*.

Returns attribute values in dictionary.

Return type Dict[str, Any]

load_model (*fname*)

Load neural network parameters.

```
algo.load_model('model.pt')
```

Parameters **fname** (*str*) – source file path.

Return type None

predict (*x*)

Returns greedy actions.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

actions = algo.predict(x)
# actions.shape == (100, action size) for continuous control
# actions.shape == (100,) for discrete control
```

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations

Returns greedy actions

Return type numpy.ndarray

predict_value (*x*, *action*, *with_std=False*)

Returns predicted action-values.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

# for continuous control
# 100 actions with shape of (2,)
actions = np.random.random((100, 2))

# for discrete control
# 100 actions in integer values
actions = np.random.randint(2, size=100)

values = algo.predict_value(x, actions)
# values.shape == (100,)

values, stds = algo.predict_value(x, actions, with_std=True)
# stds.shape  == (100,)
```

Parameters

- **x** (*Union[numpy.ndarray, List[Any]]*) – observations
- **action** (*Union[numpy.ndarray, List[Any]]*) – actions
- **with_std** (*bool*) – flag to return standard deviation of ensemble estimation. This deviation reflects uncertainty for the given observations. This uncertainty will be more accurate if you enable `bootstrap` flag and increase `n_critics` value.

Returns predicted action-values

Return type Union[numpy.ndarray, Tuple[numpy.ndarray, numpy.ndarray]]

sample_action (*x*)

Returns sampled actions.

The sampled actions are identical to the output of *predict* method if the policy is deterministic.

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations.

Returns sampled actions.

Return type numpy.ndarray

save_model (*fname*)

Saves neural network parameters.

```
algo.save_model('model.pt')
```

Parameters **fname** (*str*) – destination file path.

Return type None

save_policy (*fname*, *as_onnx=False*)

Save the greedy-policy computational graph as TorchScript or ONNX.

```
# save as TorchScript
algo.save_policy('policy.pt')

# save as ONNX
algo.save_policy('policy.onnx', as_onnx=True)
```

The artifacts saved with this method will work without d3rlpy. This method is especially useful to deploy the learned policy to production environments or embedding systems.

See also

- https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html (for Python).
- https://pytorch.org/tutorials/advanced/cpp_export.html (for C++).
- https://onnx.ai (for ONNX)

Parameters

- **fname** (*str*) – destination file path.
- **as_onnx** (*bool*) – flag to save as ONNX format.

Return type None

set_params(***params*)

Sets the given arguments to the attributes if they exist.

This method sets the given values to the attributes including ones in subclasses. If the values that don't exist as attributes are passed, they are ignored. Some of scikit-learn utilities will use this method.

```
algo.set_params(batch_size=100)
```

Parameters **params** (*Any*) – arbitrary inputs to set as attributes.

Returns itself.

Return type d3rlpy.base.LearnableBase

update(*epoch*, *total_step*, *batch*)

Update parameters with mini-batch of data.

Parameters

- **epoch** (*int*) – the current number of epochs.
- **total_step** (*int*) – the current number of total iterations.
- **batch** (d3rlpy.dataset.TransitionMiniBatch) – mini-batch data.

Returns loss values.

Return type list

Attributes

action_size

Action size.

Returns action size.

Return type Optional[int]

batch_size

Batch size to train.

Returns batch size.

Return type int

gamma

Discount factor.

Returns discount factor.

Return type float

impl

Implementation object.

Returns implementation object.

Return type Optional[ImplBase]

n_frames

Number of frames to stack.

This is only for image observation.

Returns number of frames to stack.

Return type int

n_steps
N-step TD backup.

Returns N-step TD backup.

Return type int

observation_shape
Observation shape.

Returns observation shape.

Return type Optional[Sequence[int]]

scaler
Preprocessing scaler.

Returns preprocessing scaler.

Return type Optional[Scaler]

d3rlpy.algos.BCQ

class d3rlpy.algos.**BCQ**(*, *actor_learning_rate=0.001*, *critic_learning_rate=0.001*, *imitator_learning_rate=0.001*, *actor_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>*, *critic_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>*, *imitator_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>*, *actor_encoder_factory='default'*, *critic_encoder_factory='default'*, *imitator_encoder_factory='default'*, *q_func_factory='mean'*, *batch_size=100*, *n_frames=1*, *n_steps=1*, *gamma=0.99*, *tau=0.005*, *n_critics=2*, *bootstrap=False*, *share_encoder=False*, *update_actor_interval=1*, *lam=0.75*, *n_action_samples=100*, *action_flexibility=0.05*, *rl_start_epoch=0*, *latent_size=32*, *beta=0.5*, *use_gpu=False*, *scaler=None*, *augmentation=None*, *generator=None*, *impl=None*, ***kwargs*)

Batch-Constrained Q-learning algorithm.

BCQ is the very first practical data-driven deep reinforcement learning lgorithm. The major difference from DDPG is that the policy function is represented as combination of conditional VAE and perturbation function in order to remedy extrapolation error emerging from target value estimation.

The encoder and the decoder of the conditional VAE is represented as E_ω and D_ω respectively.

$$L(\omega) = E_{s_t,a_t \sim D}[(a - \tilde{a})^2 + D_{KL}(N(\mu, \sigma)|N(0,1))]$$

where $\mu, \sigma = E_\omega(s_t, a_t)$, $\tilde{a} = D_\omega(s_t, z)$ and $z \sim N(\mu, \sigma)$.

The policy function is represented as a residual function with the VAE and the perturbation function represented as $\xi_\phi(s, a)$.

$$\pi(s, a) = a + \Phi\xi_\phi(s, a)$$

where $a = D_\omega(s, z)$, $z \sim N(0, 0.5)$ and Φ is a perturbation scale designated by *action_flexibility*. Although the policy is learned closely to data distribution, the perturbation function can lead to more rewarded states.

BCQ also leverages twin Q functions and computes weighted average over maximum values and minimum values.

$$L(\theta_i) = \mathbb{E}_{s_t, a_t, r_{t+1}, s_{t+1} \sim D}[(y - Q_{\theta_i}(s_t, a_t))^2]$$

$$y = r_{t+1} + \gamma \max_{a_i}[\lambda \min_j Q_{\theta'_j}(s_{t+1}, a_i) + (1 - \lambda) \max_j Q_{\theta'_j}(s_{t+1}, a_i)]$$

where $\{a_i \sim D(s_{t+1}, z), z \sim N(0, 0.5)\}_{i=1}^n$. The number of sampled actions is designated with *n_action_samples*.

Finally, the perturbation function is trained just like DDPG's policy function.

$$J(\phi) = \mathbb{E}_{s_t \sim D, a_t \sim D_\omega(s_t, z), z \sim N(0, 0.5)}[Q_{\theta_1}(s_t, \pi(s_t, a_t))]$$

At inference time, action candidates are sampled as many as *n_action_samples*, and the action with highest value estimation is taken.

$$\pi'(s) = \text{argmax}_{\pi(s, a_i)} Q_{\theta_1}(s, \pi(s, a_i))$$

Note: The greedy action is not deterministic because the action candidates are always randomly sampled. This might affect *save_policy* method and the performance at production.

References

- Fujimoto et al., Off-Policy Deep Reinforcement Learning without Exploration.

Parameters

- **actor_learning_rate** (*float*) – learning rate for policy function.
- **critic_learning_rate** (*float*) – learning rate for Q functions.
- **imitator_learning_rate** (*float*) – learning rate for Conditional VAE.
- **actor_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the actor.
- **critic_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the critic.
- **imitator_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the conditional VAE.
- **actor_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the actor.
- **critic_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the critic.
- **imitator_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the conditional VAE.
- **q_func_factory** (*d3rlpy.models.q_functions.QFunctionFactory or str*) – Q function factory.
- **batch_size** (*int*) – mini-batch size.
- **n_frames** (*int*) – the number of frames to stack for image observation.

- **n_steps** (*int*) – N-step TD calculation.
- **gamma** (*float*) – discount factor.
- **tau** (*float*) – target network synchronization coefficiency.
- **n_critics** (*int*) – the number of Q functions for ensemble.
- **bootstrap** (*bool*) – flag to bootstrap Q functions.
- **share_encoder** (*bool*) – flag to share encoder network.
- **update_actor_interval** (*int*) – interval to update policy function.
- **lam** (*float*) – weight factor for critic ensemble.
- **n_action_samples** (*int*) – the number of action samples to estimate action-values.
- **action_flexibility** (*float*) – output scale of perturbation function represented as Φ.
- **rl_start_epoch** (*int*) – epoch to start to update policy function and Q functions. If this is large, RL training would be more stabilized.
- **latent_size** (*int*) – size of latent vector for Conditional VAE.
- **beta** (*float*) – KL reguralization term for Conditional VAE.
- **use_gpu** (*bool, int or d3rlpy.gpu.Device*) – flag to use GPU, device ID or device.
- **scaler** (*d3rlpy.preprocessing.Scaler or str*) – preprocessor. The available options are *['pixel', 'min_max', 'standard']*
- **augmentation** (*d3rlpy.augmentation.AugmentationPipeline or list(str)*) – augmentation pipeline.
- **generator** (*d3rlpy.algos.base.DataGenerator*) – dynamic dataset generator (e.g. model-based RL).
- **impl** (*d3rlpy.algos.torch.bcq_impl.BCQImpl*) – algorithm implementation.

Methods

build_with_dataset(*dataset*)
Instantiate implementation object with MDPDataset object.

Parameters dataset (d3rlpy.dataset.MDPDataset) – dataset.

Return type None

build_with_env(*env*)
Instantiate implementation object with OpenAI Gym object.

Parameters env (*gym.core.Env*) – gym-like environment.

Return type None

create_impl(*observation_shape, action_size*)
Instantiate implementation objects with the dataset shapes.

This method will be used internally when *fit* method is called.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.

- **action_size** (*int*) – dimension of action-space.

Return type None

fit(*episodes*, *n_epochs=1000*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*, *eval_episodes=None*, *save_interval=1*, *scorers=None*, *shuffle=True*)

Trains with the given dataset.

```
algo.fit(episodes)
```

Parameters

- **episodes** (*List[*d3rlpy.dataset.Episode*]*) – list of episodes to train.
- **n_epochs** (*int*) – the number of epochs to train.
- **save_metrics** (*bool*) – flag to record metrics in files. If False, the log directory is not created and the model parameters are not saved during training.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be *{class name}_{timestamp}*.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)
- **eval_episodes** (*Optional[List[*d3rlpy.dataset.Episode*]]*) – list of episodes to test.
- **save_interval** (*int*) – interval to save parameters.
- **scorers** (*Optional[Dict[str, Callable[[Any, List[*d3rlpy.dataset.Episode*]], float]]]*) – list of scorer functions used with *eval_episodes*.
- **shuffle** (*bool*) – flag to shuffle transitions on each epoch.

Return type None

fit_online(*env*, *buffer*, *explorer=None*, *n_steps=1000000*, *n_steps_per_epoch=10000*, *update_interval=1*, *update_start_step=0*, *eval_env=None*, *eval_epsilon=0.0*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*)

Start training loop of online deep reinforcement learning.

Parameters

- **env** (*gym.core.Env*) – gym-like environment.
- **buffer** (*d3rlpy.online.buffers.Buffer*) – replay buffer.
- **explorer** (*Optional[d3rlpy.online.explorers.Explorer]*) – action explorer.
- **n_steps** (*int*) – the number of total steps to train.
- **n_steps_per_epoch** (*int*) – the number of steps per epoch.

- **update_interval** (*int*) – the number of steps per update.
- **update_start_step** (*int*) – the steps before starting updates.
- **eval_env** (*Optional[gym.core.Env]*) – gym-like environment. If None, evaluation is skipped.
- **eval_epsilon** (*float*) – ϵ-greedy factor during evaluation.
- **save_metrics** (*bool*) – flag to record metrics. If False, the log directory is not created and the model parameters are not saved.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be `{class name}_online_{timestamp}`.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

Return type None

classmethod from_json(*fname*, *use_gpu=False*)

Returns algorithm configured with json file.

The Json file should be the one saved during fitting.

```
from d3rlpy.algos import Algo

# create algorithm with saved configuration
algo = Algo.from_json('d3rlpy_logs/<path-to-json>/params.json')

# ready to load
algo.load_model('d3rlpy_logs/<path-to-model>/model_100.pt')

# ready to predict
algo.predict(...)
```

Parameters

- **fname** (*str*) – file path to *params.json*.
- **use_gpu** (*Optional[Union[bool, int, d3rlpy.gpu.Device]]*) – flag to use GPU, device ID or device.

Returns algorithm.

Return type d3rlpy.base.LearnableBase

get_params(*deep=True*)

Returns the all attributes.

This method returns the all attributes including ones in subclasses. Some of scikit-learn utilities will use this method.

```
params = algo.get_params(deep=True)

# the returned values can be used to instantiate the new object.
algo2 = AlgoBase(**params)
```

Parameters **deep** (*bool*) – flag to deeply copy objects such as *impl*.

Returns attribute values in dictionary.

Return type Dict[str, Any]

load_model (*fname*)

Load neural network parameters.

```
algo.load_model('model.pt')
```

Parameters **fname** (*str*) – source file path.

Return type None

predict (*x*)

Returns greedy actions.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

actions = algo.predict(x)
# actions.shape == (100, action size) for continuous control
# actions.shape == (100,) for discrete control
```

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations

Returns greedy actions

Return type numpy.ndarray

predict_value (*x, action, with_std=False*)

Returns predicted action-values.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

# for continuous control
# 100 actions with shape of (2,)
actions = np.random.random((100, 2))

# for discrete control
# 100 actions in integer values
actions = np.random.randint(2, size=100)

values = algo.predict_value(x, actions)
# values.shape == (100,)

values, stds = algo.predict_value(x, actions, with_std=True)
# stds.shape  == (100,)
```

Parameters

- **x** (*Union[numpy.ndarray, List[Any]]*) – observations
- **action** (*Union[numpy.ndarray, List[Any]]*) – actions
- **with_std** (*bool*) – flag to return standard deviation of ensemble estimation. This deviation reflects uncertainty for the given observations. This uncertainty will be more accurate if you enable `bootstrap` flag and increase `n_critics` value.

Returns predicted action-values

Return type Union[numpy.ndarray, Tuple[numpy.ndarray, numpy.ndarray]]

sample_action (*x*)

BCQ does not support sampling action.

Parameters x (*Union[numpy.ndarray, List[Any]]*) –

Return type numpy.ndarray

save_model (*fname*)

Saves neural network parameters.

```
algo.save_model('model.pt')
```

Parameters fname (*str*) – destination file path.

Return type None

save_policy (*fname, as_onnx=False*)

Save the greedy-policy computational graph as TorchScript or ONNX.

```
# save as TorchScript
algo.save_policy('policy.pt')

# save as ONNX
algo.save_policy('policy.onnx', as_onnx=True)
```

The artifacts saved with this method will work without d3rlpy. This method is especially useful to deploy the learned policy to production environments or embedding systems.

See also

- https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html (for Python).
- https://pytorch.org/tutorials/advanced/cpp_export.html (for C++).
- https://onnx.ai (for ONNX)

Parameters

- **fname** (*str*) – destination file path.
- **as_onnx** (*bool*) – flag to save as ONNX format.

Return type None

set_params (***params*)

Sets the given arguments to the attributes if they exist.

This method sets the given values to the attributes including ones in subclasses. If the values that don't exist as attributes are passed, they are ignored. Some of scikit-learn utilities will use this method.

```
algo.set_params(batch_size=100)
```

Parameters **params** (*Any*) – arbitrary inputs to set as attributes.

Returns itself.

Return type d3rlpy.base.LearnableBase

update(*epoch*, *total_step*, *batch*)

Update parameters with mini-batch of data.

Parameters

- **epoch** (*int*) – the current number of epochs.
- **total_step** (*int*) – the current number of total iterations.
- **batch** (d3rlpy.dataset.TransitionMiniBatch) – mini-batch data.

Returns loss values.

Return type list

Attributes

action_size

Action size.

Returns action size.

Return type Optional[int]

batch_size

Batch size to train.

Returns batch size.

Return type int

gamma

Discount factor.

Returns discount factor.

Return type float

impl

Implementation object.

Returns implementation object.

Return type Optional[ImplBase]

n_frames

Number of frames to stack.

This is only for image observation.

Returns number of frames to stack.

Return type int

n_steps

N-step TD backup.

Returns N-step TD backup.

Return type int

observation_shape
Observation shape.

Returns observation shape.

Return type Optional[Sequence[int]]

scaler
Preprocessing scaler.

Returns preprocessing scaler.

Return type Optional[Scaler]

d3rlpy.algos.BEAR

class d3rlpy.algos.**BEAR**(*, *actor_learning_rate=0.0003*, *critic_learning_rate=0.0003*, *imitator_learning_rate=0.001*, *temp_learning_rate=0.0003*, *alpha_learning_rate=0.001*, *actor_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>*, *critic_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>*, *imitator_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>*, *temp_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>*, *alpha_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>*, *actor_encoder_factory='default'*, *critic_encoder_factory='default'*, *imitator_encoder_factory='default'*, *q_func_factory='mean'*, *batch_size=100*, *n_frames=1*, *n_steps=1*, *gamma=0.99*, *tau=0.005*, *n_critics=2*, *bootstrap=False*, *share_encoder=False*, *update_actor_interval=1*, *initial_temperature=1.0*, *initial_alpha=1.0*, *alpha_threshold=0.05*, *lam=0.75*, *n_action_samples=4*, *mmd_sigma=20.0*, *rl_start_epoch=0*, *use_gpu=False*, *scaler=None*, *augmentation=None*, *generator=None*, *impl=None*, ***kwargs*)

Bootstrapping Error Accumulation Reduction algorithm.

BEAR is a SAC-based data-driven deep reinforcement learning algorithm.

BEAR constrains the support of the policy function within data distribution by minimizing Maximum Mean Discreptancy (MMD) between the policy function and the approximated beahvior policy function $\pi_\beta(a|s)$ which is optimized through L2 loss.

$$L(\beta) = \mathbb{E}_{s_t, a_t \sim D, a \sim \pi_\beta(\cdot|s_t)}[(a - a_t)^2]$$

The policy objective is a combination of SAC's objective and MMD penalty.

$$J(\phi) = J_{SAC}(\phi) - \mathbb{E}_{s_t \sim D} \alpha (\text{MMD}(\pi_\beta(\cdot|s_t), \pi_\phi(\cdot|s_t)) - \epsilon)$$

where MMD is computed as follows.

$$\text{MMD}(x, y) = \frac{1}{N^2} \sum_{i,i'} k(x_i, x_{i'}) - \frac{2}{NM} \sum_{i,j} k(x_i, y_j) + \frac{1}{M^2} \sum_{j,j'} k(y_j, y_{j'})$$

where $k(x, y)$ is a gaussian kernel $k(x, y) = \exp((x - y)^2 / (2\sigma^2))$.

α is also adjustable through dual gradient decsent where α becomes smaller if MMD is smaller than the threshold ϵ.

References

- Kumar et al., Stabilizing Off-Policy Q-Learning via Bootstrapping Error Reduction.

Parameters

- **actor_learning_rate** (*float*) – learning rate for policy function.
- **critic_learning_rate** (*float*) – learning rate for Q functions.
- **imitator_learning_rate** (*float*) – learning rate for behavior policy function.
- **temp_learning_rate** (*float*) – learning rate for temperature parameter.
- **alpha_learning_rate** (*float*) – learning rate for α.
- **actor_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the actor.
- **critic_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the critic.
- **imitator_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the behavior policy.
- **temp_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the temperature.
- **alpha_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for α.
- **actor_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the actor.
- **critic_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the critic.
- **imitator_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the behavior policy.
- **q_func_factory** (*d3rlpy.models.q_functions.QFunctionFactory or str*) – Q function factory.
- **batch_size** (*int*) – mini-batch size.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **n_steps** (*int*) – N-step TD calculation.
- **gamma** (*float*) – discount factor.
- **tau** (*float*) – target network synchronization coefficiency.
- **n_critics** (*int*) – the number of Q functions for ensemble.
- **bootstrap** (*bool*) – flag to bootstrap Q functions.
- **share_encoder** (*bool*) – flag to share encoder network.
- **update_actor_interval** (*int*) – interval to update policy function.
- **initial_temperature** (*float*) – initial temperature value.
- **initial_alpha** (*float*) – initial α value.
- **alpha_threshold** (*float*) – threshold value described as ϵ.

- **lam** (*float*) – weight for critic ensemble.
- **n_action_samples** (*int*) – the number of action samples to estimate action-values.
- **mmd_sigma** (*float*) – σ for gaussian kernel in MMD calculation.
- **rl_start_epoch** (*int*) – epoch to start to update policy function and Q functions. If this is large, RL training would be more stabilized.
- **use_gpu** (*bool, int or d3rlpy.gpu.Device*) – flag to use GPU, device iD or device.
- **scaler** (*d3rlpy.preprocessing.Scaler or str*) – preprocessor. The avaiable options are *['pixel', 'min_max', 'standard']*.
- **augmentation** (*d3rlpy.augmentation.AugmentationPipeline or list(str)*) – augmentation pipeline.
- **generator** (*d3rlpy.algos.base.DataGenerator*) – dynamic dataset generator (e.g. model-based RL).
- **impl** (*d3rlpy.algos.torch.bear_impl.BEARImpl*) – algorithm implementation.

Methods

build_with_dataset (*dataset*)

Instantiate implementation object with MDPDataset object.

Parameters **dataset** (d3rlpy.dataset.MDPDataset) – dataset.

Return type None

build_with_env (*env*)

Instantiate implementation object with OpenAI Gym object.

Parameters **env** (*gym.core.Env*) – gym-like environment.

Return type None

create_impl (*observation_shape, action_size*)

Instantiate implementation objects with the dataset shapes.

This method will be used internally when *fit* method is called.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – dimension of action-space.

Return type None

fit (*episodes, n_epochs=1000, save_metrics=True, experiment_name=None, with_timestamp=True, logdir='d3rlpy_logs', verbose=True, show_progress=True, tensorboard=True, eval_episodes=None, save_interval=1, scorers=None, shuffle=True*)

Trains with the given dataset.

```
algo.fit(episodes)
```

Parameters

- **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes to train.

- **n_epochs** (*int*) – the number of epochs to train.
- **save_metrics** (*bool*) – flag to record metrics in files. If False, the log directory is not created and the model parameters are not saved during training.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be *{class name}_{timestamp}*.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)
- **eval_episodes** (*Optional[List[d3rlpy.dataset.Episode]]*) – list of episodes to test.
- **save_interval** (*int*) – interval to save parameters.
- **scorers** (*Optional[Dict[str, Callable[[Any, List[d3rlpy.dataset.Episode]], float]]]*) – list of scorer functions used with *eval_episodes*.
- **shuffle** (*bool*) – flag to shuffle transitions on each epoch.

Return type None

fit_online(*env*, *buffer*, *explorer=None*, *n_steps=1000000*, *n_steps_per_epoch=10000*, *update_interval=1*, *update_start_step=0*, *eval_env=None*, *eval_epsilon=0.0*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*)

Start training loop of online deep reinforcement learning.

Parameters

- **env** (*gym.core.Env*) – gym-like environment.
- **buffer** (*d3rlpy.online.buffers.Buffer*) – replay buffer.
- **explorer** (*Optional[d3rlpy.online.explorers.Explorer]*) – action explorer.
- **n_steps** (*int*) – the number of total steps to train.
- **n_steps_per_epoch** (*int*) – the number of steps per epoch.
- **update_interval** (*int*) – the number of steps per update.
- **update_start_step** (*int*) – the steps before starting updates.
- **eval_env** (*Optional[gym.core.Env]*) – gym-like environment. If None, evaluation is skipped.
- **eval_epsilon** (*float*) – ϵ-greedy factor during evaluation.
- **save_metrics** (*bool*) – flag to record metrics. If False, the log directory is not created and the model parameters are not saved.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be `{class name}_online_{timestamp}`.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.

- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

Return type None

classmethod from_json (*fname*, *use_gpu=False*)

Returns algorithm configured with json file.

The Json file should be the one saved during fitting.

```
from d3rlpy.algos import Algo

# create algorithm with saved configuration
algo = Algo.from_json('d3rlpy_logs/<path-to-json>/params.json')

# ready to load
algo.load_model('d3rlpy_logs/<path-to-model>/model_100.pt')

# ready to predict
algo.predict(...)
```

Parameters

- **fname** (*str*) – file path to *params.json*.
- **use_gpu** (*Optional[Union[bool, int, d3rlpy.gpu.Device]]*) – flag to use GPU, device ID or device.

Returns algorithm.

Return type d3rlpy.base.LearnableBase

get_params (*deep=True*)

Returns the all attributes.

This method returns the all attributes including ones in subclasses. Some of scikit-learn utilities will use this method.

```
params = algo.get_params(deep=True)

# the returned values can be used to instantiate the new object.
algo2 = AlgoBase(**params)
```

Parameters deep (*bool*) – flag to deeply copy objects such as *impl*.

Returns attribute values in dictionary.

Return type Dict[str, Any]

load_model (*fname*)

Load neural network parameters.

```
algo.load_model('model.pt')
```

Parameters fname (*str*) – source file path.

Return type None

predict (*x*)

Returns greedy actions.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

actions = algo.predict(x)
# actions.shape == (100, action size) for continuous control
# actions.shape == (100,) for discrete control
```

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations

Returns greedy actions

Return type numpy.ndarray

predict_value (*x*, *action*, *with_std=False*)

Returns predicted action-values.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

# for continuous control
# 100 actions with shape of (2,)
actions = np.random.random((100, 2))

# for discrete control
# 100 actions in integer values
actions = np.random.randint(2, size=100)

values = algo.predict_value(x, actions)
# values.shape == (100,)

values, stds = algo.predict_value(x, actions, with_std=True)
# stds.shape  == (100,)
```

Parameters

- **x** (*Union[numpy.ndarray, List[Any]]*) – observations
- **action** (*Union[numpy.ndarray, List[Any]]*) – actions
- **with_std** (*bool*) – flag to return standard deviation of ensemble estimation. This deviation reflects uncertainty for the given observations. This uncertainty will be more accurate if you enable `bootstrap` flag and increase `n_critics` value.

Returns predicted action-values

Return type Union[numpy.ndarray, Tuple[numpy.ndarray, numpy.ndarray]]

sample_action (*x*)

Returns sampled actions.

The sampled actions are identical to the output of *predict* method if the policy is deterministic.

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations.

Returns sampled actions.

Return type numpy.ndarray

save_model (*fname*)

Saves neural network parameters.

```
algo.save_model('model.pt')
```

Parameters **fname** (*str*) – destination file path.

Return type None

save_policy (*fname*, *as_onnx=False*)

Save the greedy-policy computational graph as TorchScript or ONNX.

```
# save as TorchScript
algo.save_policy('policy.pt')

# save as ONNX
algo.save_policy('policy.onnx', as_onnx=True)
```

The artifacts saved with this method will work without d3rlpy. This method is especially useful to deploy the learned policy to production environments or embedding systems.

See also

- https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html (for Python).
- https://pytorch.org/tutorials/advanced/cpp_export.html (for C++).
- https://onnx.ai (for ONNX)

Parameters

- **fname** (*str*) – destination file path.
- **as_onnx** (*bool*) – flag to save as ONNX format.

Return type None

set_params (***params*)

Sets the given arguments to the attributes if they exist.

This method sets the given values to the attributes including ones in subclasses. If the values that don't exist as attributes are passed, they are ignored. Some of scikit-learn utilities will use this method.

```
algo.set_params(batch_size=100)
```

Parameters **params** (*Any*) – arbitrary inputs to set as attributes.

Returns itself.

Return type d3rlpy.base.LearnableBase

update (*epoch*, *total_step*, *batch*)

Update parameters with mini-batch of data.

Parameters

- **epoch** (*int*) – the current number of epochs.
- **total_step** (*int*) – the current number of total iterations.

- **batch** (d3rlpy.dataset.TransitionMiniBatch) – mini-batch data.

Returns loss values.

Return type list

Attributes

action_size
Action size.

Returns action size.

Return type Optional[int]

batch_size
Batch size to train.

Returns batch size.

Return type int

gamma
Discount factor.

Returns discount factor.

Return type float

impl
Implementation object.

Returns implementation object.

Return type Optional[ImplBase]

n_frames
Number of frames to stack.

This is only for image observation.

Returns number of frames to stack.

Return type int

n_steps
N-step TD backup.

Returns N-step TD backup.

Return type int

observation_shape
Observation shape.

Returns observation shape.

Return type Optional[Sequence[int]]

scaler
Preprocessing scaler.

Returns preprocessing scaler.

Return type Optional[Scaler]

d3rlpy.algos.CQL

class d3rlpy.algos.**CQL**(***, *actor_learning_rate=3e-05*, *critic_learning_rate=0.0003*, *temp_learning_rate=3e-05*, *alpha_learning_rate=0.0003*, *actor_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>*, *critic_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>*, *temp_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>*, *alpha_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>*, *actor_encoder_factory='default'*, *critic_encoder_factory='default'*, *q_func_factory='mean'*, *batch_size=100*, *n_frames=1*, *n_steps=1*, *gamma=0.99*, *tau=0.005*, *n_critics=2*, *bootstrap=False*, *share_encoder=False*, *update_actor_interval=1*, *initial_temperature=1.0*, *initial_alpha=5.0*, *alpha_threshold=10.0*, *n_action_samples=10*, *use_gpu=False*, *scaler=None*, *augmentation=None*, *generator=None*, *impl=None*, ***kwargs*)

Conservative Q-Learning algorithm.

CQL is a SAC-based data-driven deep reinforcement learning algorithm, which achieves state-of-the-art performance in offline RL problems.

CQL mitigates overestimation error by minimizing action-values under the current policy and maximizing values under data distribution for underestimation issue.

$$L(\theta_i) = \alpha \mathbb{E}_{s_t \sim D}[\log \sum_a \exp Q_{\theta_i}(s_t, a) - \mathbb{E}_{a \sim D}[Q_{\theta_i}(s, a)] - \tau] + L_{SAC}(\theta_i)$$

where α is an automatically adjustable value via Lagrangian dual gradient descent and τ is a threshold value. If the action-value difference is smaller than τ, the α will become smaller. Otherwise, the α will become larger to aggressively penalize action-values.

In continuous control, $\log \sum_a \exp Q(s, a)$ is computed as follows.

$$\log \sum_a \exp Q(s, a) \approx \log \left(\frac{1}{2N} \sum_{a_i \sim \text{Unif}(a)}^N \left[\frac{\exp Q(s, a_i)}{\text{Unif}(a)}\right] + \frac{1}{2N} \sum_{a_i \sim \pi_\phi(a|s)}^N \left[\frac{\exp Q(s, a_i)}{\pi_\phi(a_i|s)}\right]\right)$$

where N is the number of sampled actions.

The rest of optimization is exactly same as `d3rlpy.algos.SAC`.

References

- Kumar et al., Conservative Q-Learning for Offline Reinforcement Learning.

Parameters

- **actor_learning_rate** (`float`) – learning rate for policy function.
- **critic_learning_rate** (`float`) – learning rate for Q functions.
- **temp_learning_rate** (`float`) – learning rate for temperature parameter of SAC.
- **alpha_learning_rate** (`float`) – learning rate for α.
- **actor_optim_factory** (`d3rlpy.models.optimizers.OptimizerFactory`) – optimizer factory for the actor.
- **critic_optim_factory** (`d3rlpy.models.optimizers.OptimizerFactory`) – optimizer factory for the critic.

- **temp_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the temperature.
- **alpha_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for α.
- **actor_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the actor.
- **critic_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the critic.
- **q_func_factory** (*d3rlpy.models.q_functions.QFunctionFactory or str*) – Q function factory.
- **batch_size** (*int*) – mini-batch size.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **n_steps** (*int*) – N-step TD calculation.
- **gamma** (*float*) – discount factor.
- **tau** (*float*) – target network synchronization coefficiency.
- **n_critics** (*int*) – the number of Q functions for ensemble.
- **bootstrap** (*bool*) – flag to bootstrap Q functions.
- **share_encoder** (*bool*) – flag to share encoder network.
- **update_actor_interval** (*int*) – interval to update policy function.
- **initial_temperature** (*float*) – initial temperature value.
- **initial_alpha** (*float*) – initial α value.
- **alpha_threshold** (*float*) – threshold value described as τ.
- **n_action_samples** (*int*) – the number of sampled actions to compute $\log \sum_a \exp Q(s, a)$.
- **use_gpu** (*bool, int or d3rlpy.gpu.Device*) – flag to use GPU, device ID or device.
- **scaler** (*d3rlpy.preprocessing.Scaler or str*) – preprocessor. The available options are *['pixel', 'min_max', 'standard']*
- **augmentation** (*d3rlpy.augmentation.AugmentationPipeline or list(str)*) – augmentation pipeline.
- **generator** (*d3rlpy.algos.base.DataGenerator*) – dynamic dataset generator (e.g. model-based RL).
- **impl** (*d3rlpy.algos.torch.cql_impl.CQLImpl*) – algorithm implementation.

Methods

build_with_dataset (*dataset*)

Instantiate implementation object with MDPDataset object.

Parameters **dataset** (d3rlpy.dataset.MDPDataset) – dataset.

Return type None

build_with_env (*env*)

Instantiate implementation object with OpenAI Gym object.

Parameters **env** (*gym.core.Env*) – gym-like environment.

Return type None

create_impl (*observation_shape*, *action_size*)

Instantiate implementation objects with the dataset shapes.

This method will be used internally when *fit* method is called.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – dimension of action-space.

Return type None

fit (*episodes*, *n_epochs=1000*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*, *eval_episodes=None*, *save_interval=1*, *scorers=None*, *shuffle=True*)

Trains with the given dataset.

```
algo.fit(episodes)
```

Parameters

- **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes to train.
- **n_epochs** (*int*) – the number of epochs to train.
- **save_metrics** (*bool*) – flag to record metrics in files. If False, the log directory is not created and the model parameters are not saved during training.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be *{class name}_{timestamp}*.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)
- **eval_episodes** (*Optional[List[d3rlpy.dataset.Episode]]*) – list of episodes to test.
- **save_interval** (*int*) – interval to save parameters.

