# CONTENTS:

1 Key Features ............................................. 3
2 Basic Concepts .......................................... 5
3 Communication ......................................... 7
4 Contribution ............................................. 9
5 License .................................................. 11
6 Reference ................................................ 13
   6.1 Installation ...................................... 13
   6.2 Tutorial .......................................... 13
   6.3 API Reference ................................... 53
   6.4 FAQ .............................................. 271
7 Indices and tables ....................................... 281
Python Module Index ..................................... 283
Index ..................................................... 285
Optuna is an automatic hyperparameter optimization software framework, particularly designed for machine learning. It features an imperative, define-by-run style user API. Thanks to our define-by-run API, the code written with Optuna enjoys high modularity, and the user of Optuna can dynamically construct the search spaces for the hyperparameters.
Optuna has modern functionalities as follows:

- **Lightweight, versatile, and platform agnostic architecture**
  - Handle a wide variety of tasks with a simple installation that has few requirements.

- **Pythonic search spaces**
  - Define search spaces using familiar Python syntax including conditionals and loops.

- **Efficient optimization algorithms**
  - Adopt state-of-the-art algorithms for sampling hyperparameters and efficiently pruning unpromising trials.

- **Easy parallelization**
  - Scale studies to tens or hundreds or workers with little or no changes to the code.

- **Quick visualization**
  - Inspect optimization histories from a variety of plotting functions.
We use the terms *study* and *trial* as follows:

- **Study**: optimization based on an objective function
- **Trial**: a single execution of the objective function

Please refer to sample code below. The goal of a *study* is to find out the optimal set of hyperparameter values (e.g., `classifier` and `svm_c`) through multiple *trials* (e.g., `n_trials=100`). Optuna is a framework designed for the automation and the acceleration of the optimization *studies*.

```python
import ...

# Define an objective function to be minimized.
def objective(trial):
    # Invoke suggest methods of a Trial object to generate hyperparameters.
    regressor_name = trial.suggest_categorical('classifier', ['SVR', 'RandomForest'])
    if regressor_name == 'SVR':
        svr_c = trial.suggest_float('svr_c', 1e-10, 1e10, log=True)
        regressor_obj = sklearn.svm.SVR(C=svr_c)
    else:
        rf_max_depth = trial.suggest_int('rf_max_depth', 2, 32)
        regressor_obj = sklearn.ensemble.RandomForestRegressor(max_depth=rf_max_depth)

    X, y = sklearn.datasets.load_boston(return_X_y=True)
    X_train, X_val, y_train, y_val = sklearn.model_selection.train_test_split(X, y, random_state=0)

    regressor_obj.fit(X_train, y_train)
    y_pred = regressor_obj.predict(X_val)

    error = sklearn.metrics.mean_squared_error(y_val, y_pred)
    return error  # An objective value linked with the Trial object.

study = optuna.create_study()  # Create a new study.
study.optimize(objective, n_trials=100)  # Invoke optimization of the objective function.
```
COMMUNICATION

- GitHub Issues for bug reports, feature requests and questions.
- Gitter for interactive chat with developers.
- Stack Overflow for questions.
Any contributions to Optuna are welcome! When you send a pull request, please follow the contribution guide.
MIT License (see LICENSE).

6.1 Installation

Optuna supports Python 3.6 or newer.

We recommend to install Optuna via pip:

$ pip install optuna

You can also install the development version of Optuna from master branch of Git repository:

$ pip install git+https://github.com/optuna/optuna.git

You can also install Optuna via conda:

$ conda install -c conda-forge optuna

6.2 Tutorial

If you are new to Optuna or want a general introduction, we highly recommend the below video.

6.2.1 Key Features

Showcases Optuna’s Key Features.

Lightweight, versatile, and platform agnostic architecture

Optuna is entirely written in Python and has few dependencies. This means that we can quickly move to the real example once you get interested in Optuna.
Quadratic Function Example

Usually, Optuna is used to optimize hyperparameters, but as an example, let’s optimize a simple quadratic function: $(x - 2)^2$.