- **scorers** (*Optional[Dict[str, Callable[[Any, List[d3rlpy.dataset.Episode]], float]]]*) – list of scorer functions used with *eval_episodes*.
- **shuffle** (*bool*) – flag to shuffle transitions on each epoch.

Return type None

fit_online(*env*, *buffer*, *explorer=None*, *n_steps=1000000*, *n_steps_per_epoch=10000*, *update_interval=1*, *update_start_step=0*, *eval_env=None*, *eval_epsilon=0.0*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*)
Start training loop of online deep reinforcement learning.

Parameters

- **env** (*gym.core.Env*) – gym-like environment.
- **buffer** (*d3rlpy.online.buffers.Buffer*) – replay buffer.
- **explorer** (*Optional[d3rlpy.online.explorers.Explorer]*) – action explorer.
- **n_steps** (*int*) – the number of total steps to train.
- **n_steps_per_epoch** (*int*) – the number of steps per epoch.
- **update_interval** (*int*) – the number of steps per update.
- **update_start_step** (*int*) – the steps before starting updates.
- **eval_env** (*Optional[gym.core.Env]*) – gym-like environment. If None, evaluation is skipped.
- **eval_epsilon** (*float*) – ϵ-greedy factor during evaluation.
- **save_metrics** (*bool*) – flag to record metrics. If False, the log directory is not created and the model parameters are not saved.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be `{class name}_online_{timestamp}`.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

Return type None

classmethod from_json(*fname*, *use_gpu=False*)
Returns algorithm configured with json file.

The Json file should be the one saved during fitting.

```
from d3rlpy.algos import Algo

# create algorithm with saved configuration
algo = Algo.from_json('d3rlpy_logs/<path-to-json>/params.json')
```

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```
# ready to load
algo.load_model('d3rlpy_logs/<path-to-model>/model_100.pt')

# ready to predict
algo.predict(...)
```

Parameters

- **fname** (*str*) – file path to *params.json*.
- **use_gpu** (*Optional[Union[bool, int, d3rlpy.gpu.Device]]*) – flag to use GPU, device ID or device.

Returns algorithm.

Return type d3rlpy.base.LearnableBase

get_params (*deep=True*)

Returns the all attributes.

This method returns the all attributes including ones in subclasses. Some of scikit-learn utilities will use this method.

```
params = algo.get_params(deep=True)

# the returned values can be used to instantiate the new object.
algo2 = AlgoBase(**params)
```

Parameters **deep** (*bool*) – flag to deeply copy objects such as *impl*.

Returns attribute values in dictionary.

Return type Dict[str, Any]

load_model (*fname*)

Load neural network parameters.

```
algo.load_model('model.pt')
```

Parameters **fname** (*str*) – source file path.

Return type None

predict (*x*)

Returns greedy actions.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

actions = algo.predict(x)
# actions.shape == (100, action size) for continuous control
# actions.shape == (100,) for discrete control
```

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations

Returns greedy actions

Return type numpy.ndarray

predict_value (*x*, *action*, *with_std=False*)

Returns predicted action-values.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

# for continuous control
# 100 actions with shape of (2,)
actions = np.random.random((100, 2))

# for discrete control
# 100 actions in integer values
actions = np.random.randint(2, size=100)

values = algo.predict_value(x, actions)
# values.shape == (100,)

values, stds = algo.predict_value(x, actions, with_std=True)
# stds.shape  == (100,)
```

Parameters

- **x** (*Union[numpy.ndarray, List[Any]]*) – observations
- **action** (*Union[numpy.ndarray, List[Any]]*) – actions
- **with_std** (*bool*) – flag to return standard deviation of ensemble estimation. This deviation reflects uncertainty for the given observations. This uncertainty will be more accurate if you enable `bootstrap` flag and increase `n_critics` value.

Returns predicted action-values

Return type Union[numpy.ndarray, Tuple[numpy.ndarray, numpy.ndarray]]

sample_action (*x*)

Returns sampled actions.

The sampled actions are identical to the output of *predict* method if the policy is deterministic.

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations.

Returns sampled actions.

Return type numpy.ndarray

save_model (*fname*)

Saves neural network parameters.

```
algo.save_model('model.pt')
```

Parameters **fname** (*str*) – destination file path.

Return type None

save_policy (*fname*, *as_onnx=False*)

Save the greedy-policy computational graph as TorchScript or ONNX.

```
# save as TorchScript
algo.save_policy('policy.pt')
```

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```
# save as ONNX
algo.save_policy('policy.onnx', as_onnx=True)
```

The artifacts saved with this method will work without d3rlpy. This method is especially useful to deploy the learned policy to production environments or embedding systems.

See also

- https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html (for Python).
- https://pytorch.org/tutorials/advanced/cpp_export.html (for C++).
- https://onnx.ai (for ONNX)

Parameters

- **fname** (*str*) – destination file path.
- **as_onnx** (*bool*) – flag to save as ONNX format.

Return type None

set_params (***params*)

Sets the given arguments to the attributes if they exist.

This method sets the given values to the attributes including ones in subclasses. If the values that don't exist as attributes are passed, they are ignored. Some of scikit-learn utilities will use this method.

```
algo.set_params(batch_size=100)
```

Parameters **params** (*Any*) – arbitrary inputs to set as attributes.

Returns itself.

Return type d3rlpy.base.LearnableBase

update (*epoch*, *total_step*, *batch*)

Update parameters with mini-batch of data.

Parameters

- **epoch** (*int*) – the current number of epochs.
- **total_step** (*int*) – the current number of total iterations.
- **batch** (d3rlpy.dataset.TransitionMiniBatch) – mini-batch data.

Returns loss values.

Return type list

Attributes

action_size
Action size.

Returns action size.

Return type Optional[int]

batch_size
Batch size to train.

Returns batch size.

Return type int

gamma
Discount factor.

Returns discount factor.

Return type float

impl
Implementation object.

Returns implementation object.

Return type Optional[ImplBase]

n_frames
Number of frames to stack.

This is only for image observation.

Returns number of frames to stack.

Return type int

n_steps
N-step TD backup.

Returns N-step TD backup.

Return type int

observation_shape
Observation shape.

Returns observation shape.

Return type Optional[Sequence[int]]

scaler
Preprocessing scaler.

Returns preprocessing scaler.

Return type Optional[Scaler]

d3rlpy.algos.AWR

class d3rlpy.algos.**AWR**(**, actor_learning_rate=5e-05, critic_learning_rate=0.0001, actor_optim_factory=<d3rlpy.models.optimizers.SGDFactory object>, critic_optim_factory=<d3rlpy.models.optimizers.SGDFactory object>, actor_encoder_factory='default', critic_encoder_factory='default', batch_size=2048, n_frames=1, gamma=0.99, batch_size_per_update=256, n_actor_updates=1000, n_critic_updates=200, lam=0.95, beta=1.0, max_weight=20.0, use_gpu=False, scaler=None, augmentation=None, generator=None, impl=None, **kwargs*)

Advantage-Weighted Regression algorithm.

AWR is an actor-critic algorithm that trains via supervised regression way, and has shown strong performance in online and offline settings.

The value function is trained as a supervised regression problem.

$$L(\theta) = \mathbb{E}_{s_t, R_t \sim D}[(R_t - V(s_t|\theta))^2]$$

where R_t is approximated using TD(λ) to mitigate high variance issue.

The policy function is also trained as a supervised regression problem.

$$J(\phi) = \mathbb{E}_{s_t, a_t, R_t \sim D}[\log \pi(a_t|s_t, \phi) \exp(\frac{1}{B}(R_t - V(s_t|\theta)))]$$

where B is a constant factor.

References

- Peng et al., Advantage-Weighted Regression: Simple and Scalable Off-Policy Reinforcement Learning

Parameters

- **actor_learning_rate** (*float*) – learning rate for policy function.
- **critic_learning_rate** (*float*) – learning rate for value function.
- **actor_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the actor.
- **critic_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the critic.
- **actor_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the actor.
- **critic_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the critic.
- **batch_size** (*int*) – batch size per iteration.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **gamma** (*float*) – discount factor.
- **batch_size_per_update** (*int*) – mini-batch size.
- **n_actor_updates** (*int*) – actor gradient steps per iteration.
- **n_critic_updates** (*int*) – critic gradient steps per iteration.
- **lam** (*float*) – λ for TD(λ).

- **beta** (*float*) – B for weight scale.
- **max_weight** (*float*) – $w_{\max}$ for weight clipping.
- **use_gpu** (*bool, int or d3rlpy.gpu.Device*) – flag to use GPU, device ID or device.
- **scaler** (*d3rlpy.preprocessing.Scaler or str*) – preprocessor. The available options are *['pixel', 'min_max', 'standard']*
- **augmentation** (*d3rlpy.augmentation.AugmentationPipeline or list(str)*) – augmentation pipeline.
- **generator** (*d3rlpy.algos.base.DataGenerator*) – dynamic dataset generator (e.g. model-based RL).
- **impl** (*d3rlpy.algos.torch.awr_impl.AWRImpl*) – algorithm implementation.

Methods

build_with_dataset(*dataset*)

Instantiate implementation object with MDPDataset object.

Parameters **dataset** (d3rlpy.dataset.MDPDataset) – dataset.

Return type None

build_with_env(*env*)

Instantiate implementation object with OpenAI Gym object.

Parameters **env** (*gym.core.Env*) – gym-like environment.

Return type None

create_impl(*observation_shape*, *action_size*)

Instantiate implementation objects with the dataset shapes.

This method will be used internally when *fit* method is called.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – dimension of action-space.

Return type None

fit(*episodes*, *n_epochs=1000*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*, *eval_episodes=None*, *save_interval=1*, *scorers=None*, *shuffle=True*)

Trains with the given dataset.

```
algo.fit(episodes)
```

Parameters

- **episodes** (*List[*d3rlpy.dataset.Episode*]*) – list of episodes to train.
- **n_epochs** (*int*) – the number of epochs to train.
- **save_metrics** (*bool*) – flag to record metrics in files. If False, the log directory is not created and the model parameters are not saved during training.

- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be *{class name}_{timestamp}*.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)
- **eval_episodes** (*Optional[List[d3rlpy.dataset.Episode]]*) – list of episodes to test.
- **save_interval** (*int*) – interval to save parameters.
- **scorers** (*Optional[Dict[str, Callable[[Any, List[d3rlpy.dataset.Episode]], float]]]*) – list of scorer functions used with *eval_episodes*.
- **shuffle** (*bool*) – flag to shuffle transitions on each epoch.

Return type None

fit_online(*env*, *buffer*, *explorer=None*, *n_steps=1000000*, *n_steps_per_epoch=10000*, *update_interval=1*, *update_start_step=0*, *eval_env=None*, *eval_epsilon=0.0*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*)

Start training loop of online deep reinforcement learning.

Parameters

- **env** (*gym.core.Env*) – gym-like environment.
- **buffer** (*d3rlpy.online.buffers.Buffer*) – replay buffer.
- **explorer** (*Optional[d3rlpy.online.explorers.Explorer]*) – action explorer.
- **n_steps** (*int*) – the number of total steps to train.
- **n_steps_per_epoch** (*int*) – the number of steps per epoch.
- **update_interval** (*int*) – the number of steps per update.
- **update_start_step** (*int*) – the steps before starting updates.
- **eval_env** (*Optional[gym.core.Env]*) – gym-like environment. If None, evaluation is skipped.
- **eval_epsilon** (*float*) – ϵ-greedy factor during evaluation.
- **save_metrics** (*bool*) – flag to record metrics. If False, the log directory is not created and the model parameters are not saved.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be `{class name}_online_{timestamp}`.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.

- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

Return type None

classmethod from_json (*fname*, *use_gpu=False*)

Returns algorithm configured with json file.

The Json file should be the one saved during fitting.

```
from d3rlpy.algos import Algo

# create algorithm with saved configuration
algo = Algo.from_json('d3rlpy_logs/<path-to-json>/params.json')

# ready to load
algo.load_model('d3rlpy_logs/<path-to-model>/model_100.pt')

# ready to predict
algo.predict(...)
```

Parameters

- **fname** (*str*) – file path to *params.json*.
- **use_gpu** (*Optional[Union[bool, int, d3rlpy.gpu.Device]]*) – flag to use GPU, device ID or device.

Returns algorithm.

Return type d3rlpy.base.LearnableBase

get_params (*deep=True*)

Returns the all attributes.

This method returns the all attributes including ones in subclasses. Some of scikit-learn utilities will use this method.

```
params = algo.get_params(deep=True)

# the returned values can be used to instantiate the new object.
algo2 = AlgoBase(**params)
```

Parameters **deep** (*bool*) – flag to deeply copy objects such as *impl*.

Returns attribute values in dictionary.

Return type Dict[str, Any]

load_model (*fname*)

Load neural network parameters.

```
algo.load_model('model.pt')
```

Parameters **fname** (*str*) – source file path.

Return type None

predict (*x*)

Returns greedy actions.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

actions = algo.predict(x)
# actions.shape == (100, action size) for continuous control
# actions.shape == (100,) for discrete control
```

Parameters **x** (`Union[numpy.ndarray, List[Any]]`) – observations

Returns greedy actions

Return type numpy.ndarray

predict_value (*x*, **args*, ***kwargs*)

Returns predicted state values.

Parameters

- **x** (`Union[numpy.ndarray, List[Any]]`) – observations.
- **args** (`Any`) –
- **kwargs** (`Any`) –

Returns predicted state values.

Return type numpy.ndarray

sample_action (*x*)

Returns sampled actions.

The sampled actions are identical to the output of *predict* method if the policy is deterministic.

Parameters **x** (`Union[numpy.ndarray, List[Any]]`) – observations.

Returns sampled actions.

Return type numpy.ndarray

save_model (*fname*)

Saves neural network parameters.

```
algo.save_model('model.pt')
```

Parameters **fname** (`str`) – destination file path.

Return type None

save_policy (*fname*, *as_onnx=False*)

Save the greedy-policy computational graph as TorchScript or ONNX.

```
# save as TorchScript
algo.save_policy('policy.pt')

# save as ONNX
algo.save_policy('policy.onnx', as_onnx=True)
```

The artifacts saved with this method will work without d3rlpy. This method is especially useful to deploy the learned policy to production environments or embedding systems.

See also

- https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html (for Python).
- https://pytorch.org/tutorials/advanced/cpp_export.html (for C++).
- https://onnx.ai (for ONNX)

Parameters

- **fname** (*str*) – destination file path.
- **as_onnx** (*bool*) – flag to save as ONNX format.

Return type None

set_params (***params*)

Sets the given arguments to the attributes if they exist.

This method sets the given values to the attributes including ones in subclasses. If the values that don't exist as attributes are passed, they are ignored. Some of scikit-learn utilities will use this method.

```
algo.set_params(batch_size=100)
```

Parameters **params** (*Any*) – arbitrary inputs to set as attributes.

Returns itself.

Return type d3rlpy.base.LearnableBase

update (*epoch*, *total_step*, *batch*)

Update parameters with mini-batch of data.

Parameters

- **epoch** (*int*) – the current number of epochs.
- **total_step** (*int*) – the current number of total iterations.
- **batch** (d3rlpy.dataset.TransitionMiniBatch) – mini-batch data.

Returns loss values.

Return type list

Attributes

action_size

Action size.

Returns action size.

Return type Optional[int]

batch_size

Batch size to train.

Returns batch size.

Return type int

gamma
Discount factor.

Returns discount factor.

Return type float

impl
Implementation object.

Returns implementation object.

Return type Optional[ImplBase]

n_frames
Number of frames to stack.

This is only for image observation.

Returns number of frames to stack.

Return type int

n_steps
N-step TD backup.

Returns N-step TD backup.

Return type int

observation_shape
Observation shape.

Returns observation shape.

Return type Optional[Sequence[int]]

scaler
Preprocessing scaler.

Returns preprocessing scaler.

Return type Optional[Scaler]

d3rlpy.algos.AWAC

class d3rlpy.algos.**AWAC**(**, actor_learning_rate=0.0003, critic_learning_rate=0.0003, actor_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, critic_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, actor_encoder_factory='default', critic_encoder_factory='default', q_func_factory='mean', batch_size=1024, n_frames=1, n_steps=1, gamma=0.99, tau=0.005, lam=1.0, n_action_samples=1, max_weight=20.0, n_critics=2, bootstrap=False, share_encoder=False, update_actor_interval=1, use_gpu=False, scaler=None, augmentation=None, generator=None, impl=None, **kwargs*)

Advantage Weighted Actor-Critic algorithm.

AWAC is a TD3-based actor-critic algorithm that enables efficient fine-tuning where the policy is trained with offline datasets and is deployed to online training.

The policy is trained as a supervised regression.

$$J(\phi) = \mathbb{E}_{s_t, a_t \sim D} [\log \pi_\phi(a_t|s_t) \exp(\frac{1}{\lambda} A^\pi (s_t, a_t))]$$

where $A^\pi(s_t, a_t) = Q_\theta(s_t, a_t) - Q_\theta(s_t, a'_t)$ and $a'_t \sim \pi_\phi(\cdot|s_t)$

The key difference from AWR is that AWAC uses Q-function trained via TD learning for the better sample-efficiency.

References

- Nair et al., Accelerating Online Reinforcement Learning with Offline Datasets.

Parameters

- **actor_learning_rate** (*float*) – learning rate for policy function.
- **critic_learning_rate** (*float*) – learning rate for Q functions.
- **actor_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the actor.
- **critic_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the critic.
- **actor_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the actor.
- **critic_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the critic.
- **q_func_factory** (*d3rlpy.models.q_functions.QFunctionFactory or str*) – Q function factory.
- **batch_size** (*int*) – mini-batch size.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **n_steps** (*int*) – N-step TD calculation.
- **gamma** (*float*) – discount factor.
- **tau** (*float*) – target network synchronization coefficiency.
- **lam** (*float*) – λ for weight calculation.
- **n_action_samples** (*int*) – the number of sampled actions to calculate $A^\pi(s_t, a_t)$.
- **max_weight** (*float*) – maximum weight for cross-entropy loss.
- **n_critics** (*int*) – the number of Q functions for ensemble.
- **bootstrap** (*bool*) – flag to bootstrap Q functions.
- **share_encoder** (*bool*) – flag to share encoder network.
- **update_actor_interval** (*int*) – interval to update policy function.
- **use_gpu** (*bool, int or d3rlpy.gpu.Device*) – flag to use GPU, device ID or device.
- **scaler** (*d3rlpy.preprocessing.Scaler or str*) – preprocessor. The available options are *['pixel', 'min_max', 'standard']*
- **augmentation** (*d3rlpy.augmentation.AugmentationPipeline or list(str)*) – augmentation pipeline.
- **generator** (*d3rlpy.algos.base.DataGenerator*) – dynamic dataset generator (e.g. model-based RL).

- **impl** (*d3rlpy.algos.torch.sac_impl.SACImpl*) – algorithm implementation.

Methods

build_with_dataset (*dataset*)
Instantiate implementation object with MDPDataset object.

Parameters dataset (d3rlpy.dataset.MDPDataset) – dataset.

Return type None

build_with_env (*env*)
Instantiate implementation object with OpenAI Gym object.

Parameters env (*gym.core.Env*) – gym-like environment.

Return type None

create_impl (*observation_shape*, *action_size*)
Instantiate implementation objects with the dataset shapes.

This method will be used internally when *fit* method is called.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – dimension of action-space.

Return type None

fit (*episodes*, *n_epochs=1000*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*, *eval_episodes=None*, *save_interval=1*, *scorers=None*, *shuffle=True*)
Trains with the given dataset.

```
algo.fit(episodes)
```

Parameters

- **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes to train.
- **n_epochs** (*int*) – the number of epochs to train.
- **save_metrics** (*bool*) – flag to record metrics in files. If False, the log directory is not created and the model parameters are not saved during training.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be *{class name}_{timestamp}*.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)
- **eval_episodes** (*Optional[List[d3rlpy.dataset.Episode]]*) – list of episodes to test.
- **save_interval** (*int*) – interval to save parameters.

- **scorers** (*Optional[Dict[str, Callable[[Any, List[d3rlpy.dataset.Episode]], float]]]*) – list of scorer functions used with *eval_episodes*.
- **shuffle** (*bool*) – flag to shuffle transitions on each epoch.

Return type None

fit_online(*env*, *buffer*, *explorer=None*, *n_steps=1000000*, *n_steps_per_epoch=10000*, *update_interval=1*, *update_start_step=0*, *eval_env=None*, *eval_epsilon=0.0*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*)

Start training loop of online deep reinforcement learning.

Parameters

- **env** (*gym.core.Env*) – gym-like environment.
- **buffer** (*d3rlpy.online.buffers.Buffer*) – replay buffer.
- **explorer** (*Optional[d3rlpy.online.explorers.Explorer]*) – action explorer.
- **n_steps** (*int*) – the number of total steps to train.
- **n_steps_per_epoch** (*int*) – the number of steps per epoch.
- **update_interval** (*int*) – the number of steps per update.
- **update_start_step** (*int*) – the steps before starting updates.
- **eval_env** (*Optional[gym.core.Env]*) – gym-like environment. If None, evaluation is skipped.
- **eval_epsilon** (*float*) – ϵ-greedy factor during evaluation.
- **save_metrics** (*bool*) – flag to record metrics. If False, the log directory is not created and the model parameters are not saved.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be `{class name}_online_{timestamp}`.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

Return type None

classmethod from_json(*fname*, *use_gpu=False*)

Returns algorithm configured with json file.

The Json file should be the one saved during fitting.

```
from d3rlpy.algos import Algo

# create algorithm with saved configuration
algo = Algo.from_json('d3rlpy_logs/<path-to-json>/params.json')
```

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```
# ready to load
algo.load_model('d3rlpy_logs/<path-to-model>/model_100.pt')

# ready to predict
algo.predict(...)
```

Parameters

- **fname** (*str*) – file path to *params.json*.
- **use_gpu** (*Optional[Union[bool, int, d3rlpy.gpu.Device]]*) – flag to use GPU, device ID or device.

Returns algorithm.

Return type d3rlpy.base.LearnableBase

get_params (*deep=True*)

Returns the all attributes.

This method returns the all attributes including ones in subclasses. Some of scikit-learn utilities will use this method.

```
params = algo.get_params(deep=True)

# the returned values can be used to instantiate the new object.
algo2 = AlgoBase(**params)
```

Parameters **deep** (*bool*) – flag to deeply copy objects such as *impl*.

Returns attribute values in dictionary.

Return type Dict[str, Any]

load_model (*fname*)

Load neural network parameters.

```
algo.load_model('model.pt')
```

Parameters **fname** (*str*) – source file path.

Return type None

predict (*x*)

Returns greedy actions.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

actions = algo.predict(x)
# actions.shape == (100, action size) for continuous control
# actions.shape == (100,) for discrete control
```

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations

Returns greedy actions

Return type numpy.ndarray

predict_value (*x*, *action*, *with_std=False*)

Returns predicted action-values.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

# for continuous control
# 100 actions with shape of (2,)
actions = np.random.random((100, 2))

# for discrete control
# 100 actions in integer values
actions = np.random.randint(2, size=100)

values = algo.predict_value(x, actions)
# values.shape == (100,)

values, stds = algo.predict_value(x, actions, with_std=True)
# stds.shape  == (100,)
```

Parameters

- **x** (`Union[numpy.ndarray, List[Any]]`) – observations
- **action** (`Union[numpy.ndarray, List[Any]]`) – actions
- **with_std** (`bool`) – flag to return standard deviation of ensemble estimation. This deviation reflects uncertainty for the given observations. This uncertainty will be more accurate if you enable `bootstrap` flag and increase `n_critics` value.

Returns predicted action-values

Return type Union[numpy.ndarray, Tuple[numpy.ndarray, numpy.ndarray]]

sample_action (*x*)

Returns sampled actions.

The sampled actions are identical to the output of *predict* method if the policy is deterministic.

Parameters **x** (`Union[numpy.ndarray, List[Any]]`) – observations.

Returns sampled actions.

Return type numpy.ndarray

save_model (*fname*)

Saves neural network parameters.

```
algo.save_model('model.pt')
```

Parameters **fname** (`str`) – destination file path.

Return type None

save_policy (*fname*, *as_onnx=False*)

Save the greedy-policy computational graph as TorchScript or ONNX.

```
# save as TorchScript
algo.save_policy('policy.pt')
```

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```
# save as ONNX
algo.save_policy('policy.onnx', as_onnx=True)
```

The artifacts saved with this method will work without d3rlpy. This method is especially useful to deploy the learned policy to production environments or embedding systems.

See also

- https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html (for Python).
- https://pytorch.org/tutorials/advanced/cpp_export.html (for C++).
- https://onnx.ai (for ONNX)

Parameters

- **fname** (*str*) – destination file path.
- **as_onnx** (*bool*) – flag to save as ONNX format.

Return type None

set_params (***params*)

Sets the given arguments to the attributes if they exist.

This method sets the given values to the attributes including ones in subclasses. If the values that don't exist as attributes are passed, they are ignored. Some of scikit-learn utilities will use this method.

```
algo.set_params(batch_size=100)
```

Parameters **params** (*Any*) – arbitrary inputs to set as attributes.

Returns itself.

Return type d3rlpy.base.LearnableBase

update (*epoch*, *total_step*, *batch*)

Update parameters with mini-batch of data.

Parameters

- **epoch** (*int*) – the current number of epochs.
- **total_step** (*int*) – the current number of total iterations.
- **batch** (d3rlpy.dataset.TransitionMiniBatch) – mini-batch data.

Returns loss values.

Return type list

Attributes

action_size
Action size.

Returns action size.

Return type Optional[int]

batch_size
Batch size to train.

Returns batch size.

Return type int

gamma
Discount factor.

Returns discount factor.

Return type float

impl
Implementation object.

Returns implementation object.

Return type Optional[ImplBase]

n_frames
Number of frames to stack.

This is only for image observation.

Returns number of frames to stack.

Return type int

n_steps
N-step TD backup.

Returns N-step TD backup.

Return type int

observation_shape
Observation shape.

Returns observation shape.

Return type Optional[Sequence[int]]

scaler
Preprocessing scaler.

Returns preprocessing scaler.

Return type Optional[Scaler]

d3rlpy.algos.PLAS

class d3rlpy.algos.**PLAS**(**, actor_learning_rate=0.0003, critic_learning_rate=0.0003, imitator_learning_rate=0.0003, actor_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, critic_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, imitator_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, actor_encoder_factory='default', critic_encoder_factory='default', imitator_encoder_factory='default', q_func_factory='mean', batch_size=256, n_frames=1, n_steps=1, gamma=0.99, tau=0.005, n_critics=2, bootstrap=False, share_encoder=False, update_actor_interval=1, lam=0.75, rl_start_epoch=10, beta=0.5, use_gpu=False, scaler=None, augmentation=None, generator=None, impl=None, **kwargs*)

Policy in Latent Action Space algorithm.

PLAS is an offline deep reinforcement learning algorithm whose policy function is trained in latent space of Conditional VAE. Unlike other algorithms, PLAS can achieve good performance by using its less constrained policy function.

$$a \sim p_\beta(a|s, z = \pi_\phi(s))$$

where β is a parameter of the decoder in Conditional VAE.

References

- Zhou et al., PLAS: latent action space for offline reinforcement learning.

Parameters

- **actor_learning_rate** (*float*) – learning rate for policy function.
- **critic_learning_rate** (*float*) – learning rate for Q functions.
- **imitator_learning_rate** (*float*) – learning rate for Conditional VAE.
- **actor_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the actor.
- **critic_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the critic.
- **imitator_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the conditional VAE.
- **actor_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the actor.
- **critic_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the critic.
- **imitator_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the conditional VAE.
- **q_func_factory** (*d3rlpy.models.q_functions.QFunctionFactory or str*) – Q function factory.
- **batch_size** (*int*) – mini-batch size.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **n_steps** (*int*) – N-step TD calculation.

- **gamma** (*float*) – discount factor.
- **tau** (*float*) – target network synchronization coefficiency.
- **n_critics** (*int*) – the number of Q functions for ensemble.
- **bootstrap** (*bool*) – flag to bootstrap Q functions.
- **share_encoder** (*bool*) – flag to share encoder network.
- **update_actor_interval** (*int*) – interval to update policy function.
- **lam** (*float*) – weight factor for critic ensemble.
- **rl_start_epoch** (*int*) – epoch to start to update policy function and Q functions. If this is large, RL training would be more stabilized.
- **beta** (*float*) – KL reguralization term for Conditional VAE.
- **use_gpu** (*bool, int or d3rlpy.gpu.Device*) – flag to use GPU, device ID or device.
- **scaler** (*d3rlpy.preprocessing.Scaler or str*) – preprocessor. The available options are *['pixel', 'min_max', 'standard']*
- **augmentation** (*d3rlpy.augmentation.AugmentationPipeline or list(str)*) – augmentation pipeline.
- **generator** (*d3rlpy.algos.base.DataGenerator*) – dynamic dataset generator (e.g. model-based RL).
- **impl** (*d3rlpy.algos.torch.bcq_impl.BCQImpl*) – algorithm implementation.

Methods

build_with_dataset (*dataset*)

Instantiate implementation object with MDPDataset object.

Parameters **dataset** (d3rlpy.dataset.MDPDataset) – dataset.

Return type None

build_with_env (*env*)

Instantiate implementation object with OpenAI Gym object.

Parameters **env** (*gym.core.Env*) – gym-like environment.

Return type None

create_impl (*observation_shape*, *action_size*)

Instantiate implementation objects with the dataset shapes.

This method will be used internally when *fit* method is called.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – dimension of action-space.

Return type None

fit (*episodes*, *n_epochs=1000*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*, *eval_episodes=None*, *save_interval=1*, *scorers=None*, *shuffle=True*)

Trains with the given dataset.

```
algo.fit(episodes)
```

Parameters

- **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes to train.
- **n_epochs** (*int*) – the number of epochs to train.
- **save_metrics** (*bool*) – flag to record metrics in files. If False, the log directory is not created and the model parameters are not saved during training.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be *{class name}_{timestamp}*.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)
- **eval_episodes** (*Optional[List[d3rlpy.dataset.Episode]]*) – list of episodes to test.
- **save_interval** (*int*) – interval to save parameters.
- **scorers** (*Optional[Dict[str, Callable[[Any, List[d3rlpy.dataset.Episode]], float]]]*) – list of scorer functions used with *eval_episodes*.
- **shuffle** (*bool*) – flag to shuffle transitions on each epoch.

Return type None

fit_online(*env*, *buffer*, *explorer=None*, *n_steps=1000000*, *n_steps_per_epoch=10000*, *update_interval=1*, *update_start_step=0*, *eval_env=None*, *eval_epsilon=0.0*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*)

Start training loop of online deep reinforcement learning.

Parameters

- **env** (*gym.core.Env*) – gym-like environment.
- **buffer** (*d3rlpy.online.buffers.Buffer*) – replay buffer.
- **explorer** (*Optional[d3rlpy.online.explorers.Explorer]*) – action explorer.
- **n_steps** (*int*) – the number of total steps to train.
- **n_steps_per_epoch** (*int*) – the number of steps per epoch.
- **update_interval** (*int*) – the number of steps per update.
- **update_start_step** (*int*) – the steps before starting updates.
- **eval_env** (*Optional[gym.core.Env]*) – gym-like environment. If None, evaluation is skipped.
- **eval_epsilon** (*float*) – ϵ-greedy factor during evaluation.

- **save_metrics** (*bool*) – flag to record metrics. If False, the log directory is not created and the model parameters are not saved.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be `{class name}_online_{timestamp}`.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

Return type None

classmethod from_json (*fname*, *use_gpu=False*)

Returns algorithm configured with json file.

The Json file should be the one saved during fitting.

```
from d3rlpy.algos import Algo

# create algorithm with saved configuration
algo = Algo.from_json('d3rlpy_logs/<path-to-json>/params.json')

# ready to load
algo.load_model('d3rlpy_logs/<path-to-model>/model_100.pt')

# ready to predict
algo.predict(...)
```

Parameters

- **fname** (*str*) – file path to *params.json*.
- **use_gpu** (*Optional[Union[bool, int, d3rlpy.gpu.Device]]*) – flag to use GPU, device ID or device.

Returns algorithm.

Return type d3rlpy.base.LearnableBase

get_params (*deep=True*)

Returns the all attributes.

This method returns the all attributes including ones in subclasses. Some of scikit-learn utilities will use this method.

```
params = algo.get_params(deep=True)

# the returned values can be used to instantiate the new object.
algo2 = AlgoBase(**params)
```

Parameters **deep** (*bool*) – flag to deeply copy objects such as *impl*.

Returns attribute values in dictionary.

Return type Dict[str, Any]

load_model (*fname*)

Load neural network parameters.

```
algo.load_model('model.pt')
```

Parameters **fname** (*str*) – source file path.

Return type None

predict (*x*)

Returns greedy actions.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

actions = algo.predict(x)
# actions.shape == (100, action size) for continuous control
# actions.shape == (100,) for discrete control
```

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations

Returns greedy actions

Return type numpy.ndarray

predict_value (*x*, *action*, *with_std=False*)

Returns predicted action-values.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

# for continuous control
# 100 actions with shape of (2,)
actions = np.random.random((100, 2))

# for discrete control
# 100 actions in integer values
actions = np.random.randint(2, size=100)

values = algo.predict_value(x, actions)
# values.shape == (100,)

values, stds = algo.predict_value(x, actions, with_std=True)
# stds.shape  == (100,)
```

Parameters

- **x** (*Union[numpy.ndarray, List[Any]]*) – observations
- **action** (*Union[numpy.ndarray, List[Any]]*) – actions
- **with_std** (*bool*) – flag to return standard deviation of ensemble estimation. This deviation reflects uncertainty for the given observations. This uncertainty will be more accurate if you enable `bootstrap` flag and increase `n_critics` value.

Returns predicted action-values

Return type Union[numpy.ndarray, Tuple[numpy.ndarray, numpy.ndarray]]

sample_action (*x*)

Returns sampled actions.

The sampled actions are identical to the output of *predict* method if the policy is deterministic.

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations.

Returns sampled actions.

Return type numpy.ndarray

save_model (*fname*)

Saves neural network parameters.

```
algo.save_model('model.pt')
```

Parameters **fname** (*str*) – destination file path.

Return type None

save_policy (*fname*, *as_onnx=False*)

Save the greedy-policy computational graph as TorchScript or ONNX.

```
# save as TorchScript
algo.save_policy('policy.pt')

# save as ONNX
algo.save_policy('policy.onnx', as_onnx=True)
```

The artifacts saved with this method will work without d3rlpy. This method is especially useful to deploy the learned policy to production environments or embedding systems.

See also

- https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html (for Python).
- https://pytorch.org/tutorials/advanced/cpp_export.html (for C++).
- https://onnx.ai (for ONNX)

Parameters

- **fname** (*str*) – destination file path.
- **as_onnx** (*bool*) – flag to save as ONNX format.

Return type None

set_params (***params*)

Sets the given arguments to the attributes if they exist.

This method sets the given values to the attributes including ones in subclasses. If the values that don't exist as attributes are passed, they are ignored. Some of scikit-learn utilities will use this method.

```
algo.set_params(batch_size=100)
```

Parameters **params** (*Any*) – arbitrary inputs to set as attributes.

Returns itself.

Return type d3rlpy.base.LearnableBase

update (*epoch*, *total_step*, *batch*)

Update parameters with mini-batch of data.

Parameters

- **epoch** (*int*) – the current number of epochs.
- **total_step** (*int*) – the current number of total iterations.
- **batch** (d3rlpy.dataset.TransitionMiniBatch) – mini-batch data.

Returns loss values.

Return type list

Attributes

action_size

Action size.

Returns action size.

Return type Optional[int]

batch_size

Batch size to train.

Returns batch size.

Return type int

gamma

Discount factor.

Returns discount factor.

Return type float

impl

Implementation object.

Returns implementation object.

Return type Optional[ImplBase]

n_frames

Number of frames to stack.

This is only for image observation.

Returns number of frames to stack.

Return type int

n_steps

N-step TD backup.

Returns N-step TD backup.

Return type int

observation_shape

Observation shape.

Returns observation shape.

Return type Optional[Sequence[int]]

scaler

Preprocessing scaler.

Returns preprocessing scaler.

Return type Optional[Scaler]

d3rlpy.algos.PLASWithPerturbation

class d3rlpy.algos.**PLASWithPerturbation**(**, actor_learning_rate=0.0003, critic_learning_rate=0.0003, imitator_learning_rate=0.0003, actor_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, critic_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, imitator_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, actor_encoder_factory='default', critic_encoder_factory='default', imitator_encoder_factory='default', q_func_factory='mean', batch_size=256, n_frames=1, n_steps=1, gamma=0.99, tau=0.005, n_critics=2, bootstrap=False, share_encoder=False, update_actor_interval=1, lam=0.75, action_flexibility=0.05, rl_start_epoch=10, beta=0.5, use_gpu=False, scaler=None, augmentation=None, generator=None, impl=None, **kwargs*)

Policy in Latent Action Space algorithm with perturbation layer.

PLAS with perturbation layer enables PLAS to output out-of-distribution action.

References

- Zhou et al., PLAS: latent action space for offline reinforcement learning.

Parameters

- **actor_learning_rate** (*float*) – learning rate for policy function.
- **critic_learning_rate** (*float*) – learning rate for Q functions.
- **imitator_learning_rate** (*float*) – learning rate for Conditional VAE.
- **actor_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the actor.
- **critic_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the critic.
- **imitator_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the conditional VAE.
- **actor_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the actor.
- **critic_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the critic.
- **imitator_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the conditional VAE.

- **q_func_factory** (*d3rlpy.models.q_functions.QFunctionFactory or str*) – Q function factory.
- **batch_size** (*int*) – mini-batch size.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **n_steps** (*int*) – N-step TD calculation.
- **gamma** (*float*) – discount factor.
- **tau** (*float*) – target network synchronization coefficiency.
- **n_critics** (*int*) – the number of Q functions for ensemble.
- **bootstrap** (*bool*) – flag to bootstrap Q functions.
- **share_encoder** (*bool*) – flag to share encoder network.
- **update_actor_interval** (*int*) – interval to update policy function.
- **lam** (*float*) – weight factor for critic ensemble.
- **action_flexibility** (*float*) – output scale of perturbation layer.
- **rl_start_epoch** (*int*) – epoch to start to update policy function and Q functions. If this is large, RL training would be more stabilized.
- **beta** (*float*) – KL reguralization term for Conditional VAE.
- **use_gpu** (*bool, int or d3rlpy.gpu.Device*) – flag to use GPU, device ID or device.
- **scaler** (*d3rlpy.preprocessing.Scaler or str*) – preprocessor. The available options are *['pixel', 'min_max', 'standard']*
- **augmentation** (*d3rlpy.augmentation.AugmentationPipeline or list(str)*) – augmentation pipeline.
- **generator** (*d3rlpy.algos.base.DataGenerator*) – dynamic dataset generator (e.g. model-based RL).
- **impl** (*d3rlpy.algos.torch.bcq_impl.BCQImpl*) – algorithm implementation.

Methods

build_with_dataset(*dataset*)

Instantiate implementation object with MDPDataset object.

Parameters dataset (d3rlpy.dataset.MDPDataset) – dataset.

Return type None

build_with_env(*env*)

Instantiate implementation object with OpenAI Gym object.

Parameters env (*gym.core.Env*) – gym-like environment.

Return type None

create_impl(*observation_shape*, *action_size*)

Instantiate implementation objects with the dataset shapes.

This method will be used internally when *fit* method is called.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – dimension of action-space.

Return type None

fit(*episodes*, *n_epochs=1000*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*, *eval_episodes=None*, *save_interval=1*, *scorers=None*, *shuffle=True*)
Trains with the given dataset.

```
algo.fit(episodes)
```

Parameters

- **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes to train.
- **n_epochs** (*int*) – the number of epochs to train.
- **save_metrics** (*bool*) – flag to record metrics in files. If False, the log directory is not created and the model parameters are not saved during training.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be *{class name}_{timestamp}*.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)
- **eval_episodes** (*Optional[List[d3rlpy.dataset.Episode]]*) – list of episodes to test.
- **save_interval** (*int*) – interval to save parameters.
- **scorers** (*Optional[Dict[str, Callable[[Any, List[d3rlpy.dataset.Episode]], float]]]*) – list of scorer functions used with *eval_episodes*.
- **shuffle** (*bool*) – flag to shuffle transitions on each epoch.

Return type None

fit_online(*env*, *buffer*, *explorer=None*, *n_steps=1000000*, *n_steps_per_epoch=10000*, *update_interval=1*, *update_start_step=0*, *eval_env=None*, *eval_epsilon=0.0*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*)
Start training loop of online deep reinforcement learning.

Parameters

- **env** (*gym.core.Env*) – gym-like environment.
- **buffer** (*d3rlpy.online.buffers.Buffer*) – replay buffer.
- **explorer** (*Optional[d3rlpy.online.explorers.Explorer]*) – action explorer.
- **n_steps** (*int*) – the number of total steps to train.

- **n_steps_per_epoch** (*int*) – the number of steps per epoch.
- **update_interval** (*int*) – the number of steps per update.
- **update_start_step** (*int*) – the steps before starting updates.
- **eval_env** (*Optional[gym.core.Env]*) – gym-like environment. If None, evaluation is skipped.
- **eval_epsilon** (*float*) – ϵ-greedy factor during evaluation.
- **save_metrics** (*bool*) – flag to record metrics. If False, the log directory is not created and the model parameters are not saved.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be `{class name}_online_{timestamp}`.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

Return type None

classmethod from_json(*fname*, *use_gpu=False*)

Returns algorithm configured with json file.

The Json file should be the one saved during fitting.

```
from d3rlpy.algos import Algo

# create algorithm with saved configuration
algo = Algo.from_json('d3rlpy_logs/<path-to-json>/params.json')

# ready to load
algo.load_model('d3rlpy_logs/<path-to-model>/model_100.pt')

# ready to predict
algo.predict(...)
```

Parameters

- **fname** (*str*) – file path to *params.json*.
- **use_gpu** (*Optional[Union[bool, int, d3rlpy.gpu.Device]]*) – flag to use GPU, device ID or device.

Returns algorithm.

Return type d3rlpy.base.LearnableBase

get_params(*deep=True*)

Returns the all attributes.

This method returns the all attributes including ones in subclasses. Some of scikit-learn utilities will use this method.

```
params = algo.get_params(deep=True)

# the returned values can be used to instantiate the new object.
algo2 = AlgoBase(**params)
```

Parameters **deep** (*bool*) – flag to deeply copy objects such as *impl*.

Returns attribute values in dictionary.

Return type Dict[str, Any]

load_model (*fname*)

Load neural network parameters.

```
algo.load_model('model.pt')
```

Parameters **fname** (*str*) – source file path.

Return type None

predict (*x*)

Returns greedy actions.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

actions = algo.predict(x)
# actions.shape == (100, action size) for continuous control
# actions.shape == (100,) for discrete control
```

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations

Returns greedy actions

Return type numpy.ndarray

predict_value (*x*, *action*, *with_std=False*)

Returns predicted action-values.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

# for continuous control
# 100 actions with shape of (2,)
actions = np.random.random((100, 2))

# for discrete control
# 100 actions in integer values
actions = np.random.randint(2, size=100)

values = algo.predict_value(x, actions)
# values.shape == (100,)

values, stds = algo.predict_value(x, actions, with_std=True)
# stds.shape  == (100,)
```

Parameters

- **x** (*Union[numpy.ndarray, List[Any]]*) – observations
- **action** (*Union[numpy.ndarray, List[Any]]*) – actions
- **with_std** (*bool*) – flag to return standard deviation of ensemble estimation. This deviation reflects uncertainty for the given observations. This uncertainty will be more accurate if you enable `bootstrap` flag and increase `n_critics` value.

Returns predicted action-values

Return type Union[numpy.ndarray, Tuple[numpy.ndarray, numpy.ndarray]]

sample_action (*x*)

Returns sampled actions.

The sampled actions are identical to the output of *predict* method if the policy is deterministic.

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations.

Returns sampled actions.

Return type numpy.ndarray

save_model (*fname*)

Saves neural network parameters.

```
algo.save_model('model.pt')
```

Parameters **fname** (*str*) – destination file path.

Return type None

save_policy (*fname*, *as_onnx=False*)

Save the greedy-policy computational graph as TorchScript or ONNX.

```
# save as TorchScript
algo.save_policy('policy.pt')

# save as ONNX
algo.save_policy('policy.onnx', as_onnx=True)
```

The artifacts saved with this method will work without d3rlpy. This method is especially useful to deploy the learned policy to production environments or embedding systems.

See also

- https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html (for Python).
- https://pytorch.org/tutorials/advanced/cpp_export.html (for C++).
- https://onnx.ai (for ONNX)

Parameters

- **fname** (*str*) – destination file path.
- **as_onnx** (*bool*) – flag to save as ONNX format.

Return type None

set_params(***params*)

Sets the given arguments to the attributes if they exist.

This method sets the given values to the attributes including ones in subclasses. If the values that don't exist as attributes are passed, they are ignored. Some of scikit-learn utilities will use this method.

```
algo.set_params(batch_size=100)
```

Parameters **params** (*Any*) – arbitrary inputs to set as attributes.

Returns itself.

Return type d3rlpy.base.LearnableBase

update(*epoch*, *total_step*, *batch*)

Update parameters with mini-batch of data.

Parameters

- **epoch** (*int*) – the current number of epochs.
- **total_step** (*int*) – the current number of total iterations.
- **batch** (d3rlpy.dataset.TransitionMiniBatch) – mini-batch data.

Returns loss values.

Return type list

Attributes

action_size

Action size.

Returns action size.

Return type Optional[int]

batch_size

Batch size to train.

Returns batch size.

Return type int

gamma

Discount factor.

Returns discount factor.

Return type float

impl

Implementation object.

Returns implementation object.

Return type Optional[ImplBase]

n_frames

Number of frames to stack.

This is only for image observation.

Returns number of frames to stack.

Return type int

n_steps
N-step TD backup.

Returns N-step TD backup.

Return type int

observation_shape
Observation shape.

Returns observation shape.

Return type Optional[Sequence[int]]

scaler
Preprocessing scaler.

Returns preprocessing scaler.

Return type Optional[Scaler]

3.1.2 Discrete control algorithms

d3rlpy.algos.DiscreteBC	Behavior Cloning algorithm for discrete control.
d3rlpy.algos.DQN	Deep Q-Network algorithm.
d3rlpy.algos.DoubleDQN	Double Deep Q-Network algorithm.
d3rlpy.algos.DiscreteSAC	Soft Actor-Critic algorithm for discrete action-space.
d3rlpy.algos.DiscreteBCQ	Discrete version of Batch-Constrained Q-learning algorithm.
d3rlpy.algos.DiscreteCQL	Discrete version of Conservative Q-Learning algorithm.
d3rlpy.algos.DiscreteAWR	Discrete veriosn of Advantage-Weighted Regression algorithm.

d3rlpy.algos.DiscreteBC

class d3rlpy.algos.**DiscreteBC**(**, learning_rate=0.001, optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, encoder_factory='default', batch_size=100, n_frames=1, beta=0.5, use_gpu=False, scaler=None, augmentation=None, generator=None, impl=None, **kwargs*)

Behavior Cloning algorithm for discrete control.

Behavior Cloning (BC) is to imitate actions in the dataset via a supervised learning approach. Since BC is only imitating action distributions, the performance will be close to the mean of the dataset even though BC mostly works better than online RL algorithms.

$$L(\theta) = \mathbb{E}_{a_t, s_t \sim D}[-\sum_a p(a|s_t) \log \pi_\theta(a|s_t)]$$

where $p(a|s_t)$ is implemented as a one-hot vector.

Parameters

- **learning_rate** (*float*) – learing rate.

- **optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory.
- **encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory.
- **batch_size** (*int*) – mini-batch size.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **beta** (*float*) – reguralization factor.
- **use_gpu** (*bool, int or d3rlpy.gpu.Device*) – flag to use GPU, device ID or device.
- **scaler** (*d3rlpy.preprocessing.Scaler or str*) – preprocessor. The available options are *['pixel', 'min_max', 'standard']*
- **augmentation** (*d3rlpy.augmentation.AugmentationPipeline or list(str)*) – augmentation pipeline.
- **generator** (*d3rlpy.algos.base.DataGenerator*) – dynamic dataset generator (e.g. model-based RL).
- **impl** (*d3rlpy.algos.torch.bc_impl.DiscreteBCImpl*) – implemenation of the algorithm.

Methods

build_with_dataset (*dataset*)

Instantiate implementation object with MDPDataset object.

Parameters **dataset** (d3rlpy.dataset.MDPDataset) – dataset.

Return type None

build_with_env (*env*)

Instantiate implementation object with OpenAI Gym object.

Parameters **env** (*gym.core.Env*) – gym-like environment.

Return type None

create_impl (*observation_shape*, *action_size*)

Instantiate implementation objects with the dataset shapes.

This method will be used internally when *fit* method is called.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – dimension of action-space.

Return type None

fit (*episodes*, *n_epochs=1000*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*, *eval_episodes=None*, *save_interval=1*, *scorers=None*, *shuffle=True*)

Trains with the given dataset.

```
algo.fit(episodes)
```

Parameters

- **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes to train.
- **n_epochs** (*int*) – the number of epochs to train.
- **save_metrics** (*bool*) – flag to record metrics in files. If False, the log directory is not created and the model parameters are not saved during training.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be *{class name}_{timestamp}*.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)
- **eval_episodes** (*Optional[List[d3rlpy.dataset.Episode]]*) – list of episodes to test.
- **save_interval** (*int*) – interval to save parameters.
- **scorers** (*Optional[Dict[str, Callable[[Any, List[d3rlpy.dataset.Episode]], float]]]*) – list of scorer functions used with *eval_episodes*.
- **shuffle** (*bool*) – flag to shuffle transitions on each epoch.

Return type None

fit_online(*env, buffer, explorer=None, n_steps=1000000, n_steps_per_epoch=10000, update_interval=1, update_start_step=0, eval_env=None, eval_epsilon=0.0, save_metrics=True, experiment_name=None, with_timestamp=True, logdir='d3rlpy_logs', verbose=True, show_progress=True, tensorboard=True*)

Start training loop of online deep reinforcement learning.

Parameters

- **env** (*gym.core.Env*) – gym-like environment.
- **buffer** (*d3rlpy.online.buffers.Buffer*) – replay buffer.
- **explorer** (*Optional[d3rlpy.online.explorers.Explorer]*) – action explorer.
- **n_steps** (*int*) – the number of total steps to train.
- **n_steps_per_epoch** (*int*) – the number of steps per epoch.
- **update_interval** (*int*) – the number of steps per update.
- **update_start_step** (*int*) – the steps before starting updates.
- **eval_env** (*Optional[gym.core.Env]*) – gym-like environment. If None, evaluation is skipped.
- **eval_epsilon** (*float*) – ϵ-greedy factor during evaluation.
- **save_metrics** (*bool*) – flag to record metrics. If False, the log directory is not created and the model parameters are not saved.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be `{class name}_online_{timestamp}`.

- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

Return type None

classmethod from_json (*fname*, *use_gpu=False*)
Returns algorithm configured with json file.

The Json file should be the one saved during fitting.

```
from d3rlpy.algos import Algo

# create algorithm with saved configuration
algo = Algo.from_json('d3rlpy_logs/<path-to-json>/params.json')

# ready to load
algo.load_model('d3rlpy_logs/<path-to-model>/model_100.pt')

# ready to predict
algo.predict(...)
```

Parameters

- **fname** (*str*) – file path to *params.json*.
- **use_gpu** (*Optional[Union[bool, int, d3rlpy.gpu.Device]]*) – flag to use GPU, device ID or device.

Returns algorithm.

Return type d3rlpy.base.LearnableBase

get_params (*deep=True*)
Returns the all attributes.

This method returns the all attributes including ones in subclasses. Some of scikit-learn utilities will use this method.

```
params = algo.get_params(deep=True)

# the returned values can be used to instantiate the new object.
algo2 = AlgoBase(**params)
```

Parameters **deep** (*bool*) – flag to deeply copy objects such as *impl*.

Returns attribute values in dictionary.

Return type Dict[str, Any]

load_model (*fname*)
Load neural network parameters.

```
algo.load_model('model.pt')
```

Parameters **fname** (*str*) – source file path.

Return type None

predict (*x*)

Returns greedy actions.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

actions = algo.predict(x)
# actions.shape == (100, action size) for continuous control
# actions.shape == (100,) for discrete control
```

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations

Returns greedy actions

Return type numpy.ndarray

predict_value (*x, action, with_std=False*)

value prediction is not supported by BC algorithms.

Parameters

- **x** (*Union[numpy.ndarray, List[Any]]*) –
- **action** (*Union[numpy.ndarray, List[Any]]*) –
- **with_std** (*bool*) –

Return type numpy.ndarray

sample_action (*x*)

sampling action is not supported by BC algorithm.

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) –

Return type None

save_model (*fname*)

Saves neural network parameters.

```
algo.save_model('model.pt')
```

Parameters **fname** (*str*) – destination file path.

Return type None

save_policy (*fname, as_onnx=False*)

Save the greedy-policy computational graph as TorchScript or ONNX.

```
# save as TorchScript
algo.save_policy('policy.pt')

# save as ONNX
algo.save_policy('policy.onnx', as_onnx=True)
```

The artifacts saved with this method will work without d3rlpy. This method is especially useful to deploy the learned policy to production environments or embedding systems.

See also

- https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html (for Python).
- https://pytorch.org/tutorials/advanced/cpp_export.html (for C++).
- https://onnx.ai (for ONNX)

Parameters

- **fname** (*str*) – destination file path.
- **as_onnx** (*bool*) – flag to save as ONNX format.

Return type None

set_params (***params*)

Sets the given arguments to the attributes if they exist.

This method sets the given values to the attributes including ones in subclasses. If the values that don't exist as attributes are passed, they are ignored. Some of scikit-learn utilities will use this method.

```
algo.set_params(batch_size=100)
```

Parameters params (*Any*) – arbitrary inputs to set as attributes.

Returns itself.

Return type d3rlpy.base.LearnableBase

update (*epoch, total_step, batch*)

Update parameters with mini-batch of data.

Parameters

- **epoch** (*int*) – the current number of epochs.
- **total_step** (*int*) – the current number of total iterations.
- **batch** (d3rlpy.dataset.TransitionMiniBatch) – mini-batch data.

Returns loss values.

Return type list

Attributes

action_size

Action size.

Returns action size.

Return type Optional[int]

batch_size

Batch size to train.

Returns batch size.

Return type int

gamma

Discount factor.

Returns discount factor.

Return type float

impl
Implementation object.

Returns implementation object.

Return type Optional[ImplBase]

n_frames
Number of frames to stack.

This is only for image observation.

Returns number of frames to stack.

Return type int

n_steps
N-step TD backup.

Returns N-step TD backup.

Return type int

observation_shape
Observation shape.

Returns observation shape.

Return type Optional[Sequence[int]]

scaler
Preprocessing scaler.

Returns preprocessing scaler.

Return type Optional[Scaler]

d3rlpy.algos.DQN

class d3rlpy.algos.**DQN**(**, learning_rate=6.25e-05, optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, encoder_factory='default', q_func_factory='mean', batch_size=32, n_frames=1, n_steps=1, gamma=0.99, n_critics=1, bootstrap=False, share_encoder=False, target_update_interval=8000, use_gpu=False, scaler=None, augmentation=None, generator=None, impl=None, **kwargs*)

Deep Q-Network algorithm.

$$L(\theta) = \mathbb{E}_{s_t, a_t, r_{t+1}, s_{t+1} \sim D}[(r_{t+1} + \gamma \max_a Q_{\theta'}(s_{t+1}, a) - Q_\theta(s_t, a_t))^2]$$

where θ' is the target network parameter. The target network parameter is synchronized every *target_update_interval* iterations.

References

- Mnih et al., Human-level control through deep reinforcement learning.

Parameters

- **learning_rate** (*float*) – learning rate.
- **optim_factory** (d3rlpy.models.optimizers.OptimizerFactory *or* str) – optimizer factory.
- **encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or* str) – encoder factory.
- **q_func_factory** (*d3rlpy.models.q_functions.QFunctionFactory or* str) – Q function factory.
- **batch_size** (*int*) – mini-batch size.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **n_steps** (*int*) – N-step TD calculation.
- **gamma** (*float*) – discount factor.
- **n_critics** (*int*) – the number of Q functions for ensemble.
- **bootstrap** (*bool*) – flag to bootstrap Q functions.
- **share_encoder** (*bool*) – flag to share encoder network.
- **target_update_interval** (*int*) – interval to update the target network.
- **use_gpu** (*bool, int or d3rlpy.gpu.Device*) – flag to use GPU, device ID or device.
- **scaler** (*d3rlpy.preprocessing.Scaler or* str) – preprocessor. The available options are *['pixel', 'min_max', 'standard']*
- **augmentation** (*d3rlpy.augmentation.AugmentationPipeline or list(str)*) – augmentation pipeline.
- **generator** (*d3rlpy.algos.base.DataGenerator*) – dynamic dataset generator (e.g. model-based RL).
- **impl** (*d3rlpy.algos.torch.dqn_impl.DQNImpl*) – algorithm implementation.

Methods

build_with_dataset(*dataset*)
Instantiate implementation object with MDPDataset object.

Parameters **dataset** (d3rlpy.dataset.MDPDataset) – dataset.

Return type None

build_with_env(*env*)
Instantiate implementation object with OpenAI Gym object.

Parameters **env** (*gym.core.Env*) – gym-like environment.

Return type None

create_impl(*observation_shape*, *action_size*)

Instantiate implementation objects with the dataset shapes.

This method will be used internally when *fit* method is called.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – dimension of action-space.

Return type None

fit(*episodes*, *n_epochs=1000*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*, *eval_episodes=None*, *save_interval=1*, *scorers=None*, *shuffle=True*)

Trains with the given dataset.

```
algo.fit(episodes)
```

Parameters

- **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes to train.
- **n_epochs** (*int*) – the number of epochs to train.
- **save_metrics** (*bool*) – flag to record metrics in files. If False, the log directory is not created and the model parameters are not saved during training.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be *{class name}_{timestamp}*.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)
- **eval_episodes** (*Optional[List[d3rlpy.dataset.Episode]]*) – list of episodes to test.
- **save_interval** (*int*) – interval to save parameters.
- **scorers** (*Optional[Dict[str, Callable[[Any, List[d3rlpy.dataset.Episode]], float]]]*) – list of scorer functions used with *eval_episodes*.
- **shuffle** (*bool*) – flag to shuffle transitions on each epoch.

Return type None

fit_online(*env*, *buffer*, *explorer=None*, *n_steps=1000000*, *n_steps_per_epoch=10000*, *update_interval=1*, *update_start_step=0*, *eval_env=None*, *eval_epsilon=0.0*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*)

Start training loop of online deep reinforcement learning.

Parameters

- **env** (*gym.core.Env*) – gym-like environment.

- **buffer** (*d3rlpy.online.buffers.Buffer*) – replay buffer.
- **explorer** (*Optional[d3rlpy.online.explorers.Explorer]*) – action explorer.
- **n_steps** (*int*) – the number of total steps to train.
- **n_steps_per_epoch** (*int*) – the number of steps per epoch.
- **update_interval** (*int*) – the number of steps per update.
- **update_start_step** (*int*) – the steps before starting updates.
- **eval_env** (*Optional[gym.core.Env]*) – gym-like environment. If None, evaluation is skipped.
- **eval_epsilon** (*float*) – ϵ-greedy factor during evaluation.
- **save_metrics** (*bool*) – flag to record metrics. If False, the log directory is not created and the model parameters are not saved.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be `{class name}_online_{timestamp}`.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

Return type None

classmethod from_json (*fname*, *use_gpu=False*)

Returns algorithm configured with json file.

The Json file should be the one saved during fitting.

```
from d3rlpy.algos import Algo

# create algorithm with saved configuration
algo = Algo.from_json('d3rlpy_logs/<path-to-json>/params.json')

# ready to load
algo.load_model('d3rlpy_logs/<path-to-model>/model_100.pt')

# ready to predict
algo.predict(...)
```

Parameters

- **fname** (*str*) – file path to *params.json*.
- **use_gpu** (*Optional[Union[bool, int, d3rlpy.gpu.Device]]*) – flag to use GPU, device ID or device.

Returns algorithm.

Return type d3rlpy.base.LearnableBase

get_params (*deep=True*)
Returns the all attributes.

This method returns the all attributes including ones in subclasses. Some of scikit-learn utilities will use this method.

```
params = algo.get_params(deep=True)

# the returned values can be used to instantiate the new object.
algo2 = AlgoBase(**params)
```

Parameters **deep** (*bool*) – flag to deeply copy objects such as *impl*.

Returns attribute values in dictionary.

Return type Dict[str, Any]

load_model (*fname*)
Load neural network parameters.

```
algo.load_model('model.pt')
```

Parameters **fname** (*str*) – source file path.

Return type None

predict (*x*)
Returns greedy actions.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

actions = algo.predict(x)
# actions.shape == (100, action size) for continuous control
# actions.shape == (100,) for discrete control
```

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations

Returns greedy actions

Return type numpy.ndarray

predict_value (*x, action, with_std=False*)
Returns predicted action-values.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

# for continuous control
# 100 actions with shape of (2,)
actions = np.random.random((100, 2))

# for discrete control
# 100 actions in integer values
actions = np.random.randint(2, size=100)

values = algo.predict_value(x, actions)
```

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```
# values.shape == (100,)

values, stds = algo.predict_value(x, actions, with_std=True)
# stds.shape  == (100,)
```

Parameters

- **x** (*Union[numpy.ndarray, List[Any]]*) – observations
- **action** (*Union[numpy.ndarray, List[Any]]*) – actions
- **with_std** (*bool*) – flag to return standard deviation of ensemble estimation. This deviation reflects uncertainty for the given observations. This uncertainty will be more accurate if you enable `bootstrap` flag and increase `n_critics` value.

Returns predicted action-values

Return type Union[numpy.ndarray, Tuple[numpy.ndarray, numpy.ndarray]]

sample_action (*x*)

Returns sampled actions.

The sampled actions are identical to the output of *predict* method if the policy is deterministic.

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations.

Returns sampled actions.

Return type numpy.ndarray

save_model (*fname*)

Saves neural network parameters.

```
algo.save_model('model.pt')
```

Parameters **fname** (*str*) – destination file path.

Return type None

save_policy (*fname, as_onnx=False*)

Save the greedy-policy computational graph as TorchScript or ONNX.

```
# save as TorchScript
algo.save_policy('policy.pt')

# save as ONNX
algo.save_policy('policy.onnx', as_onnx=True)
```

The artifacts saved with this method will work without d3rlpy. This method is especially useful to deploy the learned policy to production environments or embedding systems.

See also

- https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html (for Python).
- https://pytorch.org/tutorials/advanced/cpp_export.html (for C++).
- https://onnx.ai (for ONNX)

Parameters

- **fname** (*str*) – destination file path.
- **as_onnx** (*bool*) – flag to save as ONNX format.

Return type None

set_params(***params*)

Sets the given arguments to the attributes if they exist.

This method sets the given values to the attributes including ones in subclasses. If the values that don't exist as attributes are passed, they are ignored. Some of scikit-learn utilities will use this method.

```
algo.set_params(batch_size=100)
```

Parameters **params** (*Any*) – arbitrary inputs to set as attributes.

Returns itself.

Return type d3rlpy.base.LearnableBase

update(*epoch, total_step, batch*)

Update parameters with mini-batch of data.

Parameters

- **epoch** (*int*) – the current number of epochs.
- **total_step** (*int*) – the current number of total iterations.
- **batch** (d3rlpy.dataset.TransitionMiniBatch) – mini-batch data.

Returns loss values.

Return type list

Attributes

action_size

Action size.

Returns action size.

Return type Optional[int]

batch_size

Batch size to train.

Returns batch size.

Return type int

gamma

Discount factor.

Returns discount factor.

Return type float

impl

Implementation object.

Returns implementation object.

Return type Optional[ImplBase]

n_frames
Number of frames to stack.

This is only for image observation.

Returns number of frames to stack.

Return type int

n_steps
N-step TD backup.

Returns N-step TD backup.

Return type int

observation_shape
Observation shape.

Returns observation shape.

Return type Optional[Sequence[int]]

scaler
Preprocessing scaler.

Returns preprocessing scaler.

Return type Optional[Scaler]

d3rlpy.algos.DoubleDQN

class d3rlpy.algos.**DoubleDQN**(**, learning_rate=6.25e-05, optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, encoder_factory='default', q_func_factory='mean', batch_size=32, n_frames=1, n_steps=1, gamma=0.99, n_critics=1, bootstrap=False, share_encoder=False, target_update_interval=8000, use_gpu=False, scaler=None, augmentation=None, generator=None, impl=None, **kwargs*)

Double Deep Q-Network algorithm.

The difference from DQN is that the action is taken from the current Q function instead of the target Q function. This modification significantly decreases overestimation bias of TD learning.

$$L(\theta) = \mathbb{E}_{s_t, a_t, r_{t+1}, s_{t+1} \sim D}[(r_{t+1} + \gamma Q_{\theta'}(s_{t+1}, \text{argmax}_a Q_\theta(s_{t+1}, a)) - Q_\theta(s_t, a_t))^2]$$

where θ' is the target network parameter. The target network parameter is synchronized every *target_update_interval* iterations.

References

- Hasselt et al., Deep reinforcement learning with double Q-learning.

Parameters

- **learning_rate** (*float*) – learning rate.
- **optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory.

- **encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory.
- **q_func_factory** (*d3rlpy.models.q_functions.QFunctionFactory or str*) – Q function factory.
- **batch_size** (*int*) – mini-batch size.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **n_steps** (*int*) – N-step TD calculation.
- **gamma** (*float*) – discount factor.
- **n_critics** (*int*) – the number of Q functions.
- **bootstrap** (*bool*) – flag to bootstrap Q functions.
- **share_encoder** (*bool*) – flag to share encoder network.
- **target_update_interval** (*int*) – interval to synchronize the target network.
- **use_gpu** (*bool, int or d3rlpy.gpu.Device*) – flag to use GPU, device ID or device.
- **scaler** (*d3rlpy.preprocessing.Scaler or str*) – preprocessor. The available options are *['pixel', 'min_max', 'standard']*
- **augmentation** (*d3rlpy.augmentation.AugmentationPipeline or list(str)*) – augmentation pipeline.
- **generator** (*d3rlpy.algos.base.DataGenerator*) – dynamic dataset generator (e.g. model-based RL).
- **impl** (*d3rlpy.algos.torch.dqn_impl.DoubleDQNImpl*) – algorithm implementation.

Methods

build_with_dataset(*dataset*)
Instantiate implementation object with MDPDataset object.

Parameters **dataset** (d3rlpy.dataset.MDPDataset) – dataset.

Return type None

build_with_env(*env*)
Instantiate implementation object with OpenAI Gym object.

Parameters **env** (*gym.core.Env*) – gym-like environment.

Return type None

create_impl(*observation_shape, action_size*)
Instantiate implementation objects with the dataset shapes.

This method will be used internally when *fit* method is called.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – dimension of action-space.

Return type None

fit(*episodes, n_epochs=1000, save_metrics=True, experiment_name=None, with_timestamp=True, logdir='d3rlpy_logs', verbose=True, show_progress=True, tensorboard=True, eval_episodes=None, save_interval=1, scorers=None, shuffle=True*)

Trains with the given dataset.