First of all, import `optuna`.

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", -10, 10)
    return (x - 2) ** 2
```

This function returns the value of $(x - 2)^2$. Our goal is to find the value of $x$ that minimizes the output of the `objective` function. This is the “optimization.” During the optimization, Optuna repeatedly calls and evaluates the objective function with different values of $x$.

A `Trial` object corresponds to a single execution of the objective function and is internally instantiated upon each invocation of the function.

The `suggest` APIs (for example, `suggest_float()`) are called inside the objective function to obtain parameters for a trial. `suggest_float()` selects parameters uniformly within the range provided. In our example, from $-10$ to $10$.

To start the optimization, we create a study object and pass the objective function to method `optimize()` as follows.

```python
study = optuna.create_study()
study.optimize(objective, n_trials=100)
```

You can get the best parameter as follows.

```python
best_params = study.best_params
found_x = best_params["x"]
print("Found x: {}, (x - 2)^2: {}\).format(found_x, (found_x - 2) ** 2))
```

Out:

```
Found x: 2.004421833357796, (x - 2)^2: 1.9552610244116478e-05
```

We can see that the $x$ value found by Optuna is close to the optimal value of $2$.

**Note:** When used to search for hyperparameters in machine learning, usually the objective function would return the loss or accuracy of the model.
**Study Object**

Let us clarify the terminology in Optuna as follows:

- **Trial**: A single call of the objective function
- **Study**: An optimization session, which is a set of trials
- **Parameter**: A variable whose value is to be optimized, such as $x$ in the above example

In Optuna, we use the study object to manage optimization. Method `create_study()` returns a study object. A study object has useful properties for analyzing the optimization outcome.

To get the dictionary of parameter name and parameter values:

```python
study.best_params
```

Out:

```json
{'x': 2.00442183357796}
```

To get the best observed value of the objective function:

```python
study.best_value
```

Out:

```python
1.9552610244116478e-05
```

To get the best trial:

```python
study.best_trial
```

Out:

```python
FrozenTrial(number=79, values=[1.9552610244116478e-05], datetime_start=datetime.datetime(2021, 10, 4, 6, 39, 11, 53177), datetime_complete=datetime.datetime(2021, 10, 4, 6, 39, 11, 53177), params={'x': 2.00442183357796}, distributions={'x': UniformDistribution(high=10.0, low=-10.0)}, user_attrs={}, system_attrs={})
```

To get all trials:

```python
study.trials
```

Out:

```python
[ FrozenTrial(number=0, values=[3.783628290242227], datetime_start=datetime.datetime(2021, 10, 4, 6, 39, 10, 764757), datetime_complete=datetime.datetime(2021, 10, 4, 6, 39, 10, 765110), params={'x': 3.9451550812835623}, distributions={'x': UniformDistribution(high=10.0, low=-10.0)}, user_attrs={}, system_attrs={}), 
  FrozenTrial(number=1, values=[39.263251483263375], datetime_start=datetime.datetime(2021, 10, 4, 6, 39, 10, 765897), datetime_complete=datetime.datetime(2021, 10, 4, 6, 39, 10, 76598), params={'x': 8.266039537320474}, distributions={'x': UniformDistribution(high=10.0, low=-10.0)}, user_attrs={}, system_attrs={}), 
  FrozenTrial(number=2, values=[26.3910503310013], datetime_start=datetime.datetime(2021, 10, 4, 6, 39, 10, 766161), datetime_complete=datetime.datetime(2021, 10, 4, 6, 39, 10, 766305), params={'x': -3.1372220443640675}, distributions={'x': UniformDistribution(high=10.0, low=-10.0)}, user_attrs={}, system_attrs={}), 
  FrozenTrial(number=3, values=[27.47143053888496], datetime_start=datetime.datetime(2021, 10, 4, 6, 39, 10, 766993), datetime_complete=datetime.datetime(2021, 10, 4, 6, 39, 10, 766993), params={'x': 7.241319541717381}, distributions={'x': UniformDistribution(high=10.0, low=-10.0)}, user_attrs={}, system_attrs={})] (continues on next page)
```
To get the number of trials:

```python
len(study.trials)
```

Out:

```
100
```

By executing `optimize()` again, we can continue the optimization.