```
algo.fit(episodes)
```

Parameters

- **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes to train.
- **n_epochs** (*int*) – the number of epochs to train.
- **save_metrics** (*bool*) – flag to record metrics in files. If False, the log directory is not created and the model parameters are not saved during training.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be *{class name}_{timestamp}*.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)
- **eval_episodes** (*Optional[List[d3rlpy.dataset.Episode]]*) – list of episodes to test.
- **save_interval** (*int*) – interval to save parameters.
- **scorers** (*Optional[Dict[str, Callable[[Any, List[d3rlpy.dataset.Episode]], float]]]*) – list of scorer functions used with *eval_episodes*.
- **shuffle** (*bool*) – flag to shuffle transitions on each epoch.

Return type None

fit_online(*env, buffer, explorer=None, n_steps=1000000, n_steps_per_epoch=10000, update_interval=1, update_start_step=0, eval_env=None, eval_epsilon=0.0, save_metrics=True, experiment_name=None, with_timestamp=True, logdir='d3rlpy_logs', verbose=True, show_progress=True, tensorboard=True*)

Start training loop of online deep reinforcement learning.

Parameters

- **env** (*gym.core.Env*) – gym-like environment.
- **buffer** (*d3rlpy.online.buffers.Buffer*) – replay buffer.
- **explorer** (*Optional[d3rlpy.online.explorers.Explorer]*) – action explorer.
- **n_steps** (*int*) – the number of total steps to train.
- **n_steps_per_epoch** (*int*) – the number of steps per epoch.
- **update_interval** (*int*) – the number of steps per update.
- **update_start_step** (*int*) – the steps before starting updates.

- **eval_env** (*Optional[gym.core.Env]*) – gym-like environment. If None, evaluation is skipped.
- **eval_epsilon** (*float*) – ϵ-greedy factor during evaluation.
- **save_metrics** (*bool*) – flag to record metrics. If False, the log directory is not created and the model parameters are not saved.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be `{class name}_online_{timestamp}`.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

Return type None

classmethod from_json (*fname*, *use_gpu=False*)

Returns algorithm configured with json file.

The Json file should be the one saved during fitting.

```
from d3rlpy.algos import Algo

# create algorithm with saved configuration
algo = Algo.from_json('d3rlpy_logs/<path-to-json>/params.json')

# ready to load
algo.load_model('d3rlpy_logs/<path-to-model>/model_100.pt')

# ready to predict
algo.predict(...)
```

Parameters

- **fname** (*str*) – file path to *params.json*.
- **use_gpu** (*Optional[Union[bool, int, d3rlpy.gpu.Device]]*) – flag to use GPU, device ID or device.

Returns algorithm.

Return type d3rlpy.base.LearnableBase

get_params (*deep=True*)

Returns the all attributes.

This method returns the all attributes including ones in subclasses. Some of scikit-learn utilities will use this method.

```
params = algo.get_params(deep=True)

# the returned values can be used to instantiate the new object.
algo2 = AlgoBase(**params)
```

Parameters **deep** (*bool*) – flag to deeply copy objects such as *impl*.

Returns attribute values in dictionary.

Return type Dict[str, Any]

load_model (*fname*)

Load neural network parameters.

```
algo.load_model('model.pt')
```

Parameters **fname** (*str*) – source file path.

Return type None

predict (*x*)

Returns greedy actions.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

actions = algo.predict(x)
# actions.shape == (100, action size) for continuous control
# actions.shape == (100,) for discrete control
```

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations

Returns greedy actions

Return type numpy.ndarray

predict_value (*x, action, with_std=False*)

Returns predicted action-values.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

# for continuous control
# 100 actions with shape of (2,)
actions = np.random.random((100, 2))

# for discrete control
# 100 actions in integer values
actions = np.random.randint(2, size=100)

values = algo.predict_value(x, actions)
# values.shape == (100,)

values, stds = algo.predict_value(x, actions, with_std=True)
# stds.shape  == (100,)
```

Parameters

- **x** (*Union[numpy.ndarray, List[Any]]*) – observations
- **action** (*Union[numpy.ndarray, List[Any]]*) – actions

- **with_std** (*bool*) – flag to return standard deviation of ensemble estimation. This deviation reflects uncertainty for the given observations. This uncertainty will be more accurate if you enable `bootstrap` flag and increase `n_critics` value.

Returns predicted action-values

Return type Union[numpy.ndarray, Tuple[numpy.ndarray, numpy.ndarray]]

sample_action (*x*)

Returns sampled actions.

The sampled actions are identical to the output of *predict* method if the policy is deterministic.

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations.

Returns sampled actions.

Return type numpy.ndarray

save_model (*fname*)

Saves neural network parameters.

```
algo.save_model('model.pt')
```

Parameters **fname** (*str*) – destination file path.

Return type None

save_policy (*fname*, *as_onnx=False*)

Save the greedy-policy computational graph as TorchScript or ONNX.

```
# save as TorchScript
algo.save_policy('policy.pt')

# save as ONNX
algo.save_policy('policy.onnx', as_onnx=True)
```

The artifacts saved with this method will work without d3rlpy. This method is especially useful to deploy the learned policy to production environments or embedding systems.

See also

- https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html (for Python).
- https://pytorch.org/tutorials/advanced/cpp_export.html (for C++).
- https://onnx.ai (for ONNX)

Parameters

- **fname** (*str*) – destination file path.
- **as_onnx** (*bool*) – flag to save as ONNX format.

Return type None

set_params (***params*)

Sets the given arguments to the attributes if they exist.

This method sets the given values to the attributes including ones in subclasses. If the values that don't exist as attributes are passed, they are ignored. Some of scikit-learn utilities will use this method.

```
algo.set_params(batch_size=100)
```

Parameters **params** (*Any*) – arbitrary inputs to set as attributes.

Returns itself.

Return type d3rlpy.base.LearnableBase

update(*epoch*, *total_step*, *batch*)

Update parameters with mini-batch of data.

Parameters

- **epoch** (*int*) – the current number of epochs.
- **total_step** (*int*) – the current number of total iterations.
- **batch** (d3rlpy.dataset.TransitionMiniBatch) – mini-batch data.

Returns loss values.

Return type list

Attributes

action_size

Action size.

Returns action size.

Return type Optional[int]

batch_size

Batch size to train.

Returns batch size.

Return type int

gamma

Discount factor.

Returns discount factor.

Return type float

impl

Implementation object.

Returns implementation object.

Return type Optional[ImplBase]

n_frames

Number of frames to stack.

This is only for image observation.

Returns number of frames to stack.

Return type int

n_steps

N-step TD backup.

Returns N-step TD backup.

Return type int

observation_shape

Observation shape.

Returns observation shape.

Return type Optional[Sequence[int]]

scaler

Preprocessing scaler.

Returns preprocessing scaler.

Return type Optional[Scaler]

d3rlpy.algos.DiscreteSAC

class d3rlpy.algos.**DiscreteSAC**(**, actor_learning_rate=0.0003, critic_learning_rate=0.0003, temp_learning_rate=0.0003, actor_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, critic_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, temp_optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, actor_encoder_factory='default', critic_encoder_factory='default', q_func_factory='mean', batch_size=64, n_frames=1, n_steps=1, gamma=0.99, n_critics=2, bootstrap=False, share_encoder=False, initial_temperature=1.0, target_update_interval=8000, use_gpu=False, scaler=None, augmentation=None, generator=None, impl=None, **kwargs*)

Soft Actor-Critic algorithm for discrete action-space.

This discrete version of SAC is built based on continuous version of SAC with additional modifications.

The target state-value is calculated as expectation of all action-values.

$$V(s_t) = \pi_\phi(s_t)^T [Q_\theta(s_t) - \alpha \log(\pi_\phi(s_t))]$$

Similarly, the objective function for the temperature parameter is as follows.

$$J(\alpha) = \pi_\phi(s_t)^T [-\alpha(\log(\pi_\phi(s_t)) + H)]$$

Finally, the objective function for the policy function is as follows.

$$J(\phi) = \mathbb{E}_{s_t \sim D} [\pi_\phi(s_t)^T [\alpha \log(\pi_\phi(s_t)) - Q_\theta(s_t)]]$$

References

- Christodoulou, Soft Actor-Critic for Discrete Action Settings.

Parameters

- **actor_learning_rate** (*float*) – learning rate for policy function.
- **critic_learning_rate** (*float*) – learning rate for Q functions.
- **temp_learning_rate** (*float*) – learning rate for temperature parameter.

- **actor_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the actor.
- **critic_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the critic.
- **temp_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the temperature.
- **actor_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the actor.
- **critic_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the critic.
- **q_func_factory** (*d3rlpy.models.q_functions.QFunctionFactory or str*) – Q function factory.
- **batch_size** (*int*) – mini-batch size.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **n_steps** (*int*) – N-step TD calculation.
- **gamma** (*float*) – discount factor.
- **n_critics** (*int*) – the number of Q functions for ensemble.
- **bootstrap** (*bool*) – flag to bootstrap Q functions.
- **share_encoder** (*bool*) – flag to share encoder network.
- **initial_temperature** (*float*) – initial temperature value.
- **use_gpu** (*bool, int or d3rlpy.gpu.Device*) – flag to use GPU, device ID or device.
- **scaler** (*d3rlpy.preprocessing.Scaler or str*) – preprocessor. The available options are *['pixel', 'min_max', 'standard']*
- **augmentation** (*d3rlpy.augmentation.AugmentationPipeline or list(str)*) – augmentation pipeline.
- **generator** (*d3rlpy.algos.base.DataGenerator*) – dynamic dataset generator (e.g. model-based RL).
- **impl** (*d3rlpy.algos.torch.sac_impl.DiscreteSACImpl*) – algorithm implementation.

Methods

build_with_dataset (*dataset*)

Instantiate implementation object with MDPDataset object.

Parameters **dataset** (d3rlpy.dataset.MDPDataset) – dataset.

Return type None

build_with_env (*env*)

Instantiate implementation object with OpenAI Gym object.

Parameters **env** (*gym.core.Env*) – gym-like environment.

Return type None

create_impl(*observation_shape*, *action_size*)

Instantiate implementation objects with the dataset shapes.

This method will be used internally when *fit* method is called.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – dimension of action-space.

Return type None

fit(*episodes*, *n_epochs=1000*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*, *eval_episodes=None*, *save_interval=1*, *scorers=None*, *shuffle=True*)

Trains with the given dataset.

```
algo.fit(episodes)
```

Parameters

- **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes to train.
- **n_epochs** (*int*) – the number of epochs to train.
- **save_metrics** (*bool*) – flag to record metrics in files. If False, the log directory is not created and the model parameters are not saved during training.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be *{class name}_{timestamp}*.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)
- **eval_episodes** (*Optional[List[d3rlpy.dataset.Episode]]*) – list of episodes to test.
- **save_interval** (*int*) – interval to save parameters.
- **scorers** (*Optional[Dict[str, Callable[[Any, List[d3rlpy.dataset.Episode]], float]]]*) – list of scorer functions used with *eval_episodes*.
- **shuffle** (*bool*) – flag to shuffle transitions on each epoch.

Return type None

fit_online(*env*, *buffer*, *explorer=None*, *n_steps=1000000*, *n_steps_per_epoch=10000*, *update_interval=1*, *update_start_step=0*, *eval_env=None*, *eval_epsilon=0.0*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*)

Start training loop of online deep reinforcement learning.

Parameters

- **env** (*gym.core.Env*) – gym-like environment.

- **buffer** (*d3rlpy.online.buffers.Buffer*) – replay buffer.
- **explorer** (*Optional[d3rlpy.online.explorers.Explorer]*) – action explorer.
- **n_steps** (*int*) – the number of total steps to train.
- **n_steps_per_epoch** (*int*) – the number of steps per epoch.
- **update_interval** (*int*) – the number of steps per update.
- **update_start_step** (*int*) – the steps before starting updates.
- **eval_env** (*Optional[gym.core.Env]*) – gym-like environment. If None, evaluation is skipped.
- **eval_epsilon** (*float*) – ϵ-greedy factor during evaluation.
- **save_metrics** (*bool*) – flag to record metrics. If False, the log directory is not created and the model parameters are not saved.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be `{class name}_online_{timestamp}`.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

Return type None

classmethod from_json(*fname*, *use_gpu=False*)

Returns algorithm configured with json file.

The Json file should be the one saved during fitting.

```
from d3rlpy.algos import Algo

# create algorithm with saved configuration
algo = Algo.from_json('d3rlpy_logs/<path-to-json>/params.json')

# ready to load
algo.load_model('d3rlpy_logs/<path-to-model>/model_100.pt')

# ready to predict
algo.predict(...)
```

Parameters

- **fname** (*str*) – file path to *params.json*.
- **use_gpu** (*Optional[Union[bool, int, d3rlpy.gpu.Device]]*) – flag to use GPU, device ID or device.

Returns algorithm.

Return type d3rlpy.base.LearnableBase

get_params (*deep=True*)
Returns the all attributes.

This method returns the all attributes including ones in subclasses. Some of scikit-learn utilities will use this method.

```
params = algo.get_params(deep=True)

# the returned values can be used to instantiate the new object.
algo2 = AlgoBase(**params)
```

Parameters **deep** (*bool*) – flag to deeply copy objects such as *impl*.

Returns attribute values in dictionary.

Return type Dict[str, Any]

load_model (*fname*)
Load neural network parameters.

```
algo.load_model('model.pt')
```

Parameters **fname** (*str*) – source file path.

Return type None

predict (*x*)
Returns greedy actions.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

actions = algo.predict(x)
# actions.shape == (100, action size) for continuous control
# actions.shape == (100,) for discrete control
```

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations

Returns greedy actions

Return type numpy.ndarray

predict_value (*x, action, with_std=False*)
Returns predicted action-values.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

# for continuous control
# 100 actions with shape of (2,)
actions = np.random.random((100, 2))

# for discrete control
# 100 actions in integer values
actions = np.random.randint(2, size=100)

values = algo.predict_value(x, actions)
```

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```
# values.shape == (100,)

values, stds = algo.predict_value(x, actions, with_std=True)
# stds.shape  == (100,)
```

Parameters

- **x** (*Union[numpy.ndarray, List[Any]]*) – observations
- **action** (*Union[numpy.ndarray, List[Any]]*) – actions
- **with_std** (*bool*) – flag to return standard deviation of ensemble estimation. This deviation reflects uncertainty for the given observations. This uncertainty will be more accurate if you enable `bootstrap` flag and increase `n_critics` value.

Returns predicted action-values

Return type Union[numpy.ndarray, Tuple[numpy.ndarray, numpy.ndarray]]

sample_action(*x*)

Returns sampled actions.

The sampled actions are identical to the output of *predict* method if the policy is deterministic.

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations.

Returns sampled actions.

Return type numpy.ndarray

save_model(*fname*)

Saves neural network parameters.

```
algo.save_model('model.pt')
```

Parameters **fname** (*str*) – destination file path.

Return type None

save_policy(*fname*, *as_onnx=False*)

Save the greedy-policy computational graph as TorchScript or ONNX.

```
# save as TorchScript
algo.save_policy('policy.pt')

# save as ONNX
algo.save_policy('policy.onnx', as_onnx=True)
```

The artifacts saved with this method will work without d3rlpy. This method is especially useful to deploy the learned policy to production environments or embedding systems.

See also

- https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html (for Python).
- https://pytorch.org/tutorials/advanced/cpp_export.html (for C++).
- https://onnx.ai (for ONNX)

Parameters

- **fname** (*str*) – destination file path.
- **as_onnx** (*bool*) – flag to save as ONNX format.

Return type None

set_params(***params*)

Sets the given arguments to the attributes if they exist.

This method sets the given values to the attributes including ones in subclasses. If the values that don't exist as attributes are passed, they are ignored. Some of scikit-learn utilities will use this method.

```
algo.set_params(batch_size=100)
```

Parameters **params** (*Any*) – arbitrary inputs to set as attributes.

Returns itself.

Return type d3rlpy.base.LearnableBase

update(*epoch*, *total_step*, *batch*)

Update parameters with mini-batch of data.

Parameters

- **epoch** (*int*) – the current number of epochs.
- **total_step** (*int*) – the current number of total iterations.
- **batch** (d3rlpy.dataset.TransitionMiniBatch) – mini-batch data.

Returns loss values.

Return type list

Attributes

action_size

Action size.

Returns action size.

Return type Optional[int]

batch_size

Batch size to train.

Returns batch size.

Return type int

gamma

Discount factor.

Returns discount factor.

Return type float

impl

Implementation object.

Returns implementation object.

Return type Optional[ImplBase]

n_frames
Number of frames to stack.

This is only for image observation.

Returns number of frames to stack.

Return type int

n_steps
N-step TD backup.

Returns N-step TD backup.

Return type int

observation_shape
Observation shape.

Returns observation shape.

Return type Optional[Sequence[int]]

scaler
Preprocessing scaler.

Returns preprocessing scaler.

Return type Optional[Scaler]

d3rlpy.algos.DiscreteBCQ

class d3rlpy.algos.**DiscreteBCQ**(**, learning_rate=6.25e-05, optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, encoder_factory='default', q_func_factory='mean', batch_size=32, n_frames=1, n_steps=1, gamma=0.99, n_critics=1, bootstrap=False, share_encoder=False, action_flexibility=0.3, beta=0.5, target_update_interval=8000, use_gpu=False, scaler=None, augmentation=None, generator=None, impl=None, **kwargs*)

Discrete version of Batch-Constrained Q-learning algorithm.

Discrete version takes theories from the continuous version, but the algorithm is much simpler than that. The imitation function $G_\omega(a|s)$ is trained as supervised learning just like Behavior Cloning.

$$L(\omega) = \mathbb{E}_{a_t, s_t \sim D}[-\sum_a p(a|s_t) \log G_\omega(a|s_t)]$$

With this imitation function, the greedy policy is defined as follows.

$$\pi(s_t) = \text{argmax}_{a|G_\omega(a|s_t)/\max_{\tilde{a}} G_\omega(\tilde{a}|s_t) > \tau} Q_\theta(s_t, a)$$

which eliminates actions with probabilities τ times smaller than the maximum one.

Finally, the loss function is computed in Double DQN style with the above constrained policy.

$$L(\theta) = \mathbb{E}_{s_t, a_t, r_{t+1}, s_{t+1} \sim D}[(r_{t+1} + \gamma Q_{\theta'}(s_{t+1}, \pi(s_{t+1})) - Q_\theta(s_t, a_t))^2]$$

References

- Fujimoto et al., Off-Policy Deep Reinforcement Learning without Exploration.
- Fujimoto et al., Benchmarking Batch Deep Reinforcement Learning Algorithms.

Parameters

- **learning_rate** (*float*) – learning rate.
- **optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory.
- **encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory.
- **q_func_factory** (*d3rlpy.models.q_functions.QFunctionFactory or str*) – Q function factory.
- **batch_size** (*int*) – mini-batch size.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **n_steps** (*int*) – N-step TD calculation.
- **gamma** (*float*) – discount factor.
- **n_critics** (*int*) – the number of Q functions for ensemble.
- **bootstrap** (*bool*) – flag to bootstrap Q functions.
- **share_encoder** (*bool*) – flag to share encoder network.
- **action_flexibility** (*float*) – probability threshold represented as τ.
- **beta** (*float*) – reguralization term for imitation function.
- **target_update_interval** (*int*) – interval to update the target network.
- **use_gpu** (*bool, int or d3rlpy.gpu.Device*) – flag to use GPU, device ID or device.
- **scaler** (*d3rlpy.preprocessing.Scaler or str*) – preprocessor. The available options are *['pixel', 'min_max', 'standard']*
- **augmentation** (*d3rlpy.augmentation.AugmentationPipeline or list(str)*) – augmentation pipeline.
- **generator** (*d3rlpy.algos.base.DataGenerator*) – dynamic dataset generator (e.g. model-based RL).
- **impl** (*d3rlpy.algos.torch.bcq_impl.DiscreteBCQImpl*) – algorithm implementation.

Methods

build_with_dataset(*dataset*)

Instantiate implementation object with MDPDataset object.

Parameters **dataset** (d3rlpy.dataset.MDPDataset) – dataset.

Return type None

build_with_env(*env*)

Instantiate implementation object with OpenAI Gym object.

Parameters **env** (*gym.core.Env*) – gym-like environment.

Return type None

create_impl(*observation_shape*, *action_size*)

Instantiate implementation objects with the dataset shapes.

This method will be used internally when *fit* method is called.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – dimension of action-space.

Return type None

fit(*episodes*, *n_epochs=1000*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*, *eval_episodes=None*, *save_interval=1*, *scorers=None*, *shuffle=True*)

Trains with the given dataset.

```
algo.fit(episodes)
```

Parameters

- **episodes** (*List[*d3rlpy.dataset.Episode*]*) – list of episodes to train.
- **n_epochs** (*int*) – the number of epochs to train.
- **save_metrics** (*bool*) – flag to record metrics in files. If False, the log directory is not created and the model parameters are not saved during training.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be *{class name}_{timestamp}*.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)
- **eval_episodes** (*Optional[List[*d3rlpy.dataset.Episode*]]*) – list of episodes to test.
- **save_interval** (*int*) – interval to save parameters.

- **scorers** (*Optional[Dict[str, Callable[[Any, List[d3rlpy.dataset.Episode]], float]]]*) – list of scorer functions used with *eval_episodes*.
- **shuffle** (*bool*) – flag to shuffle transitions on each epoch.

Return type None

fit_online(*env*, *buffer*, *explorer=None*, *n_steps=1000000*, *n_steps_per_epoch=10000*, *update_interval=1*, *update_start_step=0*, *eval_env=None*, *eval_epsilon=0.0*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*)

Start training loop of online deep reinforcement learning.

Parameters

- **env** (*gym.core.Env*) – gym-like environment.
- **buffer** (*d3rlpy.online.buffers.Buffer*) – replay buffer.
- **explorer** (*Optional[d3rlpy.online.explorers.Explorer]*) – action explorer.
- **n_steps** (*int*) – the number of total steps to train.
- **n_steps_per_epoch** (*int*) – the number of steps per epoch.
- **update_interval** (*int*) – the number of steps per update.
- **update_start_step** (*int*) – the steps before starting updates.
- **eval_env** (*Optional[gym.core.Env]*) – gym-like environment. If None, evaluation is skipped.
- **eval_epsilon** (*float*) – ϵ-greedy factor during evaluation.
- **save_metrics** (*bool*) – flag to record metrics. If False, the log directory is not created and the model parameters are not saved.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be `{class name}_online_{timestamp}`.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

Return type None

classmethod from_json(*fname*, *use_gpu=False*)

Returns algorithm configured with json file.

The Json file should be the one saved during fitting.

```
from d3rlpy.algos import Algo

# create algorithm with saved configuration
algo = Algo.from_json('d3rlpy_logs/<path-to-json>/params.json')
```

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```
# ready to load
algo.load_model('d3rlpy_logs/<path-to-model>/model_100.pt')

# ready to predict
algo.predict(...)
```

Parameters

- **fname** (*str*) – file path to *params.json*.
- **use_gpu** (*Optional[Union[bool, int, d3rlpy.gpu.Device]]*) – flag to use GPU, device ID or device.

Returns algorithm.

Return type d3rlpy.base.LearnableBase

get_params (*deep=True*)

Returns the all attributes.

This method returns the all attributes including ones in subclasses. Some of scikit-learn utilities will use this method.

```
params = algo.get_params(deep=True)

# the returned values can be used to instantiate the new object.
algo2 = AlgoBase(**params)
```

Parameters **deep** (*bool*) – flag to deeply copy objects such as *impl*.

Returns attribute values in dictionary.

Return type Dict[str, Any]

load_model (*fname*)

Load neural network parameters.

```
algo.load_model('model.pt')
```

Parameters **fname** (*str*) – source file path.

Return type None

predict (*x*)

Returns greedy actions.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

actions = algo.predict(x)
# actions.shape == (100, action size) for continuous control
# actions.shape == (100,) for discrete control
```

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations

Returns greedy actions

Return type numpy.ndarray

predict_value (*x*, *action*, *with_std=False*)

Returns predicted action-values.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

# for continuous control
# 100 actions with shape of (2,)
actions = np.random.random((100, 2))

# for discrete control
# 100 actions in integer values
actions = np.random.randint(2, size=100)

values = algo.predict_value(x, actions)
# values.shape == (100,)

values, stds = algo.predict_value(x, actions, with_std=True)
# stds.shape  == (100,)
```

Parameters

- **x** (`Union[numpy.ndarray, List[Any]]`) – observations
- **action** (`Union[numpy.ndarray, List[Any]]`) – actions
- **with_std** (`bool`) – flag to return standard deviation of ensemble estimation. This deviation reflects uncertainty for the given observations. This uncertainty will be more accurate if you enable `bootstrap` flag and increase `n_critics` value.

Returns predicted action-values

Return type Union[numpy.ndarray, Tuple[numpy.ndarray, numpy.ndarray]]

sample_action (*x*)

Returns sampled actions.

The sampled actions are identical to the output of *predict* method if the policy is deterministic.

Parameters **x** (`Union[numpy.ndarray, List[Any]]`) – observations.

Returns sampled actions.

Return type numpy.ndarray

save_model (*fname*)

Saves neural network parameters.

```
algo.save_model('model.pt')
```

Parameters **fname** (`str`) – destination file path.

Return type None

save_policy (*fname*, *as_onnx=False*)

Save the greedy-policy computational graph as TorchScript or ONNX.

```
# save as TorchScript
algo.save_policy('policy.pt')
```

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```
# save as ONNX
algo.save_policy('policy.onnx', as_onnx=True)
```

The artifacts saved with this method will work without d3rlpy. This method is especially useful to deploy the learned policy to production environments or embedding systems.

See also

- https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html (for Python).
- https://pytorch.org/tutorials/advanced/cpp_export.html (for C++).
- https://onnx.ai (for ONNX)

Parameters

- **fname** (*str*) – destination file path.
- **as_onnx** (*bool*) – flag to save as ONNX format.

Return type None

set_params(***params*)

Sets the given arguments to the attributes if they exist.

This method sets the given values to the attributes including ones in subclasses. If the values that don't exist as attributes are passed, they are ignored. Some of scikit-learn utilities will use this method.

```
algo.set_params(batch_size=100)
```

Parameters **params** (*Any*) – arbitrary inputs to set as attributes.

Returns itself.

Return type d3rlpy.base.LearnableBase

update(*epoch*, *total_step*, *batch*)

Update parameters with mini-batch of data.

Parameters

- **epoch** (*int*) – the current number of epochs.
- **total_step** (*int*) – the current number of total iterations.
- **batch** (d3rlpy.dataset.TransitionMiniBatch) – mini-batch data.

Returns loss values.

Return type list

Attributes

action_size

Action size.

Returns action size.

Return type Optional[int]

batch_size

Batch size to train.

Returns batch size.

Return type int

gamma

Discount factor.

Returns discount factor.

Return type float

impl

Implementation object.

Returns implementation object.

Return type Optional[ImplBase]

n_frames

Number of frames to stack.

This is only for image observation.

Returns number of frames to stack.

Return type int

n_steps

N-step TD backup.

Returns N-step TD backup.

Return type int

observation_shape

Observation shape.

Returns observation shape.

Return type Optional[Sequence[int]]

scaler

Preprocessing scaler.

Returns preprocessing scaler.

Return type Optional[Scaler]

d3rlpy.algos.DiscreteCQL

class d3rlpy.algos.**DiscreteCQL**(**, learning_rate=6.25e-05, optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, encoder_factory='default', q_func_factory='mean', batch_size=32, n_frames=1, n_steps=1, gamma=0.99, n_critics=1, bootstrap=False, share_encoder=False, target_update_interval=8000, use_gpu=False, scaler=None, augmentation=None, generator=None, impl=None, **kwargs*)

Discrete version of Conservative Q-Learning algorithm.

Discrete version of CQL is a DoubleDQN-based data-driven deep reinforcement learning algorithm (the original paper uses DQN), which achieves state-of-the-art performance in offline RL problems.

CQL mitigates overestimation error by minimizing action-values under the current policy and maximizing values under data distribution for underestimation issue.

$$L(\theta) = \mathbb{E}_{s_t \sim D}[\log \sum_a \exp Q_\theta(s_t, a) - \mathbb{E}_{a \sim D}[Q_\theta(s, a)]] + L_{DoubleDQN}(\theta)$$

References

- Kumar et al., Conservative Q-Learning for Offline Reinforcement Learning.

Parameters

- **learning_rate** (*float*) – learning rate.
- **optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory.
- **encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory.
- **q_func_factory** (*d3rlpy.models.q_functions.QFunctionFactory or str*) – Q function factory.
- **batch_size** (*int*) – mini-batch size.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **n_steps** (*int*) – N-step TD calculation.
- **gamma** (*float*) – discount factor.
- **n_critics** (*int*) – the number of Q functions for ensemble.
- **bootstrap** (*bool*) – flag to bootstrap Q functions.
- **target_update_interval** (*int*) – interval to synchronize the target network.
- **use_gpu** (*bool, int or d3rlpy.gpu.Device*) – flag to use GPU, device ID or device.
- **scaler** (*d3rlpy.preprocessing.Scaler or str*) – preprocessor. The available options are *['pixel', 'min_max', 'standard']*
- **augmentation** (*d3rlpy.augmentation.AugmentationPipeline or list(str)*) – augmentation pipeline.
- **generator** (*d3rlpy.algos.base.DataGenerator*) – dynamic dataset generator (e.g. model-based RL).

- **impl** (*d3rlpy.algos.torch.cql_impl.DiscreteCQLImpl*) – algorithm implementation.

Methods

build_with_dataset (*dataset*)
Instantiate implementation object with MDPDataset object.

Parameters **dataset** (d3rlpy.dataset.MDPDataset) – dataset.

Return type None

build_with_env (*env*)
Instantiate implementation object with OpenAI Gym object.

Parameters **env** (*gym.core.Env*) – gym-like environment.

Return type None

create_impl (*observation_shape*, *action_size*)
Instantiate implementation objects with the dataset shapes.

This method will be used internally when *fit* method is called.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – dimension of action-space.

Return type None

fit (*episodes*, *n_epochs=1000*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*, *eval_episodes=None*, *save_interval=1*, *scorers=None*, *shuffle=True*)
Trains with the given dataset.

```
algo.fit(episodes)
```

Parameters

- **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes to train.
- **n_epochs** (*int*) – the number of epochs to train.
- **save_metrics** (*bool*) – flag to record metrics in files. If False, the log directory is not created and the model parameters are not saved during training.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be *{class name}_{timestamp}*.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)
- **eval_episodes** (*Optional[List[d3rlpy.dataset.Episode]]*) – list of episodes to test.

- **save_interval** (*int*) – interval to save parameters.
- **scorers** (*Optional[Dict[str, Callable[[Any, List[d3rlpy.dataset.Episode]], float]]]*) – list of scorer functions used with *eval_episodes*.
- **shuffle** (*bool*) – flag to shuffle transitions on each epoch.

Return type None

fit_online(*env*, *buffer*, *explorer=None*, *n_steps=1000000*, *n_steps_per_epoch=10000*, *update_interval=1*, *update_start_step=0*, *eval_env=None*, *eval_epsilon=0.0*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*)

Start training loop of online deep reinforcement learning.

Parameters

- **env** (*gym.core.Env*) – gym-like environment.
- **buffer** (*d3rlpy.online.buffers.Buffer*) – replay buffer.
- **explorer** (*Optional[d3rlpy.online.explorers.Explorer]*) – action explorer.
- **n_steps** (*int*) – the number of total steps to train.
- **n_steps_per_epoch** (*int*) – the number of steps per epoch.
- **update_interval** (*int*) – the number of steps per update.
- **update_start_step** (*int*) – the steps before starting updates.
- **eval_env** (*Optional[gym.core.Env]*) – gym-like environment. If None, evaluation is skipped.
- **eval_epsilon** (*float*) – ϵ-greedy factor during evaluation.
- **save_metrics** (*bool*) – flag to record metrics. If False, the log directory is not created and the model parameters are not saved.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be `{class name}_online_{timestamp}`.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

Return type None

classmethod from_json(*fname*, *use_gpu=False*)

Returns algorithm configured with json file.

The Json file should be the one saved during fitting.

```
from d3rlpy.algos import Algo

# create algorithm with saved configuration
```

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```
algo = Algo.from_json('d3rlpy_logs/<path-to-json>/params.json')

# ready to load
algo.load_model('d3rlpy_logs/<path-to-model>/model_100.pt')

# ready to predict
algo.predict(...)
```

Parameters

- **fname** (*str*) – file path to *params.json*.
- **use_gpu** (*Optional[Union[bool, int, d3rlpy.gpu.Device]]*) – flag to use GPU, device ID or device.

Returns algorithm.

Return type d3rlpy.base.LearnableBase

get_params(*deep=True*)

Returns the all attributes.

This method returns the all attributes including ones in subclasses. Some of scikit-learn utilities will use this method.

```
params = algo.get_params(deep=True)

# the returned values can be used to instantiate the new object.
algo2 = AlgoBase(**params)
```

Parameters **deep** (*bool*) – flag to deeply copy objects such as *impl*.

Returns attribute values in dictionary.

Return type Dict[str, Any]

load_model(*fname*)

Load neural network parameters.

```
algo.load_model('model.pt')
```

Parameters **fname** (*str*) – source file path.

Return type None

predict(*x*)

Returns greedy actions.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

actions = algo.predict(x)
# actions.shape == (100, action size) for continuous control
# actions.shape == (100,) for discrete control
```

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations

Returns greedy actions

Return type numpy.ndarray

predict_value (*x*, *action*, *with_std=False*)
Returns predicted action-values.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

# for continuous control
# 100 actions with shape of (2,)
actions = np.random.random((100, 2))

# for discrete control
# 100 actions in integer values
actions = np.random.randint(2, size=100)

values = algo.predict_value(x, actions)
# values.shape == (100,)

values, stds = algo.predict_value(x, actions, with_std=True)
# stds.shape  == (100,)
```

Parameters

- **x** (*Union[numpy.ndarray, List[Any]]*) – observations
- **action** (*Union[numpy.ndarray, List[Any]]*) – actions
- **with_std** (*bool*) – flag to return standard deviation of ensemble estimation. This deviation reflects uncertainty for the given observations. This uncertainty will be more accurate if you enable `bootstrap` flag and increase `n_critics` value.

Returns predicted action-values

Return type Union[numpy.ndarray, Tuple[numpy.ndarray, numpy.ndarray]]

sample_action (*x*)
Returns sampled actions.

The sampled actions are identical to the output of *predict* method if the policy is deterministic.

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations.

Returns sampled actions.

Return type numpy.ndarray

save_model (*fname*)
Saves neural network parameters.

```
algo.save_model('model.pt')
```

Parameters **fname** (*str*) – destination file path.

Return type None

save_policy (*fname*, *as_onnx=False*)
Save the greedy-policy computational graph as TorchScript or ONNX.

```
# save as TorchScript
algo.save_policy('policy.pt')

# save as ONNX
algo.save_policy('policy.onnx', as_onnx=True)
```

The artifacts saved with this method will work without d3rlpy. This method is especially useful to deploy the learned policy to production environments or embedding systems.

See also

- https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html (for Python).
- https://pytorch.org/tutorials/advanced/cpp_export.html (for C++).
- https://onnx.ai (for ONNX)

Parameters

- **fname** (*str*) – destination file path.
- **as_onnx** (*bool*) – flag to save as ONNX format.

Return type None

set_params(***params*)

Sets the given arguments to the attributes if they exist.

This method sets the given values to the attributes including ones in subclasses. If the values that don't exist as attributes are passed, they are ignored. Some of scikit-learn utilities will use this method.

```
algo.set_params(batch_size=100)
```

Parameters **params** (*Any*) – arbitrary inputs to set as attributes.

Returns itself.

Return type d3rlpy.base.LearnableBase

update(*epoch*, *total_step*, *batch*)

Update parameters with mini-batch of data.

Parameters

- **epoch** (*int*) – the current number of epochs.
- **total_step** (*int*) – the current number of total iterations.
- **batch** (d3rlpy.dataset.TransitionMiniBatch) – mini-batch data.

Returns loss values.

Return type list

Attributes

action_size
Action size.

Returns action size.

Return type Optional[int]

batch_size
Batch size to train.

Returns batch size.

Return type int

gamma
Discount factor.

Returns discount factor.

Return type float

impl
Implementation object.

Returns implementation object.

Return type Optional[ImplBase]

n_frames
Number of frames to stack.

This is only for image observation.

Returns number of frames to stack.

Return type int

n_steps
N-step TD backup.

Returns N-step TD backup.

Return type int

observation_shape
Observation shape.

Returns observation shape.

Return type Optional[Sequence[int]]

scaler
Preprocessing scaler.

Returns preprocessing scaler.

Return type Optional[Scaler]

d3rlpy.algos.DiscreteAWR

class d3rlpy.algos.**DiscreteAWR**(*, *actor_learning_rate=5e-05*, *critic_learning_rate=0.0001*, *actor_optim_factory=<d3rlpy.models.optimizers.SGDFactory object>*, *critic_optim_factory=<d3rlpy.models.optimizers.SGDFactory object>*, *actor_encoder_factory='default'*, *critic_encoder_factory='default'*, *batch_size=2048*, *n_frames=1*, *gamma=0.99*, *batch_size_per_update=256*, *n_actor_updates=1000*, *n_critic_updates=200*, *lam=0.95*, *beta=1.0*, *max_weight=20.0*, *use_gpu=False*, *scaler=None*, *augmentation=None*, *generator=None*, *impl=None*, ***kwargs*)

Discrete veriosn of Advantage-Weighted Regression algorithm.

AWR is an actor-critic algorithm that trains via supervised regression way, and has shown strong performance in online and offline settings.

The value function is trained as a supervised regression problem.

$$L(\theta) = \mathbb{E}_{s_t, R_t \sim D} [(R_t - V(s_t|\theta))^2]$$

where R_t is approximated using TD(λ) to mitigate high variance issue.

The policy function is also trained as a supervised regression problem.

$$J(\phi) = \mathbb{E}_{s_t, a_t, R_t \sim D} [\log \pi(a_t|s_t, \phi) \exp(\frac{1}{B}(R_t - V(s_t|\theta)))]$$

where B is a constant factor.

References

- Peng et al., Advantage-Weighted Regression: Simple and Scalable Off-Policy Reinforcement Learning

Parameters

- **actor_learning_rate** (*float*) – learning rate for policy function.
- **critic_learning_rate** (*float*) – learning rate for value function.
- **actor_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the actor.
- **critic_optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory for the critic.
- **actor_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the actor.
- **critic_encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory for the critic.
- **batch_size** (*int*) – batch size per iteration.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **gamma** (*float*) – discount factor.
- **batch_size_per_update** (*int*) – mini-batch size.
- **n_actor_updates** (*int*) – actor gradient steps per iteration.
- **n_critic_updates** (*int*) – critic gradient steps per iteration.

- **lam** (*float*) – λ for TD(λ).
- **beta** (*float*) – B for weight scale.
- **max_weight** (*float*) – $w_{\max}$ for weight clipping.
- **use_gpu** (*bool, int or d3rlpy.gpu.Device*) – flag to use GPU, device ID or device.
- **scaler** (*d3rlpy.preprocessing.Scaler or str*) – preprocessor. The available options are *['pixel', 'min_max', 'standard']*
- **augmentation** (*d3rlpy.augmentation.AugmentationPipeline or list(str)*) – augmentation pipeline.
- **generator** (*d3rlpy.algos.base.DataGenerator*) – dynamic dataset generator (e.g. model-based RL).
- **impl** (*d3rlpy.algos.torch.awr_impl.DiscreteAWRImpl*) – algorithm implementation.

Methods

build_with_dataset(*dataset*)
Instantiate implementation object with MDPDataset object.

Parameters **dataset** (d3rlpy.dataset.MDPDataset) – dataset.

Return type None

build_with_env(*env*)
Instantiate implementation object with OpenAI Gym object.

Parameters **env** (*gym.core.Env*) – gym-like environment.

Return type None

create_impl(*observation_shape*, *action_size*)
Instantiate implementation objects with the dataset shapes.

This method will be used internally when *fit* method is called.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – dimension of action-space.

Return type None

fit(*episodes*, *n_epochs=1000*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*, *eval_episodes=None*, *save_interval=1*, *scorers=None*, *shuffle=True*)
Trains with the given dataset.

```
algo.fit(episodes)
```

Parameters

- **episodes** (*List[*d3rlpy.dataset.Episode*]*) – list of episodes to train.
- **n_epochs** (*int*) – the number of epochs to train.

- **save_metrics** (*bool*) – flag to record metrics in files. If False, the log directory is not created and the model parameters are not saved during training.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be *{class name}_{timestamp}*.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)
- **eval_episodes** (*Optional[List[d3rlpy.dataset.Episode]]*) – list of episodes to test.
- **save_interval** (*int*) – interval to save parameters.
- **scorers** (*Optional[Dict[str, Callable[[Any, List[d3rlpy.dataset.Episode]], float]]]*) – list of scorer functions used with *eval_episodes*.
- **shuffle** (*bool*) – flag to shuffle transitions on each epoch.

Return type None

fit_online(*env, buffer, explorer=None, n_steps=1000000, n_steps_per_epoch=10000, update_interval=1, update_start_step=0, eval_env=None, eval_epsilon=0.0, save_metrics=True, experiment_name=None, with_timestamp=True, logdir='d3rlpy_logs', verbose=True, show_progress=True, tensorboard=True*)

Start training loop of online deep reinforcement learning.

Parameters

- **env** (*gym.core.Env*) – gym-like environment.
- **buffer** (*d3rlpy.online.buffers.Buffer*) – replay buffer.
- **explorer** (*Optional[d3rlpy.online.explorers.Explorer]*) – action explorer.
- **n_steps** (*int*) – the number of total steps to train.
- **n_steps_per_epoch** (*int*) – the number of steps per epoch.
- **update_interval** (*int*) – the number of steps per update.
- **update_start_step** (*int*) – the steps before starting updates.
- **eval_env** (*Optional[gym.core.Env]*) – gym-like environment. If None, evaluation is skipped.
- **eval_epsilon** (*float*) – ϵ-greedy factor during evaluation.
- **save_metrics** (*bool*) – flag to record metrics. If False, the log directory is not created and the model parameters are not saved.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be `{class name}_online_{timestamp}`.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.

- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

Return type None

classmethod from_json (*fname, use_gpu=False*)
Returns algorithm configured with json file.

The Json file should be the one saved during fitting.

```
from d3rlpy.algos import Algo

# create algorithm with saved configuration
algo = Algo.from_json('d3rlpy_logs/<path-to-json>/params.json')

# ready to load
algo.load_model('d3rlpy_logs/<path-to-model>/model_100.pt')

# ready to predict
algo.predict(...)
```

Parameters

- **fname** (*str*) – file path to *params.json*.
- **use_gpu** (*Optional[Union[bool, int, d3rlpy.gpu.Device]]*) – flag to use GPU, device ID or device.

Returns algorithm.

Return type d3rlpy.base.LearnableBase

get_params (*deep=True*)
Returns the all attributes.

This method returns the all attributes including ones in subclasses. Some of scikit-learn utilities will use this method.

```
params = algo.get_params(deep=True)

# the returned values can be used to instantiate the new object.
algo2 = AlgoBase(**params)
```

Parameters deep (*bool*) – flag to deeply copy objects such as *impl*.

Returns attribute values in dictionary.

Return type Dict[str, Any]

load_model (*fname*)
Load neural network parameters.

```
algo.load_model('model.pt')
```

Parameters fname (*str*) – source file path.

Return type None

predict (*x*)
Returns greedy actions.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

actions = algo.predict(x)
# actions.shape == (100, action size) for continuous control
# actions.shape == (100,) for discrete control
```

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations

Returns greedy actions

Return type numpy.ndarray

predict_value (*x*, **args*, ***kwargs*)
Returns predicted state values.

Parameters

- **x** (*Union[numpy.ndarray, List[Any]]*) – observations.
- **args** (*Any*) –
- **kwargs** (*Any*) –

Returns predicted state values.

Return type numpy.ndarray

sample_action (*x*)
Returns sampled actions.

The sampled actions are identical to the output of *predict* method if the policy is deterministic.

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations.

Returns sampled actions.

Return type numpy.ndarray

save_model (*fname*)
Saves neural network parameters.

```
algo.save_model('model.pt')
```

Parameters **fname** (*str*) – destination file path.

Return type None

save_policy (*fname*, *as_onnx=False*)
Save the greedy-policy computational graph as TorchScript or ONNX.

```
# save as TorchScript
algo.save_policy('policy.pt')

# save as ONNX
algo.save_policy('policy.onnx', as_onnx=True)
```

The artifacts saved with this method will work without d3rlpy. This method is especially useful to deploy the learned policy to production environments or embedding systems.

See also

- https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html (for Python).
- https://pytorch.org/tutorials/advanced/cpp_export.html (for C++).
- https://onnx.ai (for ONNX)

Parameters

- **fname** (*str*) – destination file path.
- **as_onnx** (*bool*) – flag to save as ONNX format.

Return type None

set_params (***params*)

Sets the given arguments to the attributes if they exist.

This method sets the given values to the attributes including ones in subclasses. If the values that don't exist as attributes are passed, they are ignored. Some of scikit-learn utilities will use this method.

```
algo.set_params(batch_size=100)
```

Parameters **params** (*Any*) – arbitrary inputs to set as attributes.

Returns itself.

Return type d3rlpy.base.LearnableBase

update (*epoch, total_step, batch*)

Update parameters with mini-batch of data.

Parameters

- **epoch** (*int*) – the current number of epochs.
- **total_step** (*int*) – the current number of total iterations.
- **batch** (*d3rlpy.dataset.TransitionMiniBatch*) – mini-batch data.

Returns loss values.

Return type list

Attributes

action_size

Action size.

Returns action size.

Return type Optional[int]

batch_size

Batch size to train.

Returns batch size.

Return type int

gamma
Discount factor.

Returns discount factor.

Return type float

impl
Implementation object.

Returns implementation object.

Return type Optional[ImplBase]

n_frames
Number of frames to stack.

This is only for image observation.

Returns number of frames to stack.

Return type int

n_steps
N-step TD backup.

Returns N-step TD backup.

Return type int

observation_shape
Observation shape.

Returns observation shape.

Return type Optional[Sequence[int]]

scaler
Preprocessing scaler.

Returns preprocessing scaler.

Return type Optional[Scaler]

3.2 Q Functions

d3rlpy provides various Q functions including state-of-the-arts, which are internally used in algorithm objects. You can switch Q functions by passing `q_func_factory` argument at algorithm initialization.

```
from d3rlpy.algos import CQL

cql = CQL(q_func_factory='qr') # use Quantile Regression Q function
```

Also you can change hyper parameters.

```
from d3rlpy.models.q_functions import QRQFunctionFactory

q_func = QRQFunctionFactory(n_quantiles=32)

cql = CQL(q_func_factory=q_func)
```

The default Q function is `mean` approximator, which estimates expected scalar action-values. However, in recent advancements of deep reinforcement learning, the new type of action-value approximators has been proposed, which is called *distributional* Q functions.

Unlike the `mean` approximator, the *distributional* Q functions estimate distribution of action-values. This *distributional* approaches have shown consistently much stronger performance than the `mean` approximator.

Here is a list of available Q functions in the order of performance ascendingly. Currently, as a trade-off between performance and computational complexity, the higher performance requires the more expensive computational costs.

d3rlpy.models.q_functions.MeanQFunctionFactory	Standard Q function factory class.
d3rlpy.models.q_functions.QRQFunctionFactory	Quantile Regression Q function factory class.
d3rlpy.models.q_functions.IQNQFunctionFactory	Implicit Quantile Network Q function factory class.
d3rlpy.models.q_functions.FQFQFunctionFactory	Fully parameterized Quantile Function Q function factory.

3.2.1 d3rlpy.models.q_functions.MeanQFunctionFactory

class d3rlpy.models.q_functions.**MeanQFunctionFactory**

Standard Q function factory class.

This is the standard Q function factory class.

References

- Mnih et al., Human-level control through deep reinforcement learning.
- Lillicrap et al., Continuous control with deep reinforcement learning.

Methods

create_continuous(*encoder*)

Returns PyTorch's Q function module.

Parameters **encoder** (*d3rlpy.models.torch.encoders.EncoderWithAction*) – an encoder module that processes the observation and action to obtain feature representations.

Returns continuous Q function object.

Return type d3rlpy.models.torch.q_functions.ContinuousMeanQFunction

create_discrete(*encoder*, *action_size*)

Returns PyTorch's Q function module.

Parameters

- **encoder** (*d3rlpy.models.torch.encoders.Encoder*) – an encoder module that processes the observation to obtain feature representations.
- **action_size** (*int*) – dimension of discrete action-space.

Returns discrete Q function object.

Return type d3rlpy.models.torch.q_functions.DiscreteMeanQFunction

get_params(*deep=False*)
Returns Q function parameters.

Returns Q function parameters.

Parameters **deep** (*bool*) –

Return type Dict[str, Any]

get_type()
Returns Q function type.

Returns Q function type.

Return type str

Attributes

TYPE: ClassVar[str] = 'mean'

3.2.2 d3rlpy.models.q_functions.QRQFunctionFactory

class d3rlpy.models.q_functions.**QRQFunctionFactory**(*n_quantiles=200*)
Quantile Regression Q function factory class.

References

- Dabney et al., Distributional reinforcement learning with quantile regression.

Parameters **n_quantiles** – the number of quantiles.

Methods

create_continuous(*encoder*)
Returns PyTorch's Q function module.

Parameters **encoder** (*d3rlpy.models.torch.encoders.EncoderWithAction*) – an encoder module that processes the observation and action to obtain feature representations.

Returns continuous Q function object.

Return type d3rlpy.models.torch.q_functions.ContinuousQRQFunction

create_discrete(*encoder*, *action_size*)
Returns PyTorch's Q function module.

Parameters

- **encoder** (*d3rlpy.models.torch.encoders.Encoder*) – an encoder module that processes the observation to obtain feature representations.
- **action_size** (*int*) – dimension of discrete action-space.

Returns discrete Q function object.

Return type d3rlpy.models.torch.q_functions.DiscreteQRQFunction

get_params(*deep=False*)
Returns Q function parameters.

Returns Q function parameters.

Parameters **deep** (*bool*) –

Return type Dict[str, Any]

get_type()
Returns Q function type.

Returns Q function type.

Return type str

Attributes

TYPE: ClassVar[str] = 'qr'

n_quantiles

3.2.3 d3rlpy.models.q_functions.IQNQFunctionFactory

class d3rlpy.models.q_functions.**IQNQFunctionFactory**(*n_quantiles=64*, *n_greedy_quantiles=32*, *embed_size=64*)
Implicit Quantile Network Q function factory class.

References

- Dabney et al., Implicit quantile networks for distributional reinforcement learning.

Parameters

- **n_quantiles** – the number of quantiles.
- **n_greedy_quantiles** – the number of quantiles for inference.
- **embed_size** – the embedding size.

Methods

create_continuous(*encoder*)
Returns PyTorch's Q function module.

Parameters **encoder** (*d3rlpy.models.torch.encoders.EncoderWithAction*) – an encoder module that processes the observation and action to obtain feature representations.

Returns continuous Q function object.

Return type d3rlpy.models.torch.q_functions.ContinuousIQNQFunction

create_discrete(*encoder*, *action_size*)
Returns PyTorch's Q function module.

Parameters

- **encoder** (*d3rlpy.models.torch.encoders.Encoder*) – an encoder module that processes the observation to obtain feature representations.
- **action_size** (*int*) – dimension of discrete action-space.

Returns discrete Q function object.

Return type d3rlpy.models.torch.q_functions.DiscreteIQNQFunction

get_params(*deep=False*)

Returns Q function parameters.

Returns Q function parameters.

Parameters **deep** (*bool*) –

Return type Dict[str, Any]

get_type()

Returns Q function type.

Returns Q function type.

Return type str

Attributes

TYPE: ClassVar[str] = 'iqn'

embed_size

n_greedy_quantiles

n_quantiles

3.2.4 d3rlpy.models.q_functions.FQFQFunctionFactory

class d3rlpy.models.q_functions.**FQFQFunctionFactory**(*n_quantiles=32, embed_size=64, entropy_coeff=0.0*)

Fully parameterized Quantile Function Q function factory.

References

- Yang et al., Fully parameterized quantile function for distributional reinforcement learning.

Parameters

- **n_quantiles** – the number of quantiles.
- **embed_size** – the embedding size.
- **entropy_coeff** – the coefficiency of entropy penalty term.

Methods

create_continuous(*encoder*)

Returns PyTorch's Q function module.

Parameters **encoder** (*d3rlpy.models.torch.encoders.EncoderWithAction*) – an encoder module that processes the observation and action to obtain feature representations.

Returns continuous Q function object.

Return type d3rlpy.models.torch.q_functions.ContinuousFQFQFunction

create_discrete(*encoder*, *action_size*)

Returns PyTorch's Q function module.

Parameters

- **encoder** (*d3rlpy.models.torch.encoders.Encoder*) – an encoder module that processes the observation to obtain feature representations.
- **action_size** (*int*) – dimension of discrete action-space.

Returns discrete Q function object.

Return type d3rlpy.models.torch.q_functions.DiscreteFQFQFunction

get_params(*deep=False*)

Returns Q function parameters.

Returns Q function parameters.

Parameters **deep** (*bool*) –

Return type Dict[str, Any]

get_type()

Returns Q function type.

Returns Q function type.

Return type str

Attributes

TYPE: ClassVar[str] = 'fqf'

embed_size

entropy_coeff

n_quantiles

3.3 MDPDataset

d3rlpy provides useful dataset structure for data-driven deep reinforcement learning. In supervised learning, the training script iterates input data X and label data Y. However, in reinforcement learning, mini-batches consist with sets of $(s_t, a_t, r_{t+1}, s_{t+1})$ and episode terminal flags. Converting a set of observations, actions, rewards and terminal flags into this tuples is boring and requires some codings.

Therefore, d3rlpy provides *MDPDataset* class which enables you to handle reinforcement learning datasets without any efforts.

```
from d3rlpy.dataset import MDPDataset

# 1000 steps of observations with shape of (100,)
observations = np.random.random((1000, 100))
# 1000 steps of actions with shape of (4,)
actions = np.random.random((1000, 4))
# 1000 steps of rewards
rewards = np.random.random(1000)
# 1000 steps of terminal flags
terminals = np.random.randint(2, size=1000)

dataset = MDPDataset(observations, actions, rewards, terminals)

# automatically splitted into d3rlpy.dataset.Episode objects
dataset.episodes

# each episode is also splitted into d3rlpy.dataset.Transition objects
episode = dataset.episodes[0]
episode[0].observation
episode[0].action
episode[0].next_reward
episode[0].next_observation
episode[0].terminal

# d3rlpy.dataset.Transition object has pointers to previous and next
# transitions like linked list.
transition = episode[0]
while transition.next_transition:
    transition = transition.next_transition

# save as HDF5
dataset.dump('dataset.h5')

# load from HDF5
new_dataset = MDPDataset.load('dataset.h5')
```

d3rlpy.dataset.MDPDataset	Markov-Decision Process Dataset class.
d3rlpy.dataset.Episode	Episode class.
d3rlpy.dataset.Transition	Transition class.
d3rlpy.dataset.TransitionMiniBatch	mini-batch of Transition objects.

3.3.1 d3rlpy.dataset.MDPDataset

class d3rlpy.dataset.**MDPDataset**(*observations*, *actions*, *rewards*, *terminals*, *discrete_action=False*)

Markov-Decision Process Dataset class.

MDPDataset is deisnged for reinforcement learning datasets to use them like supervised learning datasets.

```
from d3rlpy.dataset import MDPDataset

# 1000 steps of observations with shape of (100,)
observations = np.random.random((1000, 100))
# 1000 steps of actions with shape of (4,)
actions = np.random.random((1000, 4))
# 1000 steps of rewards
rewards = np.random.random(1000)
# 1000 steps of terminal flags
terminals = np.random.randint(2, size=1000)

dataset = MDPDataset(observations, actions, rewards, terminals)
```

The MDPDataset object automatically splits the given data into list of *d3rlpy.dataset.Episode* objects. Furthermore, the MDPDataset object behaves like a list in order to use with scikit-learn utilities.

```
# returns the number of episodes
len(dataset)

# access to the first episode
episode = dataset[0]

# iterate through all episodes
for episode in dataset:
    pass
```

Parameters

- **observations** (*numpy.ndarray*) – N-D array. If the observation is a vector, the shape should be *(N, dim_observation)*. If the observations is an image, the shape should be *(N, C, H, W)*.
- **actions** (*numpy.ndarray*) – N-D array. If the actions-space is continuous, the shape should be *(N, dim_action)*. If the action-space is discrete, the shape should be *(N,)*.
- **rewards** (*numpy.ndarray*) – array of scalar rewards.
- **terminals** (*numpy.ndarray*) – array of binary terminal flags.
- **discrete_action** (*bool*) – flag to use the given actions as discrete action-space actions.

Methods

__getitem__(*index*)

__len__()

__iter__()

append(*observations*, *actions*, *rewards*, *terminals*)

Appends new data.

Parameters

- **observations** (*numpy.ndarray*) – N-D array.
- **actions** (*numpy.ndarray*) – actions.
- **rewards** (*numpy.ndarray*) – rewards.
- **terminals** (*numpy.ndarray*) – terminals.

build_episodes()

Builds episode objects.

This method will be internally called when accessing the episodes property at the first time.

clip_reward(*low=None*, *high=None*)

Clips rewards in the given range.

Parameters

- **low** (*float*) – minimum value. If None, clipping is not performed on lower edge.
- **high** (*float*) – maximum value. If None, clipping is not performed on upper edge.

compute_stats()

Computes statistics of the dataset.

```
stats = dataset.compute_stats()

# return statistics
stats['return']['mean']
stats['return']['std']
stats['return']['min']
stats['return']['max']

# reward statistics
stats['reward']['mean']
stats['reward']['std']
stats['reward']['min']
stats['reward']['max']

# action (only with continuous control actions)
stats['action']['mean']
stats['action']['std']
stats['action']['min']
stats['action']['max']

# observation (only with numpy.ndarray observations)
stats['observation']['mean']
stats['observation']['std']
stats['observation']['min']
stats['observation']['max']
```

Returns statistics of the dataset.

Return type dict

dump (*fname*)
Saves dataset as HDF5.

Parameters **fname** (*str*) – file path.

extend (*dataset*)
Extend dataset by another dataset.

Parameters **dataset** (d3rlpy.dataset.MDPDataset) – dataset.

get_action_size ()
Returns dimension of action-space.

If *discrete_action=True*, the return value will be the maximum index +1 in the give actions.

Returns dimension of action-space.

Return type int

get_observation_shape ()
Returns observation shape.

Returns observation shape.

Return type tuple

is_action_discrete ()
Returns *discrete_action* flag.

Returns *discrete_action* flag.

Return type bool

classmethod load (*fname*)
Loads dataset from HDF5.

```
import numpy as np
from d3rlpy.dataset import MDPDataset

dataset = MDPDataset(np.random.random(10, 4),
                     np.random.random(10, 2),
                     np.random.random(10),
                     np.random.randint(2, size=10))

# save as HDF5
dataset.dump('dataset.h5')

# load from HDF5
new_dataset = MDPDataset.load('dataset.h5')
```

Parameters **fname** (*str*) – file path.

size ()
Returns the number of episodes in the dataset.

Returns the number of episodes.

Return type int

Attributes

actions
Returns the actions.

Returns array of actions.

Return type numpy.ndarray

episodes
Returns the episodes.

Returns list of *d3rlpy.dataset.Episode* objects.

Return type list(*d3rlpy.dataset.Episode*)

observations
Returns the observations.

Returns array of observations.

Return type numpy.ndarray

rewards
Returns the rewards.

Returns array of rewards

Return type numpy.ndarray

terminals
Returns the terminal flags.

Returns array of terminal flags.

Return type numpy.ndarray

3.3.2 d3rlpy.dataset.Episode

class d3rlpy.dataset.**Episode**(*observation_shape*, *action_size*, *observations*, *actions*, *rewards*)
Episode class.

This class is designed to hold data collected in a single episode.

Episode object automatically splits data into list of *d3rlpy.dataset.Transition* objects. Also Episode object behaves like a list object for ease of access to transitions.

```
# return the number of transitions
len(episode)

# access to the first transition
transitions = episode[0]

# iterate through all transitions
for transition in episode:
    pass
```

Parameters

- **observation_shape** (*tuple*) – observation shape.
- **action_size** (*int*) – dimension of action-space.

- **observations** (*numpy.ndarray*) – observations.
- **actions** (*numpy.ndarray*) – actions.
- **rewards** (*numpy.ndarray*) – scalar rewards.
- **terminals** (*numpy.ndarray*) – binary terminal flags.

Methods

__getitem__(*index*)

__len__()

__iter__()

build_transitions()
Builds transition objects.

This method will be internally called when accessing the transitions property at the first time.

compute_return()
Computes sum of rewards.

$$R = \sum_{i=1} r_i$$

Returns episode return.

Return type float

get_action_size()
Returns dimension of action-space.

Returns dimension of action-space.

Return type int

get_observation_shape()
Returns observation shape.

Returns observation shape.

Return type tuple

size()
Returns the number of transitions.

Returns the number of transitions.

Return type int

Attributes

actions
Returns the actions.

Returns array of actions.

Return type numpy.ndarray

observations
Returns the observations.

Returns array of observations.

Return type numpy.ndarray

rewards
Returns the rewards.

Returns array of rewards.

Return type numpy.ndarray

transitions
Returns the transitions.

Returns list of *d3rlpy.dataset.Transition* objects.

Return type list(*d3rlpy.dataset.Transition*)

3.3.3 d3rlpy.dataset.Transition

class d3rlpy.dataset.**Transition**
Transition class.

This class is designed to hold data between two time steps, which is usually used as inputs of loss calculation in reinforcement learning.

Parameters

- **observation_shape** (*tuple*) – observation shape.
- **action_size** (*int*) – dimension of action-space.
- **observation** (*numpy.ndarray*) – observation at *t*.
- **action** (*numpy.ndarray or int*) – action at *t*.
- **reward** (*float*) – reward at *t*.
- **next_observation** (*numpy.ndarray*) – observation at *t+1*.
- **next_action** (*numpy.ndarray or int*) – action at *t+1*.
- **next_reward** (*float*) – reward at *t+1*.
- **terminal** (*int*) – terminal flag at *t+1*.
- **prev_transition** (d3rlpy.dataset.Transition) – pointer to the previous transition.
- **next_transition** (d3rlpy.dataset.Transition) – pointer to the next transition.

Methods

clear_links()
Clears links to the next and previous transitions.

This method is necessary to call when freeing this instance by GC.

get_action_size()
Returns dimension of action-space.

Returns dimension of action-space.

Return type int

get_observation_shape()

Returns observation shape.

Returns observation shape.

Return type tuple

Attributes

action

Returns action at *t*.

Returns action at *t*.

Return type (numpy.ndarray or int)

next_action

Returns action at *t+1*.

Returns action at *t+1*.

Return type (numpy.ndarray or int)

next_observation

Returns observation at *t+1*.

Returns observation at *t+1*.

Return type numpy.ndarray or torch.Tensor

next_reward

Returns reward at *t+1*.

Returns reward at *t+1*.

Return type float

next_transition

Returns pointer to the next transition.

If this is the last transition, this method should return `None`.

Returns next transition.

Return type *d3rlpy.dataset.Transition*

observation

Returns observation at *t*.

Returns observation at *t*.

Return type numpy.ndarray or torch.Tensor

prev_transition

Returns pointer to the previous transition.

If this is the first transition, this method should return `None`.

Returns previous transition.

Return type *d3rlpy.dataset.Transition*

reward

Returns reward at *t*.

Returns reward at *t*.

Return type float

terminal
Returns terminal flag at *t+1*.

Returns terminal flag at *t+1*.

Return type int

3.3.4 d3rlpy.dataset.TransitionMiniBatch

class d3rlpy.dataset.**TransitionMiniBatch**
mini-batch of Transition objects.

This class is designed to hold *d3rlpy.dataset.Transition* objects for being passed to algorithms during fitting.

If the observation is image, you can stack arbitrary frames via n_frames.

```
transition.observation.shape == (3, 84, 84)

batch_size = len(transitions)

# stack 4 frames
batch = TransitionMiniBatch(transitions, n_frames=4)

# 4 frames x 3 channels
batch.observations.shape == (batch_size, 12, 84, 84)
```

This is implemented by tracing previous transitions through prev_transition property.

Parameters

- **transitions** (*list* (d3rlpy.dataset.Transition)) – mini-batch of transitions.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **n_steps** (*int*) – length of N-step sampling.
- **gamma** (*float*) – discount factor for N-step calculation.

Methods

__getitem__(*key*, /)
Return self[key].

__len__()
Return len(self).

__iter__()
Implement iter(self).

size()
Returns size of mini-batch.

Returns mini-batch size.

Return type int

Attributes

actions

Returns mini-batch of actions at *t*.

Returns actions at *t*.

Return type numpy.ndarray

n_steps

Returns mini-batch of the number of steps before next observations.

This will always include only ones if `n_steps=1`. If `n_steps` is bigger than `1`. the values will depend on its episode length.

Returns the number of steps before next observations.

Return type numpy.ndarray

next_actions

Returns mini-batch of actions at *t+n*.

Returns actions at *t+n*.

Return type numpy.ndarray

next_observations

Returns mini-batch of observations at *t+n*.

Returns observations at *t+n*.

Return type numpy.ndarray or torch.Tensor

next_rewards

Returns mini-batch of rewards at *t+n*.

Returns rewards at *t+n*.

Return type numpy.ndarray

observations

Returns mini-batch of observations at *t*.

Returns observations at *t*.

Return type numpy.ndarray or torch.Tensor

rewards

Returns mini-batch of rewards at *t*.

Returns rewards at *t*.

Return type numpy.ndarray

terminals

Returns mini-batch of terminal flags at *t+n*.

Returns terminal flags at *t+n*.

Return type numpy.ndarray

transitions

Returns transitions.

Returns list of transitions.

Return type *d3rlpy.dataset.Transition*

3.4 Datasets

d3rlpy provides datasets for experimenting data-driven deep reinforcement learning algorithms.

d3rlpy.datasets.get_cartpole	Returns cartpole dataset and environment.
d3rlpy.datasets.get_pendulum	Returns pendulum dataset and environment.
d3rlpy.datasets.get_pybullet	Returns pybullet dataset and envrironment.
d3rlpy.datasets.get_atari	Returns atari dataset and envrironment.

3.4.1 d3rlpy.datasets.get_cartpole

d3rlpy.datasets.**get_cartpole**()

Returns cartpole dataset and environment.

The dataset is automatically downloaded to *d3rlpy_data/cartpole.pkl* if it does not exist.

Returns tuple of *d3rlpy.dataset.MDPDataset* and gym environment.

Return type Tuple[*d3rlpy.dataset.MDPDataset*, gym.core.Env]

3.4.2 d3rlpy.datasets.get_pendulum

d3rlpy.datasets.**get_pendulum**()

Returns pendulum dataset and environment.

The dataset is automatically downloaded to *d3rlpy_data/pendulum.pkl* if it does not exist.

Returns tuple of *d3rlpy.dataset.MDPDataset* and gym environment.

Return type Tuple[*d3rlpy.dataset.MDPDataset*, gym.core.Env]

3.4.3 d3rlpy.datasets.get_pybullet

d3rlpy.datasets.**get_pybullet**(*env_name*)

Returns pybullet dataset and envrironment.

The dataset is provided through d4rl-pybullet. See more details including available dataset from its GitHub page.

```
from d3rlpy.datasets import get_pybullet

dataset, env = get_pybullet('hopper-bullet-mixed-v0')
```

References

- https://github.com/takuseno/d4rl-pybullet

Parameters **env_name** (*str*) – environment id of d4rl-pybullet dataset.

Returns tuple of *d3rlpy.dataset.MDPDataset* and gym environment.

Return type Tuple[*d3rlpy.dataset.MDPDataset*, gym.core.Env]

3.4.4 d3rlpy.datasets.get_atari

d3rlpy.datasets.**get_atari**(*env_name*)

Returns atari dataset and envrironment.

The dataset is provided through d4rl-atari. See more details including available dataset from its GitHub page.

```
from d3rlpy.datasets import get_atari

dataset, env = get_atari('breakout-mixed-v0')
```

References

- https://github.com/takuseno/d4rl-atari

Parameters **env_name** (*str*) – environment id of d4rl-atari dataset.

Returns tuple of *d3rlpy.dataset.MDPDataset* and gym environment.

Return type Tuple[*d3rlpy.dataset.MDPDataset*, gym.core.Env]

3.5 Preprocessing

d3rlpy provides several preprocessors tightly incorporated with algorithms. Each preprocessor is implemented with PyTorch operation, which will be included in the model exported by *save_policy* method.

```
from d3rlpy.algos import CQL
from d3rlpy.dataset import MDPDataset

dataset = MDPDataset(...)

# choose from ['pixel', 'min_max', 'standard'] or None
cql = CQL(scaler='standard')

# scaler is fitted from the given episodes
cql.fit(dataset.episodes)

# preprocesing is included in TorchScript
cql.save_policy('policy.pt')

# you don't need to take care of preprocessing at production
policy = torch.jit.load('policy.pt')
action = policy(unpreprocessed_x)
```

You can also initialize scalers by yourself.

```
from d3rlpy.preprocessing import StandardScaler

scaler = StandardScaler(mean=..., std=...)

cql = CQL(scaler=scaler)
```

d3rlpy.preprocessing.PixelScaler	Pixel normalization preprocessing.

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Table 6 – continued from previous page

d3rlpy.preprocessing.MinMaxScaler	Min-Max normalization preprocessing.
d3rlpy.preprocessing.StandardScaler	Standardization preprocessing.

3.5.1 d3rlpy.preprocessing.PixelScaler

class d3rlpy.preprocessing.**PixelScaler**

Pixel normalization preprocessing.

$$x' = x/255$$

```
from d3rlpy.dataset import MDPDataset
from d3rlpy.algos import CQL

dataset = MDPDataset(observations, actions, rewards, terminals)

# initialize algorithm with PixelScaler
cql = CQL(scaler='pixel')

cql.fit(dataset.episodes)
```

Methods

fit(*episodes*)

Parameters **episodes** (*List[d3rlpy.dataset.Episode]*) –

Return type None

get_params(*deep=False*)

Returns scaling parameters.

PixelScaler returns empty dictionary.

Parameters **deep** (*bool*) – flag to deeply copy objects.

Returns empty dictionary.

Return type Dict[str, Any]

get_type()

Returns a scaler type.

Returns scaler type.

Return type str

reverse_transform(*x*)

Returns reversely transformed observations.

Parameters **x** (*torch.Tensor*) – normalized observation tensor.

Returns unnormalized pixel observation tensor.

Return type torch.Tensor

transform(*x*)

Returns normalized pixel observations.

Parameters **x** (*torch.Tensor*) – pixel observation tensor.

Returns normalized pixel observation tensor.

Return type torch.Tensor

Attributes

TYPE: ClassVar[str] = 'pixel'

3.5.2 d3rlpy.preprocessing.MinMaxScaler

class d3rlpy.preprocessing.**MinMaxScaler**(*dataset=None*, *maximum=None*, *minimum=None*)

Min-Max normalization preprocessing.

$$x' = (x - \min x)/(\max x - \min x)$$

```
from d3rlpy.dataset import MDPDataset
from d3rlpy.algos import CQL

dataset = MDPDataset(observations, actions, rewards, terminals)

# initialize algorithm with MinMaxScaler
cql = CQL(scaler='min_max')

# scaler is initialized from the given episodes
cql.fit(dataset.episodes)
```

You can also initialize with *d3rlpy.dataset.MDPDataset* object or manually.

```
from d3rlpy.preprocessing import MinMaxScaler

# initialize with dataset
scaler = MinMaxScaler(dataset)

# initialize manually
minimum = observations.min(axis=0)
maximum = observations.max(axis=0)
scaler = MinMaxScaler(minimum=minimum, maximum=maximum)

cql = CQL(scaler=scaler)
```

Parameters

- **dataset** (d3rlpy.dataset.MDPDataset) – dataset object.
- **min** (*numpy.ndarray*) – minimum values at each entry.
- **max** (*numpy.ndarray*) – maximum values at each entry.

Methods

fit (*episodes*)
Fits minimum and maximum from list of episodes.

Parameters **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes.

Return type None

get_params (*deep=False*)
Returns scaling parameters.

Parameters **deep** (*bool*) – flag to deeply copy objects.

Returns *maximum* and *minimum*.

Return type Dict[str, Any]

get_type ()
Returns a scaler type.

Returns scaler type.

Return type str

reverse_transform (*x*)
Returns reversely transformed observations.

Parameters **x** (*torch.Tensor*) – normalized observation tensor.

Returns unnormalized observation tensor.

Return type torch.Tensor

transform (*x*)
Returns normalized observation tensor.

Parameters **x** (*torch.Tensor*) – observation tensor.

Returns normalized observation tensor.

Return type torch.Tensor

Attributes

TYPE: ClassVar[str] = 'min_max'

3.5.3 d3rlpy.preprocessing.StandardScaler

class d3rlpy.preprocessing.**StandardScaler** (*dataset=None*, *mean=None*, *std=None*)
Standardization preprocessing.

$$x' = (x - \mu)/\sigma$$

```
from d3rlpy.dataset import MDPDataset
from d3rlpy.algos import CQL

dataset = MDPDataset(observations, actions, rewards, terminals)

# initialize algorithm with StandardScaler
```

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```
cql = CQL(scaler='standard')

# scaler is initialized from the given episodes
cql.fit(dataset.episodes)
```

You can initialize with `d3rlpy.dataset.MDPDataset` object or manually.

```
from d3rlpy.preprocessing import StandardScaler

# initialize with dataset
scaler = StandardScaler(dataset)

# initialize manually
mean = observations.mean(axis=0)
std = observations.std(axis=0)
scaler = StandardScaler(mean=mean, std=std)

cql = CQL(scaler=scaler)
```

Parameters

- **dataset** (`d3rlpy.dataset.MDPDataset`) – dataset object.
- **mean** (*numpy.ndarray*) – mean values at each entry.
- **std** (*numpy.ndarray*) – standard deviation at each entry.

Methods

fit(*episodes*)

Fits mean and standard deviation from list of episodes.

Parameters **episodes** (*List[*d3rlpy.dataset.Episode*]*) – list of episodes.

Return type None

get_params(*deep=False*)

Returns scaling parameters.

Parameters **deep** (*bool*) – flag to deeply copy objects.

Returns *mean* and *std*.

Return type Dict[str, Any]

get_type()

Returns a scaler type.

Returns scaler type.

Return type str

reverse_transform(*x*)

Returns reversely transformed observation tensor.

Parameters **x** (*torch.Tensor*) – standardized observation tensor.

Returns unstandardized observation tensor.

Return type torch.Tensor

transform(*x*)

Returns standardized observation tensor.

Parameters **x** (*torch.Tensor*) – observation tensor.

Returns standardized observation tensor.

Return type torch.Tensor

Attributes

TYPE: ClassVar[str] = 'standard'

3.6 Optimizers

d3rlpy provides `OptimizerFactory` that gives you flexible control over optimizers. `OptimizerFactory` takes PyTorch's optimizer class and its arguments to initialize, which you can check more here.

```
from torch.optim import Adam
from d3rlpy.algos import DQN
from d3rlpy.models.optimizers import OptimizerFactory

# modify weight decay
optim_factory = OptimizerFactory(Adam, weight_decay=1e-4)

# set OptimizerFactory
dqn = DQN(optim_factory=optim_factory)
```

There are also convenient alises.

```
from d3rlpy.models.optimizers import AdamFactory

# alias for Adam optimizer
optim_factory = AdamFactory(weight_decay=1e-4)

dqn = DQN(optim_factory=optim_factory)
```

d3rlpy.models.optimizers.OptimizerFactory	A factory class that creates an optimizer object in a lazy way.
d3rlpy.models.optimizers.SGDFactory	An alias for SGD optimizer.
d3rlpy.models.optimizers.AdamFactory	An alias for Adam optimizer.
d3rlpy.models.optimizers.RMSpropFactory	An alias for RMSprop optimizer.

3.6.1 d3rlpy.models.optimizers.OptimizerFactory

class d3rlpy.models.optimizers.**OptimizerFactory**(*optim_cls*, ***kwargs*)

A factory class that creates an optimizer object in a lazy way.

The optimizers in algorithms can be configured through this factory class.

```
from torch.optim Adam
from d3rlpy.optimizers import OptimizerFactory
from d3rlpy.algos import DQN

factory = OptimizerFactory(Adam, eps=0.001)

dqn = DQN(optim_factory=factory)
```

Parameters

- **optim_cls** – An optimizer class.
- **kwargs** – arbitrary keyword-arguments.

Methods

create(*params*, *lr*)

Returns an optimizer object.

Parameters

- **params** (*list*) – a list of PyTorch parameters.
- **lr** (*float*) – learning rate.

Returns an optimizer object.

Return type torch.optim.Optimizer

get_params(*deep=False*)

Returns optimizer parameters.

Parameters **deep** (*bool*) – flag to deeply copy the parameters.

Returns optimizer parameters.

Return type Dict[str, Any]

3.6.2 d3rlpy.models.optimizers.SGDFactory

class d3rlpy.models.optimizers.**SGDFactory**(*momentum=0*, *dampening=0*, *weight_decay=0*, *nesterov=False*, ***kwargs*)

An alias for SGD optimizer.

```
from d3rlpy.optimizers import SGDFactory

factory = SGDFactory(weight_decay=1e-4)
```

Parameters

- **momentum** – momentum factor.
- **dampening** – dampening for momentum.

- **weight_decay** – weight decay (L2 penalty).
- **nesterov** – flag to enable Nesterov momentum.

Methods

create (*params*, *lr*)
Returns an optimizer object.

Parameters

- **params** (*list*) – a list of PyTorch parameters.
- **lr** (*float*) – learning rate.

Returns an optimizer object.

Return type torch.optim.Optimizer

get_params (*deep=False*)
Returns optimizer parameters.

Parameters **deep** (*bool*) – flag to deeply copy the parameters.

Returns optimizer parameters.

Return type Dict[str, Any]

3.6.3 d3rlpy.models.optimizers.AdamFactory

class d3rlpy.models.optimizers.**AdamFactory** (*betas=(0.9, 0.999)*, *eps=1e-08*, *weight_decay=0*, *amsgrad=False*, ***kwargs*)
An alias for Adam optimizer.

```
from d3rlpy.optimizers import AdamFactory

factory = AdamFactory(weight_decay=1e-4)
```

Parameters

- **betas** – coefficients used for computing running averages of gradient and its square.
- **eps** – term added to the denominator to improve numerical stability.
- **weight_decay** – weight decay (L2 penalty).
- **amsgrad** – flag to use the AMSGrad variant of this algorithm.

Methods

create (*params*, *lr*)
Returns an optimizer object.

Parameters

- **params** (*list*) – a list of PyTorch parameters.
- **lr** (*float*) – learning rate.

Returns an optimizer object.

Return type torch.optim.Optimizer

get_params (*deep=False*)

Returns optimizer parameters.

Parameters **deep** (*bool*) – flag to deeply copy the parameters.

Returns optimizer parameters.

Return type Dict[str, Any]

3.6.4 d3rlpy.models.optimizers.RMSpropFactory

class d3rlpy.models.optimizers.**RMSpropFactory** (*alpha=0.95*, *eps=0.01*, *weight_decay=0*, *momentum=0*, *centered=True*, ***kwargs*)

An alias for RMSprop optimizer.

```
from d3rlpy.optimizers import RMSpropFactory

factory = RMSpropFactory(weight_decay=1e-4)
```

Parameters

- **alpha** – smoothing constant.
- **eps** – term added to the denominator to improve numerical stability.
- **weight_decay** – weight decay (L2 penalty).
- **momentum** – momentum factor.
- **centered** – flag to compute the centered RMSProp, the gradient is normalized by an estimation of its variance.

Methods

create (*params*, *lr*)

Returns an optimizer object.

Parameters

- **params** (*list*) – a list of PyTorch parameters.
- **lr** (*float*) – learning rate.

Returns an optimizer object.

Return type torch.optim.Optimizer

get_params (*deep=False*)

Returns optimizer parameters.

Parameters **deep** (*bool*) – flag to deeply copy the parameters.

Returns optimizer parameters.

Return type Dict[str, Any]

3.7 Network Architectures

In d3rlpy, the neural network architecture is automatically selected based on observation shape. If the observation is image, the algorithm uses the `Nature DQN`-based encoder at each function. Otherwise, the standard MLP architecture that consists with two linear layers with `256` hidden units.

Furthermore, d3rlpy provides `EncoderFactory` that gives you flexible control over this neural netowrk architectures.

```
from d3rlpy.algos import DQN
from d3rlpy.models.encoders import VectorEncoderFactory

# encoder factory
encoder_factory = VectorEncoderFactory(hidden_units=[300, 400],
                                       activation='tanh')

# set OptimizerFactory
dqn = DQN(encoder_factory=encoder_factory)
```

You can also build your own encoder factory.

```
import torch
import torch.nn as nn

from d3rlpy.models.encoders import EncoderFactory

# your own neural network
class CustomEncoder(nn.Module):
    def __init__(self, obsevation_shape, feature_size):
        self.feature_size = feature_size
        self.fc1 = nn.Linear(observation_shape[0], 64)
        self.fc2 = nn.Linear(64, feature_size)

    def forward(self, x):
        h = torch.relu(self.fc1(x))
        h = torch.relu(self.fc2(h))
        return h

    # THIS IS IMPORTANT!
    def get_feature_size(self):
        return self.feature_size

# your own encoder factory
class CustomEncoderFactory(EncoderFactory):
    TYPE = 'custom' # this is necessary

    def __init__(self, feature_size):
        self.feature_size = feature_size

    def create(self, observation_shape, action_size=None, discrete_action=False):
        return CustomEncoder(observation_shape, self.feature_size)

    def get_params(self, deep=False):
        return {
            'feature_size': self.feature_size
        }

dqn = DQN(encoder_factory=CustomEncoderFactory(feature_size=64))
```

You can also share the factory across functions as below.

```
class CustomEncoderWithAction(nn.Module):
    def __init__(self, obsevation_shape, action_size, feature_size):
        self.feature_size = feature_size
        self.fc1 = nn.Linear(observation_shape[0] + action_size, 64)
        self.fc2 = nn.Linear(64, feature_size)

    def forward(self, x, action): # action is also given
        h = torch.cat([x, action], dim=1)
        h = torch.relu(self.fc1(h))
        h = torch.relu(self.fc2(h))
        return h

    def get_feature_size(self):
        return self.feature_size

class CustomEncoderFactory(EncoderFactory):
    TYPE = 'custom' # this is necessary

    def __init__(self, feature_size):
        self.feature_size = feature_size

    def create(self, observation_shape, action_size=None, discrete_action=False):
        # branch based on if ``action_size`` is given.
        if action_size is None:
            return CustomEncoder(observation_shape, self.feature_size)
        else:
            return CustomEncoderWithAction(observation_shape,
                                           action_size,
                                           self.feature_size)

    def get_params(self, deep=False):
        return {
            'feature_size': self.feature_size
        }

from d3rlpy.algos import SAC

factory = CustomEncoderFactory(feature_size=64)

sac = SAC(actor_encoder_factory=factory, critic_encoder_factory=factory)
```

If you want `from_json` method to load the algorithm configuration including your encoder configuration, you need to register your encoder factory.

```
from d3rlpy.models.encoders import register_encoder_factory

# register your own encoder factory
register_encoder_factory(CustomEncoderFactory)

# load algorithm from json
dqn = DQN.from_json('<path-to-json>/params.json')
```

Once you register your encoder factory, you can specify it via `TYPE` value.

```
dqn = DQN(encoder_factory='custom')
```

d3rlpy.models.encoders.DefaultEncoderFactory	Default encoder factory class.
d3rlpy.models.encoders.PixelEncoderFactory	Pixel encoder factory class.
d3rlpy.models.encoders.VectorEncoderFactory	Vector encoder factory class.
d3rlpy.models.encoders.DenseEncoderFactory	DenseNet encoder factory class.

3.7.1 d3rlpy.models.encoders.DefaultEncoderFactory

class d3rlpy.models.encoders.**DefaultEncoderFactory**(*activation='relu'*, *use_batch_norm=False*)

Default encoder factory class.

This encoder factory returns an encoder based on observation shape.

Parameters

- **activation** (*str*) – activation function name.
- **use_batch_norm** (*bool*) – flag to insert batch normalization layers.

Methods

create(*observation_shape*)

Returns PyTorch's state enocder module.

Parameters **observation_shape** (*Sequence[int]*) – observation shape.

Returns an enocder object.

Return type d3rlpy.models.torch.encoders.Encoder

create_with_action(*observation_shape*, *action_size*, *discrete_action=False*)

Returns PyTorch's state-action enocder module.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – action size. If None, the encoder does not take action as input.
- **discrete_action** (*bool*) – flag if action-space is discrete.

Returns an enocder object.

Return type d3rlpy.models.torch.encoders.EncoderWithAction

get_params(*deep=False*)

Returns encoder parameters.

Parameters **deep** (*bool*) – flag to deeply copy the parameters.

Returns encoder parameters.

Return type Dict[str, Any]

get_type()

Returns encoder type.

Returns encoder type.

Return type str

Attributes

TYPE: ClassVar[str] = 'default'

3.7.2 d3rlpy.models.encoders.PixelEncoderFactory

class d3rlpy.models.encoders.**PixelEncoderFactory**(*filters=None*, *feature_size=512*, *activation='relu'*, *use_batch_norm=False*)

Pixel encoder factory class.

This is the default encoder factory for image observation.

Parameters

- **filters** (*list*) – list of tuples consisting with `(filter_size, kernel_size, stride)`. If None, `Nature DQN`-based architecture is used.
- **feature_size** (*int*) – the last linear layer size.
- **activation** (*str*) – activation function name.
- **use_batch_norm** (*bool*) – flag to insert batch normalization layers.

Methods

create(*observation_shape*)

Returns PyTorch's state enocder module.

Parameters **observation_shape** (*Sequence[int]*) – observation shape.

Returns an enocder object.

Return type d3rlpy.models.torch.encoders.PixelEncoder

create_with_action(*observation_shape*, *action_size*, *discrete_action=False*)

Returns PyTorch's state-action enocder module.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – action size. If None, the encoder does not take action as input.
- **discrete_action** (*bool*) – flag if action-space is discrete.

Returns an enocder object.

Return type d3rlpy.models.torch.encoders.PixelEncoderWithAction

get_params(*deep=False*)

Returns encoder parameters.

Parameters **deep** (*bool*) – flag to deeply copy the parameters.

Returns encoder parameters.

Return type Dict[str, Any]

get_type()

Returns encoder type.

Returns encoder type.

Return type str

Attributes

TYPE: ClassVar[str] = 'pixel'

3.7.3 d3rlpy.models.encoders.VectorEncoderFactory

class d3rlpy.models.encoders.**VectorEncoderFactory**(*hidden_units=None*, *activation='relu'*, *use_batch_norm=False*, *use_dense=False*)

Vector encoder factory class.

This is the default encoder factory for vector observation.

Parameters

- **hidden_units** (*list*) – list of hidden unit sizes. If None, the standard architecture with [256, 256] is used.
- **activation** (*str*) – activation function name.
- **use_batch_norm** (*bool*) – flag to insert batch normalization layers.
- **use_dense** (*bool*) – flag to use DenseNet architecture.

Methods

create(*observation_shape*)

Returns PyTorch's state enocder module.

Parameters **observation_shape** (*Sequence[int]*) – observation shape.

Returns an enocder object.

Return type d3rlpy.models.torch.encoders.VectorEncoder

create_with_action(*observation_shape*, *action_size*, *discrete_action=False*)

Returns PyTorch's state-action enocder module.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – action size. If None, the encoder does not take action as input.
- **discrete_action** (*bool*) – flag if action-space is discrete.

Returns an enocder object.

Return type d3rlpy.models.torch.encoders.VectorEncoderWithAction

get_params(*deep=False*)

Returns encoder parameters.

Parameters **deep** (*bool*) – flag to deeply copy the parameters.

Returns encoder parameters.

Return type Dict[str, Any]

get_type()

Returns encoder type.

Returns encoder type.

Return type str

Attributes

TYPE: ClassVar[str] = 'vector'

3.7.4 d3rlpy.models.encoders.DenseEncoderFactory

class d3rlpy.models.encoders.**DenseEncoderFactory**(*activation='relu'*, *use_batch_norm=False*)

DenseNet encoder factory class.

This is an alias for DenseNet architecture proposed in D2RL. This class does exactly same as follows.

```
from d3rlpy.encoders import VectorEncoderFactory

factory = VectorEncoderFactory(hidden_units=[256, 256, 256, 256],
                               use_dense=True)
```

For now, this only supports vector observations.

References

- Sinha et al., D2RL: Deep Dense Architectures in Reinforcement Learning.

Parameters

- **activation** (*str*) – activation function name.
- **use_batch_norm** (*bool*) – flag to insert batch normalization layers.

Methods

create(*observation_shape*)

Returns PyTorch's state enocder module.

Parameters **observation_shape** (*Sequence[int]*) – observation shape.

Returns an enocder object.

Return type d3rlpy.models.torch.encoders.VectorEncoder

create_with_action(*observation_shape*, *action_size*, *discrete_action=False*)

Returns PyTorch's state-action enocder module.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – action size. If None, the encoder does not take action as input.

- **discrete_action** (*bool*) – flag if action-space is discrete.

Returns an enocder object.

Return type d3rlpy.models.torch.encoders.VectorEncoderWithAction

get_params (*deep=False*)
Returns encoder parameters.

Parameters **deep** (*bool*) – flag to deeply copy the parameters.

Returns encoder parameters.

Return type Dict[str, Any]

get_type ()
Returns encoder type.

Returns encoder type.

Return type str

Attributes

TYPE: ClassVar[str] = 'dense'

3.8 Data Augmentation

d3rlpy provides data augmentation techniques tightly integrated with reinforcement learning algorithms.

1. Kostrikov et al., Image Augmentation Is All You Need: Regularizing Deep Reinforcement Learning from Pixels.
2. Laskin et al., Reinforcement Learning with Augmented Data.

   Efficient data augmentation potentially boosts algorithm performance significantly.

```
from d3rlpy.algos import DiscreteCQL

# choose data augmentation types
cql = DiscreteCQL(augmentation=['random_shift', 'intensity'])
```

You can also tune data augmentation parameters by yourself.

```
from d3rlpy.augmentation.image import RandomShift

random_shift = RandomShift(shift_size=10)

cql = DiscreteCQL(augmentation=[random_shift, 'intensity'])
```

3.8.1 Image Observation

d3rlpy.augmentation.image.RandomShift	Random shift augmentation.
d3rlpy.augmentation.image.Cutout	Cutout augmentation.
d3rlpy.augmentation.image.HorizontalFlip	Horizontal flip augmentation.
d3rlpy.augmentation.image.VerticalFlip	Vertical flip augmentation.
d3rlpy.augmentation.image.RandomRotation	Random rotation augmentation.
d3rlpy.augmentation.image.Intensity	Intensity augmentation.
d3rlpy.augmentation.image.ColorJitter	Color Jitter augmentation.

d3rlpy.augmentation.image.RandomShift

class d3rlpy.augmentation.image.**RandomShift**(*shift_size=4*)

Random shift augmentation.

References

- Kostrikov et al., Image Augmentation Is All You Need: Regularizing Deep Reinforcement Learning from Pixels.

Parameters **shift_size** (*int*) – size to shift image.

Methods

get_params(*deep=False*)

Returns augmentation parameters.

Parameters **deep** (*bool*) – flag to copy parameters.

Returns augmentation parameters.

Return type Dict[str, Any]

get_type()

Returns augmentation type.

Returns augmentation type.

Return type str

transform(*x*)

Returns augmented observation.

Parameters **x** (*torch.Tensor*) – observation.

Returns augmented observation.

Return type torch.Tensor

Attributes

TYPE: ClassVar[str] = 'random_shift'

d3rlpy.augmentation.image.Cutout

class d3rlpy.augmentation.image.**Cutout**(*probability=0.5*)

Cutout augmentation.

References

- Kostrikov et al., Image Augmentation Is All You Need: Regularizing Deep Reinforcement Learning from Pixels.

Parameters **probability** (*float*) – probability to cutout.

Methods

get_params(*deep=False*)

Returns augmentation parameters.

Parameters **deep** (*bool*) – flag to copy parameters.

Returns augmentation parameters.

Return type Dict[str, Any]

get_type()

Returns augmentation type.

Returns augmentation type.

Return type str

transform(*x*)

Returns augmented observation.

Parameters **x** (*torch.Tensor*) – observation.

Returns augmented observation.

Return type torch.Tensor

Attributes

TYPE: ClassVar[str] = 'cutout'

d3rlpy.augmentation.image.HorizontalFlip

class d3rlpy.augmentation.image.**HorizontalFlip**(*probability=0.1*)

Horizontal flip augmentation.

References

- Kostrikov et al., Image Augmentation Is All You Need: Regularizing Deep Reinforcement Learning from Pixels.

Parameters **probability** (*float*) – probability to flip horizontally.

Methods

get_params(*deep=False*)

Returns augmentation parameters.

Parameters **deep** (*bool*) – flag to copy parameters.

Returns augmentation parameters.

Return type Dict[str, Any]

get_type()

Returns augmentation type.

Returns augmentation type.

Return type str

transform(*x*)

Returns augmented observation.

Parameters **x** (*torch.Tensor*) – observation.

Returns augmented observation.

Return type torch.Tensor

Attributes

TYPE: ClassVar[str] = 'horizontal_flip'

d3rlpy.augmentation.image.VerticalFlip

class d3rlpy.augmentation.image.**VerticalFlip**(*probability=0.1*)

Vertical flip augmentation.

References

- Kostrikov et al., Image Augmentation Is All You Need: Regularizing Deep Reinforcement Learning from Pixels.

Parameters **probability** (*float*) – probability to flip vertically.

Methods

get_params(*deep=False*)
Returns augmentation parameters.

Parameters **deep** (*bool*) – flag to copy parameters.

Returns augmentation parameters.

Return type Dict[str, Any]

get_type()
Returns augmentation type.

Returns augmentation type.

Return type str

transform(*x*)
Returns augmented observation.

Parameters **x** (*torch.Tensor*) – observation.

Returns augmented observation.

Return type torch.Tensor

Attributes

TYPE: ClassVar[str] = 'vertical_flip'

d3rlpy.augmentation.image.RandomRotation

class d3rlpy.augmentation.image.**RandomRotation**(*degree=5.0*)
Random rotation augmentation.

References

- Kostrikov et al., Image Augmentation Is All You Need: Regularizing Deep Reinforcement Learning from Pixels.

Parameters **degree** (*float*) – range of degrees to rotate image.

Methods

get_params(*deep=False*)
Returns augmentation parameters.

Parameters **deep** (*bool*) – flag to copy parameters.

Returns augmentation parameters.

Return type Dict[str, Any]

get_type()
Returns augmentation type.

Returns augmentation type.

Return type str

transform(*x*)
Returns augmented observation.

Parameters **x** (*torch.Tensor*) – observation.

Returns augmented observation.

Return type torch.Tensor

Attributes

TYPE: ClassVar[str] = 'random_rotation'

d3rlpy.augmentation.image.Intensity

class d3rlpy.augmentation.image.**Intensity**(*scale=0.1*)
Intensity augmentation.

$$x' = x + n$$

where $n \sim N(0, scale)$.

References

- Kostrikov et al., Image Augmentation Is All You Need: Regularizing Deep Reinforcement Learning from Pixels.

Parameters **scale** (*float*) – scale of multiplier.

Methods

get_params(*deep=False*)
Returns augmentation parameters.

Parameters **deep** (*bool*) – flag to copy parameters.

Returns augmentation parameters.

Return type Dict[str, Any]

get_type()
Returns augmentation type.

Returns augmentation type.

Return type str

transform(*x*)
Returns augmented observation.

Parameters **x** (*torch.Tensor*) – observation.

Returns augmented observation.

Return type torch.Tensor

Attributes

TYPE: ClassVar[str] = 'intensity'

d3rlpy.augmentation.image.ColorJitter

class d3rlpy.augmentation.image.**ColorJitter**(*brightness=(0.6, 1.4)*, *contrast=(0.6, 1.4)*, *saturation=(0.6, 1.4)*, *hue=(- 0.5, 0.5)*)
Color Jitter augmentation.

This augmentation modifies the given images in the HSV channel spaces as well as a contrast change. This augmentation will be useful with the real world images.

References

- Laskin et al., Reinforcement Learning with Augmented Data.

Parameters

- **brightness** (*tuple*) – brightness scale range.
- **contrast** (*tuple*) – contrast scale range.
- **saturation** (*tuple*) – saturation scale range.
- **hue** (*tuple*) – hue scale range.

Methods

get_params(*deep=False*)
Returns augmentation parameters.

Parameters **deep** (*bool*) – flag to copy parameters.

Returns augmentation parameters.

Return type Dict[str, Any]

get_type()
Returns augmentation type.

Returns augmentation type.

Return type str

transform (x)
Returns augmented observation.

Parameters **x** (*torch.Tensor*) – observation.

Returns augmented observation.

Return type torch.Tensor

Attributes

TYPE: ClassVar[str] = 'color_jitter'

3.8.2 Vector Observation

d3rlpy.augmentation.vector.SingleAmplitudeScaling	Single Amplitude Scaling augmentation.
d3rlpy.augmentation.vector.MultipleAmplitudeScaling	Multiple Amplitude Scaling augmentation.

d3rlpy.augmentation.vector.SingleAmplitudeScaling

class d3rlpy.augmentation.vector.**SingleAmplitudeScaling** (*minimum=0.8*, *maximum=1.2*)
Single Amplitude Scaling augmentation.

$$x' = x + z$$

where $z \sim \text{Unif}(minimum, maximum)$.

References

- Laskin et al., Reinforcement Learning with Augmented Data.

Parameters

- **minimum** (*float*) – minimum amplitude scale.
- **maximum** (*float*) – maximum amplitude scale.

Methods

get_params (*deep=False*)
Returns augmentation parameters.

Parameters **deep** (*bool*) – flag to copy parameters.

Returns augmentation parameters.

Return type Dict[str, Any]

get_type ()
Returns augmentation type.

Returns augmentation type.

Return type str

transform(*x*)
Returns augmented observation.

Parameters **x** (*torch.Tensor*) – observation.

Returns augmented observation.

Return type torch.Tensor

Attributes

TYPE: ClassVar[str] = 'single_amplitude_scaling'

d3rlpy.augmentation.vector.MultipleAmplitudeScaling

class d3rlpy.augmentation.vector.**MultipleAmplitudeScaling**(*minimum=0.8*, *maximum=1.2*)
Multiple Amplitude Scaling augmentation.

$$x' = x + z$$

where $z \sim \text{Unif}(minimum, maximum)$ and z is a vector with different amplitude scale on each.

References

- Laskin et al., Reinforcement Learning with Augmented Data.

Parameters

- **minimum** (*float*) – minimum amplitude scale.
- **maximum** (*float*) – maximum amplitude scale.

Methods

get_params(*deep=False*)
Returns augmentation parameters.

Parameters **deep** (*bool*) – flag to copy parameters.

Returns augmentation parameters.

Return type Dict[str, Any]

get_type()
Returns augmentation type.

Returns augmentation type.

Return type str

transform(*x*)
Returns augmented observation.

Parameters **x** (*torch.Tensor*) – observation.

Returns augmented observation.

Return type torch.Tensor

Attributes

TYPE: ClassVar[str] = 'multiple_amplitude_scaling'

3.8.3 Augmentation Pipeline

d3rlpy.augmentation.pipeline.DrQPipeline	Data-reguralized Q augmentation pipeline.

d3rlpy.augmentation.pipeline.DrQPipeline

class d3rlpy.augmentation.pipeline.**DrQPipeline**(*augmentations=None*, *n_mean=1*)
Data-reguralized Q augmentation pipeline.

References

- Kostrikov et al., Image Augmentation Is All You Need: Regularizing Deep Reinforcement Learning from Pixels.

Parameters

- **augmentations** (*list(d3rlpy.augmentation.base.Augmentation or str)*) – list of augmentations or augmentation types.
- **n_mean** (*int*) – the number of computations to average

Methods

append(*augmentation*)
Append augmentation to pipeline.

Parameters **augmentation** (*d3rlpy.augmentation.base.Augmentation*) – augmentation.

Return type None

get_augmentation_params()
Returns augmentation parameters.

Parameters **deep** – flag to deeply copy objects.

Returns list of augmentation parameters.

Return type List[Dict[str, Any]]

get_augmentation_types()
Returns augmentation types.

Returns list of augmentation types.

Return type List[str]

get_params (*deep=False*)
Returns pipeline parameters.

Returns piple parameters.

Parameters **deep** (*bool*) –

Return type Dict[str, Any]

process (*func*, *inputs*, *targets*)
Runs a given function while augmenting inputs.

Parameters

- **func** (*Callable[[..], torch.Tensor]*) – function to compute.
- **inputs** (*Dict[str, torch.Tensor]*) – inputs to the func.
- **target** – list of argument names to augment.
- **targets** (*List[str]*) –

Returns the computation result.

Return type torch.Tensor

transform (*x*)
Returns observation processed by all augmentations.

Parameters **x** (*torch.Tensor*) – observation tensor.

Returns processed observation tensor.

Return type torch.Tensor

Attributes

augmentations

3.9 Metrics

d3rlpy provides scoring functions without compromising scikit-learn compatibility. You can evaluate many metrics with test episodes during training.

```
from d3rlpy.datasets import get_cartpole
from d3rlpy.algos import DQN
from d3rlpy.metrics.scorer import td_error_scorer
from d3rlpy.metrics.scorer import average_value_estimation_scorer
from d3rlpy.metrics.scorer import evaluate_on_environment
from sklearn.model_selection import train_test_split

dataset, env = get_cartpole()

train_episodes, test_episodes = train_test_split(dataset)

dqn = DQN()

dqn.fit(train_episodes,
        eval_episodes=test_episodes,
        scorers={
```

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```
            'td_error': td_error_scorer,
            'value_scale': average_value_estimation_scorer,
            'environment': evaluate_on_environment(env)
        })
```

You can also use them with scikit-learn utilities.

```
from sklearn.model_selection import cross_validate

scores = cross_validate(dqn,
                        dataset,
                        scoring={
                            'td_error': td_error_scorer,
                            'environment': evaluate_on_environment(env)
                        })
```

3.9.1 Algorithms

d3rlpy.metrics.scorer.td_error_scorer	Returns average TD error (in negative scale).
d3rlpy.metrics.scorer.discounted_sum_of_advantage_scorer	Returns average of discounted sum of advantage (in negative scale).
d3rlpy.metrics.scorer.average_value_estimation_scorer	Returns average value estimation (in negative scale).
d3rlpy.metrics.scorer.value_estimation_std_scorer	Returns standard deviation of value estimation (in negative scale).
d3rlpy.metrics.scorer.initial_state_value_estimation_scorer	Returns mean estimated action-values at the initial states.
d3rlpy.metrics.scorer.soft_opc_scorer	Returns Soft Off-Policy Classification metrics.
d3rlpy.metrics.scorer.continuous_action_diff_scorer	Returns squared difference of actions between algorithm and dataset.
d3rlpy.metrics.scorer.discrete_action_match_scorer	Returns percentage of identical actions between algorithm and dataset.
d3rlpy.metrics.scorer.evaluate_on_environment	Returns scorer function of evaluation on environment.
d3rlpy.metrics.comparer.compare_continuous_action_diff	Returns scorer function of action difference between algorithms.
d3rlpy.metrics.comparer.compare_discrete_action_match	Returns scorer function of action matches between algorithms.

d3rlpy.metrics.scorer.td_error_scorer

d3rlpy.metrics.scorer.**td_error_scorer**(*algo*, *episodes*)

Returns average TD error (in negative scale).

This metics suggests how Q functions overfit to training sets. If the TD error is large, the Q functions are overfitting.

$$\mathbb{E}_{s_t,a_t,r_{t+1},s_{t+1}\sim D}[Q_\theta(s_t,a_t) - (r_t + \gamma \max_a Q_\theta(s_{t+1},a))^2]$$

Parameters

- **algo** (*d3rlpy.metrics.scorer.AlgoProtocol*) – algorithm.
- **episodes** (*List[*d3rlpy.dataset.Episode*]*) – list of episodes.

Returns negative average TD error.

Return type float

d3rlpy.metrics.scorer.discounted_sum_of_advantage_scorer

d3rlpy.metrics.scorer.**discounted_sum_of_advantage_scorer**(*algo*, *episodes*)

Returns average of discounted sum of advantage (in negative scale).

This metrics suggests how the greedy-policy selects different actions in action-value space. If the sum of advantage is small, the policy selects actions with larger estimated action-values.

$$\mathbb{E}_{s_t,a_t\sim D}[\sum_{t'=t} \gamma^{t'-t} A(s_{t'},a_{t'})]$$

where $A(s_t,a_t) = Q_\theta(s_t,a_t) - \max_a Q_\theta(s_t,a)$.

References

- Murphy., A generalization error for Q-Learning.

Parameters

- **algo** (*d3rlpy.metrics.scorer.AlgoProtocol*) – algorithm.
- **episodes** (*List[*d3rlpy.dataset.Episode*]*) – list of episodes.

Returns negative average of discounted sum of advantage.

Return type float

d3rlpy.metrics.scorer.average_value_estimation_scorer

d3rlpy.metrics.scorer.**average_value_estimation_scorer**(*algo*, *episodes*)

Returns average value estimation (in negative scale).

This metrics suggests the scale for estimation of Q functions. If average value estimation is too large, the Q functions overestimate action-values, which possibly makes training failed.

$$\mathbb{E}_{s_t\sim D}[\max_a Q_\theta(s_t,a)]$$

Parameters

- **algo** (*d3rlpy.metrics.scorer.AlgoProtocol*) – algorithm.
- **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes.

Returns negative average value estimation.

Return type float

d3rlpy.metrics.scorer.value_estimation_std_scorer

d3rlpy.metrics.scorer.**value_estimation_std_scorer**(*algo*, *episodes*)

Returns standard deviation of value estimation (in negative scale).

This metrics suggests how confident Q functions are for the given episodes. This metrics will be more accurate with *boostrap* enabled and the larger *n_critics* at algorithm. If standard deviation of value estimation is large, the Q functions are overfitting to the training set.

$$\mathbb{E}_{s_t \sim D, a \sim \text{argmax}_a Q_\theta(s_t, a)}[Q_{\text{std}}(s_t, a)]$$

where $Q_{\text{std}}(s, a)$ is a standard deviation of action-value estimation over ensemble functions.

Parameters

- **algo** (*d3rlpy.metrics.scorer.AlgoProtocol*) – algorithm.
- **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes.

Returns negative standard deviation.

Return type float

d3rlpy.metrics.scorer.initial_state_value_estimation_scorer

d3rlpy.metrics.scorer.**initial_state_value_estimation_scorer**(*algo*, *episodes*)

Returns mean estimated action-values at the initial states.

This metrics suggests how much return the trained policy would get from the initial states by deploying the policy to the states. If the estimated value is large, the trained policy is expected to get higher returns.

$$\mathbb{E}_{s_0 \sim D}[Q(s_0, \pi(s_0))]$$

References

- Paine et al., Hyperparameter Selection for Offline Reinforcement Learning

Parameters

- **algo** (*d3rlpy.metrics.scorer.AlgoProtocol*) – algorithm.
- **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes.

Returns mean action-value estimation at the initial states.

Return type float

d3rlpy.metrics.scorer.soft_opc_scorer

d3rlpy.metrics.scorer.**soft_opc_scorer**(*return_threshold*)

Returns Soft Off-Policy Classification metrics.

This function returns scorer function, which is suitable to the standard scikit-learn scorer function style. The metrics of the scorer funciton is evaluating gaps of action-value estimation between the success episodes and the all episodes. If the learned Q-function is optimal, action-values in success episodes are expected to be higher than the others. The success episode is defined as an episode with a return above the given threshold.

$$\mathbb{E}_{s,a \sim D_{success}}[Q(s,a)] - \mathbb{E}_{s,a \sim D}[Q(s,a)]$$

```
from d3rlpy.datasets import get_cartpole
from d3rlpy.algos import DQN
from d3rlpy.metrics.scorer import soft_opc_scorer
from sklearn.model_selection import train_test_split

dataset, _ = get_cartpole()
train_episodes, test_episodes = train_test_split(dataset, test_size=0.2)

scorer = soft_opc_scorer(return_threshold=180)

dqn = DQN()
dqn.fit(train_episodes,
        eval_episodes=test_episodes,
        scorers={'soft_opc': scorer})
```

References

- Irpan et al., Off-Policy Evaluation via Off-Policy Classification.

Parameters **return_threshold** (*float*) – threshold of success episodes.

Returns scorer function.

Return type Callable[[d3rlpy.metrics.scorer.AlgoProtocol, List[*d3rlpy.dataset.Episode*]], float]

d3rlpy.metrics.scorer.continuous_action_diff_scorer

d3rlpy.metrics.scorer.**continuous_action_diff_scorer**(*algo*, *episodes*)

Returns squared difference of actions between algorithm and dataset.

This metrics suggests how different the greedy-policy is from the given episodes in continuous action-space. If the given episodes are near-optimal, the small action difference would be better.

$$\mathbb{E}_{s_t,a_t \sim D}[(a_t - \pi_\phi(s_t))^2]$$

Parameters

- **algo** (*d3rlpy.metrics.scorer.AlgoProtocol*) – algorithm.
- **episodes** (*List[*d3rlpy.dataset.Episode*]*) – list of episodes.

Returns negative squared action difference.

Return type float

d3rlpy.metrics.scorer.discrete_action_match_scorer

d3rlpy.metrics.scorer.**discrete_action_match_scorer**(*algo*, *episodes*)

Returns percentage of identical actions between algorithm and dataset.

This metrics suggests how different the greedy-policy is from the given episodes in discrete action-space. If the given epsisdoes are near-optimal, the large percentage would be better.

$$\frac{1}{N}\sum^{N} \parallel \{a_t = \text{argmax}_a Q_\theta(s_t, a)\}$$

Parameters

- **algo** (*d3rlpy.metrics.scorer.AlgoProtocol*) – algorithm.
- **episodes** (*List[*d3rlpy.dataset.Episode*]*) – list of episodes.

Returns percentage of identical actions.

Return type float

d3rlpy.metrics.scorer.evaluate_on_environment

d3rlpy.metrics.scorer.**evaluate_on_environment**(*env*, *n_trials=10*, *epsilon=0.0*, *render=False*)

Returns scorer function of evaluation on environment.

This function returns scorer function, which is suitable to the standard scikit-learn scorer function style. The metrics of the scorer function is ideal metrics to evaluate the resulted policies.

```
import gym

from d3rlpy.algos import DQN
from d3rlpy.metrics.scorer import evaluate_on_environment


env = gym.make('CartPole-v0')

scorer = evaluate_on_environment(env)

cql = CQL()

mean_episode_return = scorer(cql)
```

Parameters

- **env** (*gym.core.Env*) – gym-styled environment.
- **n_trials** (*int*) – the number of trials.
- **epsilon** (*float*) – noise factor for epsilon-greedy policy.
- **render** (*bool*) – flag to render environment.

Returns scoerer function.

Return type Callable[[..], float]

d3rlpy.metrics.comparer.compare_continuous_action_diff

d3rlpy.metrics.comparer.**compare_continuous_action_diff**(*base_algo*)

Returns scorer function of action difference between algorithms.

This metrics suggests how different the two algorithms are in continuous action-space. If the algorithm to compare with is near-optimal, the small action difference would be better.

$$\mathbb{E}_{s_t \sim D}[(\pi_{\phi_1}(s_t) - \pi_{\phi_2}(s_t))^2]$$

```
from d3rlpy.algos import CQL
from d3rlpy.metrics.comparer import compare_continuous_action_diff

cql1 = CQL()
cql2 = CQL()

scorer = compare_continuous_action_diff(cql1)

squared_action_diff = scorer(cql2, ...)
```

Parameters **base_algo** (*d3rlpy.metrics.scorer.AlgoProtocol*) – algorithm to comapre with.

Returns scorer function.

Return type Callable[[d3rlpy.metrics.scorer.AlgoProtocol, List[*d3rlpy.dataset.Episode*]], float]

d3rlpy.metrics.comparer.compare_discrete_action_match

d3rlpy.metrics.comparer.**compare_discrete_action_match**(*base_algo*)

Returns scorer function of action matches between algorithms.

This metrics suggests how different the two algorithms are in discrete action-space. If the algorithm to compare with is near-optimal, the small action difference would be better.

$$\mathbb{E}_{s_t \sim D}[\parallel \{\text{argmax}_a Q_{\theta_1}(s_t, a) = \text{argmax}_a Q_{\theta_2}(s_t, a)\}]$$

```
from d3rlpy.algos import DQN
from d3rlpy.metrics.comparer import compare_continuous_action_diff

dqn1 = DQN()
dqn2 = DQN()

scorer = compare_continuous_action_diff(dqn1)

percentage_of_identical_actions = scorer(dqn2, ...)
```

Parameters **base_algo** (*d3rlpy.metrics.scorer.AlgoProtocol*) – algorithm to comapre with.

Returns scorer function.

Return type Callable[[d3rlpy.metrics.scorer.AlgoProtocol, List[*d3rlpy.dataset.Episode*]], float]

3.9.2 Dynamics

d3rlpy.metrics.scorer.dynamics_observation_prediction_error_scorer	Returns MSE of observation prediction (in negative scale).
d3rlpy.metrics.scorer.dynamics_reward_prediction_error_scorer	Returns MSE of reward prediction (in negative scale).
d3rlpy.metrics.scorer.dynamics_prediction_variance_scorer	Returns prediction variance of ensemble dynamics (in negative scale).

d3rlpy.metrics.scorer.dynamics_observation_prediction_error_scorer

d3rlpy.metrics.scorer.**dynamics_observation_prediction_error_scorer**(*dynamics*, *episodes*)

Returns MSE of observation prediction (in negative scale).

This metrics suggests how dynamics model is generalized to test sets. If the MSE is large, the dynamics model are overfitting.

$$\mathbb{E}_{s_t,a_t,s_{t+1}\sim D}[(s_{t+1}-s')^2]$$

where $s' \sim T(s_t, a_t)$.

Parameters

- **dynamics** (*d3rlpy.metrics.scorer.DynamicsProtocol*) – dynamics model.
- **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes.

Returns negative mean squared error.

Return type float

d3rlpy.metrics.scorer.dynamics_reward_prediction_error_scorer

d3rlpy.metrics.scorer.**dynamics_reward_prediction_error_scorer**(*dynamics*, *episodes*)

Returns MSE of reward prediction (in negative scale).

This metrics suggests how dynamics model is generalized to test sets. If the MSE is large, the dynamics model are overfitting.

$$\mathbb{E}_{s_t,a_t,r_{t+1}\sim D}[(r_{t+1}-r')^2]$$

where $r' \sim T(s_t, a_t)$.

Parameters

- **dynamics** (*d3rlpy.metrics.scorer.DynamicsProtocol*) – dynamics model.
- **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes.

Returns negative mean squared error.

Return type float

d3rlpy.metrics.scorer.dynamics_prediction_variance_scorer

d3rlpy.metrics.scorer.**dynamics_prediction_variance_scorer**(*dynamics*, *episodes*)

Returns prediction variance of ensemble dynamics (in negative scale).

This metrics suggests how dynamics model is confident of test sets. If the variance is large, the dynamics model has large uncertainty.

Parameters

- **dynamics** (*d3rlpy.metrics.scorer.DynamicsProtocol*) – dynamics model.
- **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes.

Returns negative variance.

Return type float

3.10 Off-Policy Evaluation

The off-policy evaluation is a method to estimate the trained policy performance only with offline datasets.

```
from d3rlpy.algos import CQL
from d3rlpy.datasets import get_pybullet

# prepare the trained algorithm
cql = CQL.from_json('<path-to-json>/params.json')
cql.load_model('<path-to-model>/model.pt')

# dataset to evaluate with
dataset, env = get_pybullet('hopper-bullet-miexed-v0')

from d3rlpy.ope import FQE

# off-policy evaluation algorithm
fqe = FQE(algo=cql)

# metrics to evaluate with
from d3rlpy.metrics.scorer import initial_state_value_estimation_scorer
from d3rlpy.metrics.scorer import soft_opc_scorer

# train estimators to evaluate the trained policy
fqe.fit(dataset.episodes,
        eval_episodes=dataset.episodes,
        scorers={
           'init_value': initial_state_value_estimation_scorer,
           'soft_opc': soft_opc_scorer(return_threshold=600)
        })
```

The evaluation during fitting is evaluating the trained policy.

3.10.1 For continuous control algorithms

d3rlpy.ope.FQE	Fitted Q Evaluation.

d3rlpy.ope.FQE

class d3rlpy.ope.**FQE**(**, algo=None, learning_rate=0.0001, optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, encoder_factory='default', q_func_factory='mean', batch_size=100, n_frames=1, n_steps=1, gamma=0.99, n_critics=1, bootstrap=False, share_encoder=False, target_update_interval=100, use_gpu=False, scaler=None, impl=None, **kwargs*)

Fitted Q Evaluation.

FQE is an off-policy evaluation method that approximates a Q function $Q_\theta(s, a)$ with the trained policy $\pi_\phi(s)$.

$$L(\theta) = \mathbb{E}_{s_t, a_t, r_{t+1} s_{t+1} \sim D}[(Q_\theta(s_t, a_t) - r_{t+1} - \gamma Q_{\theta'}(s_{t+1}, \pi_\phi(s_{t+1})))^2]$$

The trained Q function in FQE will estimate evaluation metrics more accurately than learned Q function during training.

References

- Le et al., Batch Policy Learning under Constraints.

Parameters

- **algo** (*d3rlpy.algos.base.AlgoBase*) – algorithm to evaluate.
- **learning_rate** (*float*) – learning rate.
- **optim_factory** (*d3rlpy.models.optimizers.OptimizerFactory or str*) – optimizer factory.
- **encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory.
- **q_func_factory** (*d3rlpy.models.q_functions.QFunctionFactory or str*) – Q function factory.
- **batch_size** (*int*) – mini-batch size.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **n_steps** (*int*) – N-step TD calculation.
- **gamma** (*float*) – discount factor.
- **n_critics** (*int*) – the number of Q functions for ensemble.
- **bootstrap** (*bool*) – flag to bootstrap Q functions.
- **share_encoder** (*bool*) – flag to share encoder network.
- **target_update_interval** (*int*) – interval to update the target network.
- **use_gpu** (*bool, int or d3rlpy.gpu.Device*) – flag to use GPU, device ID or device.

- **scaler** (*d3rlpy.preprocessing.Scaler or str*) – preprocessor. The available options are *['pixel', 'min_max', 'standard']*
- **impl** (*d3rlpy.metrics.ope.torch.FQEImpl*) – algorithm implementation.

Methods

build_with_dataset (*dataset*)
Instantiate implementation object with MDPDataset object.

Parameters **dataset** (d3rlpy.dataset.MDPDataset) – dataset.

Return type None

build_with_env (*env*)
Instantiate implementation object with OpenAI Gym object.

Parameters **env** (*gym.core.Env*) – gym-like environment.

Return type None

create_impl (*observation_shape, action_size*)
Instantiate implementation objects with the dataset shapes.

This method will be used internally when *fit* method is called.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – dimension of action-space.

Return type None

fit (*episodes, n_epochs=1000, save_metrics=True, experiment_name=None, with_timestamp=True, logdir='d3rlpy_logs', verbose=True, show_progress=True, tensorboard=True, eval_episodes=None, save_interval=1, scorers=None, shuffle=True*)
Trains with the given dataset.

```
algo.fit(episodes)
```

Parameters

- **episodes** (*List[*d3rlpy.dataset.Episode*]*) – list of episodes to train.
- **n_epochs** (*int*) – the number of epochs to train.
- **save_metrics** (*bool*) – flag to record metrics in files. If False, the log directory is not created and the model parameters are not saved during training.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be *{class name}_{timestamp}*.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

- **eval_episodes** (*Optional[List[*d3rlpy.dataset.Episode*]]*) – list of episodes to test.
- **save_interval** (*int*) – interval to save parameters.
- **scorers** (*Optional[Dict[str, Callable[[Any, List[*d3rlpy.dataset.Episode*]], float]]]*) – list of scorer functions used with *eval_episodes*.
- **shuffle** (*bool*) – flag to shuffle transitions on each epoch.

Return type None

fit_online(*env*, *buffer*, *explorer=None*, *n_steps=1000000*, *n_steps_per_epoch=10000*, *update_interval=1*, *update_start_step=0*, *eval_env=None*, *eval_epsilon=0.0*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*)

Start training loop of online deep reinforcement learning.

Parameters

- **env** (*gym.core.Env*) – gym-like environment.
- **buffer** (*d3rlpy.online.buffers.Buffer*) – replay buffer.
- **explorer** (*Optional[d3rlpy.online.explorers.Explorer]*) – action explorer.
- **n_steps** (*int*) – the number of total steps to train.
- **n_steps_per_epoch** (*int*) – the number of steps per epoch.
- **update_interval** (*int*) – the number of steps per update.
- **update_start_step** (*int*) – the steps before starting updates.
- **eval_env** (*Optional[gym.core.Env]*) – gym-like environment. If None, evaluation is skipped.
- **eval_epsilon** (*float*) – ϵ-greedy factor during evaluation.
- **save_metrics** (*bool*) – flag to record metrics. If False, the log directory is not created and the model parameters are not saved.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be `{class name}_online_{timestamp}`.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

Return type None

classmethod from_json(*fname*, *use_gpu=False*)

Returns algorithm configured with json file.

The Json file should be the one saved during fitting.

```
from d3rlpy.algos import Algo

# create algorithm with saved configuration
algo = Algo.from_json('d3rlpy_logs/<path-to-json>/params.json')

# ready to load
algo.load_model('d3rlpy_logs/<path-to-model>/model_100.pt')

# ready to predict
algo.predict(...)
```

Parameters

- **fname** (*str*) – file path to *params.json*.
- **use_gpu** (*Optional[Union[bool, int, d3rlpy.gpu.Device]]*) – flag to use GPU, device ID or device.

Returns algorithm.

Return type d3rlpy.base.LearnableBase

get_params (*deep=True*)

Returns the all attributes.

This method returns the all attributes including ones in subclasses. Some of scikit-learn utilities will use this method.

```
params = algo.get_params(deep=True)

# the returned values can be used to instantiate the new object.
algo2 = AlgoBase(**params)
```

Parameters **deep** (*bool*) – flag to deeply copy objects such as *impl*.

Returns attribute values in dictionary.

Return type Dict[str, Any]

load_model (*fname*)

Load neural network parameters.

```
algo.load_model('model.pt')
```

Parameters **fname** (*str*) – source file path.

Return type None

predict (*x*)

Returns greedy actions.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

actions = algo.predict(x)
# actions.shape == (100, action size) for continuous control
# actions.shape == (100,) for discrete control
```

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations

Returns greedy actions

Return type numpy.ndarray

predict_value (*x*, *action*, *with_std=False*)

Returns predicted action-values.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

# for continuous control
# 100 actions with shape of (2,)
actions = np.random.random((100, 2))

# for discrete control
# 100 actions in integer values
actions = np.random.randint(2, size=100)

values = algo.predict_value(x, actions)
# values.shape == (100,)

values, stds = algo.predict_value(x, actions, with_std=True)
# stds.shape  == (100,)
```

Parameters

- **x** (*Union[numpy.ndarray, List[Any]]*) – observations
- **action** (*Union[numpy.ndarray, List[Any]]*) – actions
- **with_std** (*bool*) – flag to return standard deviation of ensemble estimation. This deviation reflects uncertainty for the given observations. This uncertainty will be more accurate if you enable `bootstrap` flag and increase `n_critics` value.

Returns predicted action-values

Return type Union[numpy.ndarray, Tuple[numpy.ndarray, numpy.ndarray]]

sample_action (*x*)

Returns sampled actions.

The sampled actions are identical to the output of *predict* method if the policy is deterministic.

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations.

Returns sampled actions.

Return type numpy.ndarray

save_model (*fname*)

Saves neural network parameters.

```
algo.save_model('model.pt')
```

Parameters **fname** (*str*) – destination file path.

Return type None

save_policy (*fname*, *as_onnx=False*)

Save the greedy-policy computational graph as TorchScript or ONNX.

```
# save as TorchScript
algo.save_policy('policy.pt')

# save as ONNX
algo.save_policy('policy.onnx', as_onnx=True)
```

The artifacts saved with this method will work without d3rlpy. This method is especially useful to deploy the learned policy to production environments or embedding systems.

See also

- https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html (for Python).
- https://pytorch.org/tutorials/advanced/cpp_export.html (for C++).
- https://onnx.ai (for ONNX)

Parameters

- **fname** (*str*) – destination file path.
- **as_onnx** (*bool*) – flag to save as ONNX format.

Return type None

set_params (***params*)

Sets the given arguments to the attributes if they exist.

This method sets the given values to the attributes including ones in subclasses. If the values that don't exist as attributes are passed, they are ignored. Some of scikit-learn utilities will use this method.

```
algo.set_params(batch_size=100)
```

Parameters **params** (*Any*) – arbitrary inputs to set as attributes.

Returns itself.

Return type d3rlpy.base.LearnableBase

update (*epoch*, *total_step*, *batch*)

Update parameters with mini-batch of data.

Parameters

- **epoch** (*int*) – the current number of epochs.
- **total_step** (*int*) – the current number of total iterations.
- **batch** (d3rlpy.dataset.TransitionMiniBatch) – mini-batch data.

Returns loss values.

Return type list

Attributes

action_size
Action size.

Returns action size.

Return type Optional[int]

batch_size
Batch size to train.

Returns batch size.

Return type int

gamma
Discount factor.

Returns discount factor.

Return type float

impl
Implementation object.

Returns implementation object.

Return type Optional[ImplBase]

n_frames
Number of frames to stack.

This is only for image observation.

Returns number of frames to stack.

Return type int

n_steps
N-step TD backup.

Returns N-step TD backup.

Return type int

observation_shape
Observation shape.

Returns observation shape.

Return type Optional[Sequence[int]]

scaler
Preprocessing scaler.

Returns preprocessing scaler.

Return type Optional[Scaler]

3.10.2 For discrete control algorithms

`d3rlpy.ope.DiscreteFQE`	Fitted Q Evaluation for discrete action-space.

d3rlpy.ope.DiscreteFQE

class d3rlpy.ope.**DiscreteFQE**(**, algo=None, learning_rate=0.0001, optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, encoder_factory='default', q_func_factory='mean', batch_size=100, n_frames=1, n_steps=1, gamma=0.99, n_critics=1, bootstrap=False, share_encoder=False, target_update_interval=100, use_gpu=False, scaler=None, impl=None, **kwargs*)

Fitted Q Evaluation for discrete action-space.

FQE is an off-policy evaluation method that approximates a Q function $Q_\theta(s, a)$ with the trained policy $\pi_\phi(s)$.

$$L(\theta) = \mathbb{E}_{s_t, a_t, r_{t+1} s_{t+1} \sim D}[(Q_\theta(s_t, a_t) - r_{t+1} - \gamma Q_{\theta'}(s_{t+1}, \pi_\phi(s_{t+1})))^2]$$

The trained Q function in FQE will estimate evaluation metrics more accurately than learned Q function during training.

References

- Le et al., Batch Policy Learning under Constraints.

Parameters

- **algo** (*d3rlpy.algos.base.AlgoBase*) – algorithm to evaluate.
- **learning_rate** (*float*) – learning rate.
- **optim_factory** (*d3rlpy.models.optimizers.OptimizerFactory or str*) – optimizer factory.
- **encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory.
- **q_func_factory** (*d3rlpy.models.q_functions.QFunctionFactory or str*) – Q function factory.
- **batch_size** (*int*) – mini-batch size.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **n_steps** (*int*) – N-step TD calculation.
- **gamma** (*float*) – discount factor.
- **n_critics** (*int*) – the number of Q functions for ensemble.
- **bootstrap** (*bool*) – flag to bootstrap Q functions.
- **share_encoder** (*bool*) – flag to share encoder network.
- **target_update_interval** (*int*) – interval to update the target network.
- **use_gpu** (*bool, int or d3rlpy.gpu.Device*) – flag to use GPU, device ID or device.

- **scaler** (*d3rlpy.preprocessing.Scaler or str*) – preprocessor. The available options are *['pixel', 'min_max', 'standard']*
- **augmentation** (*d3rlpy.augmentation.AugmentationPipeline or list(str)*) – augmentation pipeline.
- **impl** (*d3rlpy.metrics.ope.torch.FQEImpl*) – algorithm implementation.

Methods

build_with_dataset (*dataset*)
Instantiate implementation object with MDPDataset object.

Parameters **dataset** (d3rlpy.dataset.MDPDataset) – dataset.

Return type None

build_with_env (*env*)
Instantiate implementation object with OpenAI Gym object.

Parameters **env** (*gym.core.Env*) – gym-like environment.

Return type None

create_impl (*observation_shape, action_size*)
Instantiate implementation objects with the dataset shapes.

This method will be used internally when *fit* method is called.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – dimension of action-space.

Return type None

fit (*episodes, n_epochs=1000, save_metrics=True, experiment_name=None, with_timestamp=True, logdir='d3rlpy_logs', verbose=True, show_progress=True, tensorboard=True, eval_episodes=None, save_interval=1, scorers=None, shuffle=True*)
Trains with the given dataset.

```
algo.fit(episodes)
```

Parameters

- **episodes** (*List[d3rlpy.dataset.Episode]*) – list of episodes to train.
- **n_epochs** (*int*) – the number of epochs to train.
- **save_metrics** (*bool*) – flag to record metrics in files. If False, the log directory is not created and the model parameters are not saved during training.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be *{class name}_{timestamp}*.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.

- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)
- **eval_episodes** (*Optional[List[d3rlpy.dataset.Episode]]*) – list of episodes to test.
- **save_interval** (*int*) – interval to save parameters.
- **scorers** (*Optional[Dict[str, Callable[[Any, List[d3rlpy.dataset.Episode]], float]]]*) – list of scorer functions used with *eval_episodes*.
- **shuffle** (*bool*) – flag to shuffle transitions on each epoch.

Return type None

fit_online(*env*, *buffer*, *explorer=None*, *n_steps=1000000*, *n_steps_per_epoch=10000*, *update_interval=1*, *update_start_step=0*, *eval_env=None*, *eval_epsilon=0.0*, *save_metrics=True*, *experiment_name=None*, *with_timestamp=True*, *logdir='d3rlpy_logs'*, *verbose=True*, *show_progress=True*, *tensorboard=True*)

Start training loop of online deep reinforcement learning.

Parameters

- **env** (*gym.core.Env*) – gym-like environment.
- **buffer** (*d3rlpy.online.buffers.Buffer*) – replay buffer.
- **explorer** (*Optional[d3rlpy.online.explorers.Explorer]*) – action explorer.
- **n_steps** (*int*) – the number of total steps to train.
- **n_steps_per_epoch** (*int*) – the number of steps per epoch.
- **update_interval** (*int*) – the number of steps per update.
- **update_start_step** (*int*) – the steps before starting updates.
- **eval_env** (*Optional[gym.core.Env]*) – gym-like environment. If None, evaluation is skipped.
- **eval_epsilon** (*float*) – ϵ-greedy factor during evaluation.
- **save_metrics** (*bool*) – flag to record metrics. If False, the log directory is not created and the model parameters are not saved.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be `{class name}_online_{timestamp}`.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

Return type None

classmethod from_json(*fname*, *use_gpu=False*)

Returns algorithm configured with json file.

The Json file should be the one saved during fitting.

```
from d3rlpy.algos import Algo

# create algorithm with saved configuration
algo = Algo.from_json('d3rlpy_logs/<path-to-json>/params.json')

# ready to load
algo.load_model('d3rlpy_logs/<path-to-model>/model_100.pt')

# ready to predict
algo.predict(...)
```

Parameters

- **fname** (*str*) – file path to *params.json*.
- **use_gpu** (*Optional[Union[bool, int, d3rlpy.gpu.Device]]*) – flag to use GPU, device ID or device.

Returns algorithm.

Return type d3rlpy.base.LearnableBase

get_params (*deep=True*)

Returns the all attributes.

This method returns the all attributes including ones in subclasses. Some of scikit-learn utilities will use this method.

```
params = algo.get_params(deep=True)

# the returned values can be used to instantiate the new object.
algo2 = AlgoBase(**params)
```

Parameters **deep** (*bool*) – flag to deeply copy objects such as *impl*.

Returns attribute values in dictionary.

Return type Dict[str, Any]

load_model (*fname*)

Load neural network parameters.

```
algo.load_model('model.pt')
```

Parameters **fname** (*str*) – source file path.

Return type None

predict (*x*)

Returns greedy actions.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

actions = algo.predict(x)
# actions.shape == (100, action size) for continuous control
# actions.shape == (100,) for discrete control
```

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations

Returns greedy actions

Return type numpy.ndarray

predict_value (*x, action, with_std=False*)

Returns predicted action-values.

```
# 100 observations with shape of (10,)
x = np.random.random((100, 10))

# for continuous control
# 100 actions with shape of (2,)
actions = np.random.random((100, 2))

# for discrete control
# 100 actions in integer values
actions = np.random.randint(2, size=100)

values = algo.predict_value(x, actions)
# values.shape == (100,)

values, stds = algo.predict_value(x, actions, with_std=True)
# stds.shape  == (100,)
```

Parameters

- **x** (*Union[numpy.ndarray, List[Any]]*) – observations
- **action** (*Union[numpy.ndarray, List[Any]]*) – actions
- **with_std** (*bool*) – flag to return standard deviation of ensemble estimation. This deviation reflects uncertainty for the given observations. This uncertainty will be more accurate if you enable `bootstrap` flag and increase `n_critics` value.

Returns predicted action-values

Return type Union[numpy.ndarray, Tuple[numpy.ndarray, numpy.ndarray]]

sample_action (*x*)

Returns sampled actions.

The sampled actions are identical to the output of *predict* method if the policy is deterministic.

Parameters **x** (*Union[numpy.ndarray, List[Any]]*) – observations.

Returns sampled actions.

Return type numpy.ndarray

save_model (*fname*)

Saves neural network parameters.

```
algo.save_model('model.pt')
```

Parameters **fname** (*str*) – destination file path.

Return type None

save_policy (*fname*, *as_onnx=False*)

Save the greedy-policy computational graph as TorchScript or ONNX.

```
# save as TorchScript
algo.save_policy('policy.pt')

# save as ONNX
algo.save_policy('policy.onnx', as_onnx=True)
```

The artifacts saved with this method will work without d3rlpy. This method is especially useful to deploy the learned policy to production environments or embedding systems.

See also

- https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html (for Python).
- https://pytorch.org/tutorials/advanced/cpp_export.html (for C++).
- https://onnx.ai (for ONNX)

Parameters

- **fname** (*str*) – destination file path.
- **as_onnx** (*bool*) – flag to save as ONNX format.

Return type None

set_params (***params*)

Sets the given arguments to the attributes if they exist.

This method sets the given values to the attributes including ones in subclasses. If the values that don't exist as attributes are passed, they are ignored. Some of scikit-learn utilities will use this method.

```
algo.set_params(batch_size=100)
```

Parameters **params** (*Any*) – arbitrary inputs to set as attributes.

Returns itself.

Return type d3rlpy.base.LearnableBase

update (*epoch*, *total_step*, *batch*)

Update parameters with mini-batch of data.

Parameters

- **epoch** (*int*) – the current number of epochs.
- **total_step** (*int*) – the current number of total iterations.
- **batch** (d3rlpy.dataset.TransitionMiniBatch) – mini-batch data.

Returns loss values.

Return type list

Attributes

action_size
Action size.

Returns action size.

Return type Optional[int]

batch_size
Batch size to train.

Returns batch size.

Return type int

gamma
Discount factor.

Returns discount factor.

Return type float

impl
Implementation object.

Returns implementation object.

Return type Optional[ImplBase]

n_frames
Number of frames to stack.

This is only for image observation.

Returns number of frames to stack.

Return type int

n_steps
N-step TD backup.

Returns N-step TD backup.

Return type int

observation_shape
Observation shape.

Returns observation shape.

Return type Optional[Sequence[int]]

scaler
Preprocessing scaler.

Returns preprocessing scaler.

Return type Optional[Scaler]

3.11 Save and Load

3.11.1 save_model and load_model

```
from d3rlpy.datasets import get_cartpole
from d3rlpy.algos import DQN

dataset, env = get_cartpole()

dqn = DQN()
dqn.fit(dataset.episodes, n_epochs=1)

# save entire model parameters.
dqn.save_model('model.pt')
```

`save_model` method saves all parameters including optimizer states, which is useful when checking all the outputs or re-training from snapshots.

Once you save your model, you can load it via `load_model` method. Before loading the model, the algorithm object must be initialized as follows.

```
dqn = DQN()

# initialize with dataset
dqn.build_with_dataset(dataset)

# initialize with environment
# dqn.build_with_env(env)

# load entire model parameters.
dqn.load_model('model.pt')
```

3.11.2 from_json

It is very boring to set the same hyperparameters to initialize algorithms when loading model parameters. In d3rlpy, `params.json` is saved at the beggining of `fit` method, which includes all hyperparameters within the algorithm object. You can recreate algorithm objects from `params.json` via `from_json` method.

```
from d3rlpy.algos import DQN

dqn = DQN.from_json('d3rlpy_logs/<path-to-json>/params.json')

# ready to load
dqn.load_model('model.pt')
```

3.11.3 save_policy

`save_policy` method saves the only greedy-policy computation graph as TorchSciprt or ONNX. When `save_policy` method is called, the greedy-policy graph is constructed and traced via `torch.jit.trace` function.

```
from d3rlpy.datasets import get_cartpole
from d3rlpy.algos import DQN

dataset, env = get_cartpole()

dqn = DQN()
dqn.fit(dataset.episodes, n_epochs=1)

# save greedy-policy as TorchScript
dqn.save_policy('policy.pt')

# save greedy-policy as ONNX
dqn.save_policy('policy.onnx', as_onnx=True)
```

TorchScript

TorchScript is a optimizable graph expression provided by PyTorch. The saved policy can be loaded without any dependencies except PyTorch.

```
import torch

# load greedy-policy only with PyTorch
policy = torch.jit.load('policy.pt')

# returns greedy actions
actions = policy(torch.rand(32, 6))
```

This is especially useful when deploying the trained models to productions. The computation can be faster and you don't need to install d3rlpy. Moreover, TorchScript model can be easily loaded even with C++, which will empower your robotics and embedding system projects.

```
#include <torch/script.h>

int main(int argc, char* argv[]) {
  torch::jit::script::Module module;
  try {
    module = torch::jit::load("policy.pt")
  } catch (const c10::Error& e) {
    return -1;
  }
  return 0;
}
```

You can get more information about TorchScript here.

ONNX

ONNX is an open format built to represent machine learning models. This is also useful when deploying the trained model to productions with various programming languages including Python, C++, JavaScript and more.

The following example is written with onnxruntime.

```
import onnxruntime as ort

# load ONNX policy via onnxruntime
ort_session = ort.InferenceSession('policy.onnx')

# observation
observation = np.random.rand(1, 6).astype(np.float32)

# returns greedy action
action = ort_session.run(None, {'input_0': observation})[0]
```

You can get more information about ONNX here.

3.12 Logging

d3rlpy algorithms automatically save model parameters and metrics under *d3rlpy_logs* directory.

```
from d3rlpy.datasets import get_cartpole
from d3rlpy.algos import DQN

dataset, env = get_cartpole()

dqn = DQN()

# metrics and parameters are saved in `d3rlpy_logs/DQN_YYYYMMDDHHmmss`
dqn.fit(dataset.episodes)
```

You can designate the directory.

```
# the directory will be `custom_logs/custom_YYYYMMDDHHmmss`
dqn.fit(dataset.episodes, logdir='custom_logs', experiment_name='custom')
```

If you want to disable all loggings, you can pass *save_metrics=False*.

```
dqn.fit(dataset.episodes, save_metrics=False)
```

3.12.1 TensorBoard

The same information is also automatically saved for tensorboard under *runs* directory. You can interactively visualize training metrics easily.

```
$ pip install tensorboard
$ tensorboard --logdir runs
```

This tensorboard logs can be disabled by passing *tensorboard=False*.

```
dqn.fit(dataset.episodes, tensorboard=False)
```

3.13 scikit-learn compatibility

d3rlpy provides complete scikit-learn compatible APIs.

3.13.1 train_test_split

d3rlpy.dataset.MDPDataset is compatible with splitting functions in scikit-learn.

```
from d3rlpy.algos import DQN
from d3rlpy.datasets import get_cartpole
from d3rlpy.metrics.scorer import td_error_scorer
from sklearn.model_selection import train_test_split

dataset, env = get_cartpole()

train_episodes, test_episodes = train_test_split(dataset, test_size=0.2)

dqn = DQN()
dqn.fit(train_episodes,
        eval_episodes=test_episodes,
        n_epochs=1,
        scorers={'td_error': td_error_scorer})
```

3.13.2 cross_validate

cross validation is also easily performed.

```
from d3rlpy.algos import DQN
from d3rlpy.datasets import get_cartpole
from d3rlpy.metrics import td_error_scorer
from sklearn.model_selection import cross_validate

dataset, env = get_cartpole()

dqn = DQN()

scores = cross_validate(dqn,
                        dataset,
                        scoring={'td_error': td_error_scorer},
                        fit_params={'n_epochs': 1})
```

3.13.3 GridSearchCV

You can also perform grid search to find good hyperparameters.

```
from d3rlpy.algos import DQN
from d3rlpy.datasets import get_cartpole
from d3rlpy.metrics import td_error_scorer
from sklearn.model_selection import GridSearchCV

dataset, env = get_cartpole()

dqn = DQN()

gscv = GridSearchCV(estimator=dqn,
                    param_grid={'learning_rate': [1e-4, 3e-4, 1e-3]},
                    scoring={'td_error': td_error_scorer},
                    refit=False)

gscv.fit(dataset.episodes, n_epochs=1)
```

3.13.4 parallel execution with multiple GPUs

Some scikit-learn utilities provide *n_jobs* option, which enable fitting process to run in paralell to boost productivity. Idealy, if you have multiple GPUs, the multiple processes use different GPUs for computational efficiency.

d3rlpy provides special device assignment mechanism to realize this.

```
from d3rlpy.algos import DQN
from d3rlpy.datasets import get_cartpole
from d3rlpy.metrics import td_error_scorer
from d3rlpy.context import parallel
from sklearn.model_selection import cross_validate

dataset, env = get_cartpole()

# enable GPU
dqn = DQN(use_gpu=True)

# automatically assign different GPUs for the 4 processes.
with parallel():
    scores = cross_validate(dqn,
                            dataset,
                            scoring={'td_error': td_error_scorer},
                            fit_params={'n_epochs': 1},
                            n_jobs=4)
```

If *use_gpu=True* is passed, d3rlpy internally manages GPU device id via `d3rlpy.gpu.Device` object. This object is designed for scikit-learn's multi-process implementation that makes deep copies of the estimator object before dispatching. The *Device* object will increment its device id when deeply copied under the paralell context.

```
import copy
from d3rlpy.context import parallel
from d3rlpy.gpu import Device

device = Device(0)
# device.get_id() == 0
```

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```
new_device = copy.deepcopy(device)
# new_device.get_id() == 0

with parallel():
    new_device = copy.deepcopy(device)
    # new_device.get_id() == 1
    # device.get_id() == 1

    new_device = copy.deepcopy(device)
    # if you have only 2 GPUs, it goes back to 0.
    # new_device.get_id() == 0
    # device.get_id() == 0

from d3rlpy.algos import DQN

dqn = DQN(use_gpu=Device(0)) # assign id=0
dqn = DQN(use_gpu=Device(1)) # assign id=1
```

3.14 Online Training

d3rlpy provides not only offline training, but also online training utilities. Despite being designed for offline training algorithms, d3rlpy is flexible enough to be trained in an online manner with a few more utilities.

```
import gym

from d3rlpy.algos import DQN
from d3rlpy.online.buffers import ReplayBuffer
from d3rlpy.online.explorers import LinearDecayEpsilonGreedy

# setup environment
env = gym.make('CartPole-v0')
eval_env = gym.make('CartPole-v0')

# setup algorithm
dqn = DQN(batch_size=32,
          learning_rate=2.5e-4,
          target_update_interval=100,
          use_gpu=True)

# setup replay buffer
buffer = ReplayBuffer(maxlen=1000000, env=env)

# setup explorers
explorer = LinearDecayEpsilonGreedy(start_epsilon=1.0,
                                    end_epsilon=0.1,
                                    duration=10000)

# start training
dqn.fit_online(env,
               buffer,
               explorer=explorer, # you don't need this with probablistic policy␣
↪algorithms
               eval_env=eval_env,
```

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```
n_epochs=30,
n_steps_per_epoch=1000,
n_updates_per_epoch=100)
```

3.14.1 Replay Buffer

d3rlpy.online.buffers.ReplayBuffer	Standard Replay Buffer.

d3rlpy.online.buffers.ReplayBuffer

class d3rlpy.online.buffers.**ReplayBuffer**(*maxlen, env, episodes=None*)

Standard Replay Buffer.

Parameters

- **maxlen** (*int*) – the maximum number of data length.
- **env** (*gym.Env*) – gym-like environment to extract shape information.
- **episodes** (*list (d3rlpy.dataset.Episode)*) – list of episodes to initialize buffer

Methods

__len__()

Return type int

append(*observation, action, reward, terminal*)

Append observation, action, reward and terminal flag to buffer.

If the terminal flag is True, Monte-Carlo returns will be computed with an entire episode and the whole transitions will be appended.

Parameters

- **observation** (*numpy.ndarray*) – observation.
- **action** (*numpy.ndarray or int*) – action.
- **reward** (*float*) – reward.
- **terminal** (*bool or float*) – terminal flag.

Return type None

append_episode(*episode*)

Append Episode object to buffer.

Parameters **episode** (d3rlpy.dataset.Episode) – episode.

Return type None

sample(*batch_size, n_frames=1, n_steps=1, gamma=0.99*)

Returns sampled mini-batch of transitions.

If observation is image, you can stack arbitrary frames via `n_frames`.

```
buffer.observation_shape == (3, 84, 84)

# stack 4 frames
batch = buffer.sample(batch_size=32, n_frames=4)

batch.observations.shape == (32, 12, 84, 84)
```

Parameters

- **batch_size** (*int*) – mini-batch size.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **n_steps** (*int*) – the number of steps before the next observation.
- **gamma** (*float*) – discount factor used in N-step return calculation.

Returns mini-batch.

Return type *d3rlpy.dataset.TransitionMiniBatch*

size()

Returns the number of appended elements in buffer.

Returns the number of elements in buffer.

Return type int

3.14.2 Explorers

d3rlpy.online.explorers.LinearDecayEpsilonGreedy	ϵ-greedy explorer with linear decay schedule.
d3rlpy.online.explorers.NormalNoise	Normal noise explorer.

d3rlpy.online.explorers.LinearDecayEpsilonGreedy

class d3rlpy.online.explorers.**LinearDecayEpsilonGreedy**(*start_epsilon=1.0*, *end_epsilon=0.1*, *duration=1000000*)

ϵ-greedy explorer with linear decay schedule.

Parameters

- **start_epsilon** (*float*) – the beginning ϵ.
- **end_epsilon** (*float*) – the end ϵ.
- **duration** (*int*) – the scheduling duration.

Methods

compute_epsilon(*step*)

Returns decayed ϵ.

Returns ϵ.

Parameters **step** (*int*) –

Return type float

sample(*algo*, *x*, *step*)

Returns ϵ-greedy action.

Parameters

- **algo** (*d3rlpy.online.explorers._ActionProtocol*) – algorithm.
- **x** (*numpy.ndarray*) – observation.
- **step** (*int*) – current environment step.

Returns ϵ-greedy action.

Return type numpy.ndarray

d3rlpy.online.explorers.NormalNoise

class d3rlpy.online.explorers.**NormalNoise**(*mean=0.0*, *std=0.1*)

Normal noise explorer.

Parameters

- **mean** (*float*) – mean.
- **std** (*float*) – standard deviation.

Methods

sample(*algo*, *x*, *step*)

Returns action with noise injection.

Parameters

- **algo** (*d3rlpy.online.explorers._ActionProtocol*) – algorithm.
- **x** (*numpy.ndarray*) – observation.
- **step** (*int*) –

Returns action with noise injection.

Return type numpy.ndarray

3.15 Model-based Data Augmentation

d3rlpy provides model-based reinforcement learning algorithms. In d3rlpy, model-based algorithms are viewed as data augmentation techniques, which can boost performance potentially beyond the model-free algorithms.

```
from d3rlpy.datasets import get_pendulum
from d3rlpy.dynamics import MOPO
from d3rlpy.metrics.scorer import dynamics_observation_prediction_error_scorer
from d3rlpy.metrics.scorer import dynamics_reward_prediction_error_scorer
from d3rlpy.metrics.scorer import dynamics_prediction_variance_scorer
from sklearn.model_selection import train_test_split

dataset, _ = get_pendulum()

train_episodes, test_episodes = train_test_split(dataset)

mopo = MOPO(learning_rate=1e-4, use_gpu=True)

# same as algorithms
mopo.fit(train_episodes,
         eval_episodes=test_episodes,
         n_epochs=100,
         scorers={
            'observation_error': dynamics_observation_prediction_error_scorer,
            'reward_error': dynamics_reward_prediction_error_scorer,
            'variance': dynamics_prediction_variance_scorer,
         })
```

Pick the best model based on evaluation metrics.

```
from d3rlpy.dynamics import MOPO
from d3rlpy.algos import CQL

# load trained dynamics model
mopo = MOPO.from_json('<path-to-params.json>/params.json')
mopo.load_model('<path-to-model>/model_xx.pt')
mopo.n_transitions = 400 # tunable parameter
mopo.horizon = 5 # tunable parameter
mopo.lam = 1.0 # tunable parameter

# give mopo as dynamics argument.
cql = CQL(dynamics=mopo)
```

If you pass a dynamics model to algorithms, new transitions are generated at the beginning of every epoch.

d3rlpy.dynamics.mopo.MOPO	Model-based Offline Policy Optimization.

3.15.1 d3rlpy.dynamics.mopo.MOPO

class d3rlpy.dynamics.mopo.**MOPO**(**, learning_rate=0.001, optim_factory=<d3rlpy.models.optimizers.AdamFactory object>, encoder_factory='default', batch_size=100, n_frames=1, n_ensembles=5, n_transitions=400, horizon=5, lam=1.0, discrete_action=False, scaler=None, use_gpu=False, impl=None, **kwargs*)

Model-based Offline Policy Optimization.

MOPO is a model-based RL approach for offline policy optimization. MOPO leverages the probablistic ensemble dynamics model to generate new dynamics data with uncertainty penalties.

The ensemble dynamics model consists of N probablistic models $\{T_{\theta_i}\}_{i=1}^N$. At each epoch, new transitions are generated via randomly picked dynamics model T_θ.

$$s_{t+1}, r_{t+1} \sim T_\theta(s_t, a_t)$$

where $s_t \sim D$ for the first step, otherwise s_t is the previous generated observation, and $a_t \sim \pi(\cdot|s_t)$. The generated r_{t+1} would be far from the ground truth if the actions sampled from the policy function is out-of-distribution. Thus, the uncertainty penalty reguralizes this bias.

$$\tilde{r_{t+1}} = r_{t+1} - \lambda \max_{i=1}^N ||\Sigma_i(s_t, a_t)||$$

where $\Sigma(s_t, a_t)$ is the estimated variance.

Finally, the generated transitions $(s_t, a_t, \tilde{r_{t+1}}, s_{t+1})$ are appended to dataset D.

This generation process starts with randomly sampled *n_transitions* transitions till *horizon* steps.

Note: Currently, MOPO only supports vector observations.

References

- Yu et al., MOPO: Model-based Offline Policy Optimization.

Parameters

- **learning_rate** (*float*) – learning rate for dynamics model.
- **optim_factory** (d3rlpy.models.optimizers.OptimizerFactory) – optimizer factory.
- **encoder_factory** (*d3rlpy.models.encoders.EncoderFactory or str*) – encoder factory.
- **batch_size** (*int*) – mini-batch size.
- **n_frames** (*int*) – the number of frames to stack for image observation.
- **n_ensembles** (*int*) – the number of dynamics model for ensemble.
- **n_transitions** (*int*) – the number of parallel trajectories to generate.
- **horizon** (*int*) – the number of steps to generate.
- **lam** (*float*) – λ for uncertainty penalties.
- **discrete_action** (*bool*) – flag to take discrete actions.

- **scaler** (*d3rlpy.preprocessing.scalers.Scaler or str*) – preprocessor. The available options are *['pixel', 'min_max', 'standard']*.
- **use_gpu** (*bool or d3rlpy.gpu.Device*) – flag to use GPU or device.
- **impl** (*d3rlpy.dynamics.torch.MOPOImpl*) – dynamics implementation.

Methods

build_with_dataset (*dataset*)
Instantiate implementation object with MDPDataset object.

Parameters **dataset** (d3rlpy.dataset.MDPDataset) – dataset.

Return type None

build_with_env (*env*)
Instantiate implementation object with OpenAI Gym object.

Parameters **env** (*gym.core.Env*) – gym-like environment.

Return type None

create_impl (*observation_shape, action_size*)
Instantiate implementation objects with the dataset shapes.

This method will be used internally when *fit* method is called.

Parameters

- **observation_shape** (*Sequence[int]*) – observation shape.
- **action_size** (*int*) – dimension of action-space.

Return type None

fit (*episodes, n_epochs=1000, save_metrics=True, experiment_name=None, with_timestamp=True, logdir='d3rlpy_logs', verbose=True, show_progress=True, tensorboard=True, eval_episodes=None, save_interval=1, scorers=None, shuffle=True*)
Trains with the given dataset.

```
algo.fit(episodes)
```

Parameters

- **episodes** (*List[*d3rlpy.dataset.Episode*]*) – list of episodes to train.
- **n_epochs** (*int*) – the number of epochs to train.
- **save_metrics** (*bool*) – flag to record metrics in files. If False, the log directory is not created and the model parameters are not saved during training.
- **experiment_name** (*Optional[str]*) – experiment name for logging. If not passed, the directory name will be *{class name}_{timestamp}*.
- **with_timestamp** (*bool*) – flag to add timestamp string to the last of directory name.
- **logdir** (*str*) – root directory name to save logs.
- **verbose** (*bool*) – flag to show logged information on stdout.
- **show_progress** (*bool*) – flag to show progress bar for iterations.
- **tensorboard** (*bool*) – flag to save logged information in tensorboard (additional to the csv data)

- **eval_episodes** (*Optional[List[*d3rlpy.dataset.Episode*]]*) – list of episodes to test.
- **save_interval** (*int*) – interval to save parameters.
- **scorers** (*Optional[Dict[str, Callable[[Any, List[*d3rlpy.dataset.Episode*]], float]]]*) – list of scorer functions used with *eval_episodes*.
- **shuffle** (*bool*) – flag to shuffle transitions on each epoch.

Return type None

classmethod from_json (*fname*, *use_gpu=False*)

Returns algorithm configured with json file.

The Json file should be the one saved during fitting.

```
from d3rlpy.algos import Algo

# create algorithm with saved configuration
algo = Algo.from_json('d3rlpy_logs/<path-to-json>/params.json')

# ready to load
algo.load_model('d3rlpy_logs/<path-to-model>/model_100.pt')

# ready to predict
algo.predict(...)
```

Parameters

- **fname** (*str*) – file path to *params.json*.
- **use_gpu** (*Optional[Union[bool, int, d3rlpy.gpu.Device]]*) – flag to use GPU, device ID or device.

Returns algorithm.

Return type d3rlpy.base.LearnableBase

generate (*algo*, *transitions*)

Returns new transitions for data augmentation.

Parameters

- **algo** (*d3rlpy.algos.base.AlgoBase*) – algorithm.
- **transitions** (*List[*d3rlpy.dataset.Transition*]*) – list of transitions.

Returns list of generated transitions.

Return type list

get_params (*deep=True*)

Returns the all attributes.

This method returns the all attributes including ones in subclasses. Some of scikit-learn utilities will use this method.

```
params = algo.get_params(deep=True)

# the returned values can be used to instantiate the new object.
algo2 = AlgoBase(**params)
```

Parameters **deep** (*bool*) – flag to deeply copy objects such as *impl*.

Returns attribute values in dictionary.

Return type Dict[str, Any]

load_model (*fname*)

Load neural network parameters.

```
algo.load_model('model.pt')
```

Parameters **fname** (*str*) – source file path.

Return type None

predict (*x*, *action*, *with_variance=False*)

Returns predicted observation and reward.

Parameters

- **x** (*Union[numpy.ndarray, List[Any]]*) – observation
- **action** (*Union[numpy.ndarray, List[Any]]*) – action
- **with_variance** (*bool*) – flag to return prediction variance.

Returns tuple of predicted observation and reward.

Return type Union[Tuple[numpy.ndarray, numpy.ndarray], Tuple[numpy.ndarray, numpy.ndarray, numpy.ndarray]]

save_model (*fname*)

Saves neural network parameters.

```
algo.save_model('model.pt')
```

Parameters **fname** (*str*) – destination file path.

Return type None

set_params (***params*)

Sets the given arguments to the attributes if they exist.

This method sets the given values to the attributes including ones in subclasses. If the values that don't exist as attributes are passed, they are ignored. Some of scikit-learn utilities will use this method.

```
algo.set_params(batch_size=100)
```

Parameters **params** (*Any*) – arbitrary inputs to set as attributes.

Returns itself.

Return type d3rlpy.base.LearnableBase

update (*epoch*, *total_step*, *batch*)

Update parameters with mini-batch of data.

Parameters

- **epoch** (*int*) – the current number of epochs.
- **total_step** (*int*) – the current number of total iterations.

- **batch** (d3rlpy.dataset.TransitionMiniBatch) – mini-batch data.

Returns loss values.

Return type list

Attributes

action_size
Action size.

Returns action size.

Return type Optional[int]

batch_size
Batch size to train.

Returns batch size.

Return type int

gamma
Discount factor.

Returns discount factor.

Return type float

horizon

impl
Implementation object.

Returns implementation object.

Return type Optional[ImplBase]

n_frames
Number of frames to stack.

This is only for image observation.

Returns number of frames to stack.

Return type int

n_steps
N-step TD backup.

Returns N-step TD backup.

Return type int

n_transitions

observation_shape
Observation shape.

Returns observation shape.

Return type Optional[Sequence[int]]

scaler
Preprocessing scaler.

Returns preprocessing scaler.

Return type Optional[Scaler]

3.16 Stable-Baselines3 Wrapper

d3rlpy provides a minimal wrapper to use Stable-Baselines3 (SB3) features, like utility helpers or SB3 algorithms to create datasets.

Note: This wrapper is far from complete, and only provide a minimal integration with SB3.

3.16.1 Convert SB3 replay buffer to d3rlpy dataset

A replay buffer from Stable-Baselines3 can be easily converted to a *d3rlpy.dataset.MDPDataset* using `to_mdp_dataset()` utility function.

```
import stable_baselines3 as sb3

from d3rlpy.algos import AWR
from d3rlpy.wrappers.sb3 import to_mdp_dataset

# Train an off-policy agent with SB3
model = sb3.SAC("MlpPolicy", "Pendulum-v0", learning_rate=1e-3, verbose=1)
model.learn(6000)

# Convert to d3rlpy MDPDataset
dataset = to_mdp_dataset(model.replay_buffer)
# The dataset can then be used to train a d3rlpy model
offline_model = AWR()
offline_model.fit(dataset.episodes, n_epochs=100)
```

3.16.2 Convert d3rlpy to use SB3 helpers

An agent from d3rlpy can be converted to use the SB3 interface (notably follow the interface of SB3 `predict()`). This allows to use SB3 helpers like `evaluate_policy`.

```
import gym
from stable_baselines3.common.evaluation import evaluate_policy

from d3rlpy.algos import AWAC
from d3rlpy.wrappers.sb3 import SB3Wrapper

env = gym.make("Pendulum-v0")

# Define an offline RL model
offline_model = AWAC()
# Train it using for instance a dataset created by a SB3 agent (see above)
offline_model.fit(dataset.episodes, n_epochs=10)

# Use SB3 wrapper (convert `predict()` method to follow SB3 API)
# to have access to SB3 helpers
# d3rlpy model is accessible via `wrapped_model.algo`
wrapped_model = SB3Wrapper(offline_model)
```

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```
obs = env.reset()

# We can now use SB3's predict style
# it returns the action and the hidden states (for RNN policies)
actions, _ = wrapped_model.predict(observations, deterministic=True)
# The following is equivalent to offline_model.sample_action(obs)
actions, _ = wrapped_model.predict(observations, deterministic=False)

# Evaluate the trained model using SB3 helper
mean_reward, std_reward = evaluate_policy(wrapped_model, env)

print(f"mean_reward={mean_reward} +/- {std_reward}")

# Call methods from the wrapped d3rlpy model
wrapped_model.sample_action(obs)
wrapped_model.fit(dataset.episodes, n_epochs=10)

# Set attributes
wrapped_model.n_epochs = 2
# wrapped_model.n_epochs points to d3rlpy wrapped_model.algo.n_epochs
assert wrapped_model.algo.n_epochs == 2
```

CHAPTER

FOUR

COMMAND LINE INTERFACE

d3rlpy provides the convenient CLI tool.

4.1 plot

Plot the saved metrics by specifying paths:

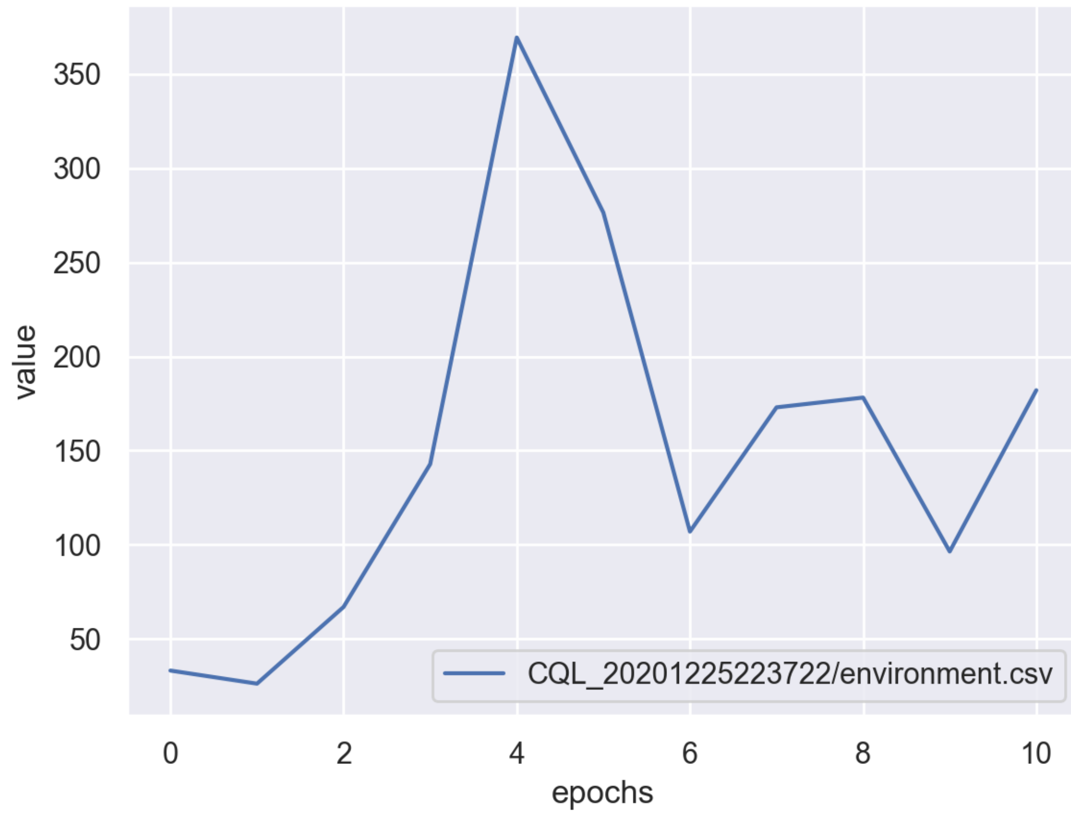
```
$ d3rlpy plot <path> [<path>...]
```

Table 1: options

option	description
`--window`	moving average window.
`--show-steps`	use iterations on x-axis.
`--show-max`	show maximum value.

example:

```
$ d3rlpy plot d3rlpy_logs/CQL_20201224224314/environment.csv
```



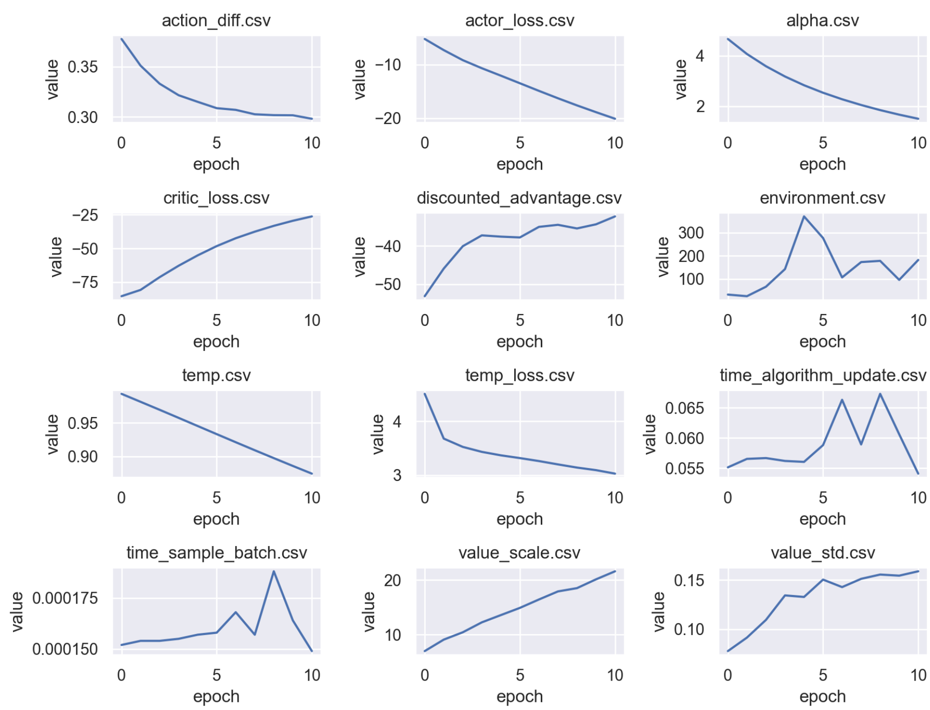
4.2 plot-all

Plot the all metrics saved in the directory:

```
$ d3rlpy plot-all <path>
```

example:

```
$ d3rlpy plot-all d3rlpy_logs/CQL_20201224224314
```



4.3 export

Export the saved model to the inference format, `onnx` and `torchscript`:

```
$ d3rlpy export <path>
```

Table 2: options

option	description
`--format`	model format (torchscript, onnx).
`--params-json`	explicitly specify params.json.
`--out`	output path.

example:

```
$ d3rlpy export d3rlpy_logs/CQL_20201224224314/model_100.pt
```

CHAPTER

FIVE

INSTALLATION

5.1 Recommended Platforms

d3rlpy supports Linux, macOS and also Windows.

5.2 Install d3rlpy

5.2.1 Install via PyPI

pip is a recommended way to install d3rlpy:

```
$ pip install d3rlpy
```

5.2.2 Install via Anaconda

d3rlpy is also available on *conda-forge*:

```
$ conda install -c conda-forge d3rlpy
```

5.2.3 Install from source

You can also install via GitHub repository:

```
$ git clone https://github.com/takuseno/d3rlpy
$ cd d3rlpy
$ pip install Cython numpy # if you have not installed them.
$ pip install -e .
```

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