```python
study.optimize(objective, n_trials=100)
```

To get the updated number of trials:

```python
len(study.trials)
```

Out:

```
200
```

As the objective function is so easy that the last 100 trials don’t improve the result. However, we can check the result again:

```python
best_params = study.best_params
found_x = best_params["x"]
print("Found x: {}, (x - 2)^2: ".format(found_x, (found_x - 2) ** 2))
```

Out:

```
Found x: 2.00442183357796, (x - 2)^2: 1.9552610244116478e-05
```

**Total running time of the script:** ( 0 minutes 0.713 seconds)

### Pythonic Search Space

For hyperparameter sampling, Optuna provides the following features:

- `optuna.trial.Trial.suggest_categorical()` for categorical parameters
- `optuna.trial.Trial.suggest_int()` for integer parameters
- `optuna.trial.Trial.suggest_float()` for floating point parameters

With optional arguments of `step` and `log`, we can discretize or take the logarithm of integer and floating point parameters.

```python
import optuna

def objective(trial):
    # Categorical parameter
    optimizer = trial.suggest_categorical("optimizer", ["MomentumSGD", "Adam")
    
    # Integer parameter
    num_layers = trial.suggest_int("num_layers", 1, 3)
```

(continues on next page)
# Integer parameter (log)
num_channels = trial.suggest_int("num_channels", 32, 512, log=True)

# Integer parameter (discretized)
num_units = trial.suggest_int("num_units", 10, 100, step=5)

# Floating point parameter
dropout_rate = trial.suggest_float("dropout_rate", 0.0, 1.0)

# Floating point parameter (log)
learning_rate = trial.suggest_float("learning_rate", 1e-5, 1e-2, log=True)

# Floating point parameter (discretized)
drop_path_rate = trial.suggest_float("drop_path_rate", 0.0, 1.0, step=0.1)

## Defining Parameter Spaces

In Optuna, we define search spaces using familiar Python syntax including conditionals and loops.

Also, you can use branches or loops depending on the parameter values.

For more various use, see examples.

- **Branches:**

```python
import sklearn.ensemble
import sklearn.svm

def objective(trial):
    classifier_name = trial.suggest_categorical("classifier", ["SVC", "RandomForest")
    if classifier_name == "SVC":
        svc_c = trial.suggest_float("svc_c", 1e-10, 1e10, log=True)
        classifier_obj = sklearn.svm.SVC(C=svc_c)
    else:
        rf_max_depth = trial.suggest_int("rf_max_depth", 2, 32, log=True)
        classifier_obj = sklearn.ensemble.RandomForestClassifier(max_depth=rf_max_depth)
```

- **Loops:**

```python
import torch
import torch.nn as nn

def create_model(trial, in_size):
    n_layers = trial.suggest_int("n_layers", 1, 3)

    layers = []
    for i in range(n_layers):
        n_units = trial.suggest_int("n_units_\{\}".format(i), 4, 128, log=True)
        layers.append(nn.Linear(in_size, n_units))
        layers.append(nn.ReLU())
        in_size = n_units
    layers.append(nn.Linear(in_size, 10))
```
Note on the Number of Parameters

The difficulty of optimization increases roughly exponentially with regard to the number of parameters. That is, the number of necessary trials increases exponentially when you increase the number of parameters, so it is recommended to not add unimportant parameters.

Total running time of the script: ( 0 minutes 0.001 seconds)

Efficient Optimization Algorithms

Optuna enables efficient hyperparameter optimization by adopting state-of-the-art algorithms for sampling hyperparameters and pruning efficiently unpromising trials.

Sampling Algorithms

Samplers basically continually narrow down the search space using the records of suggested parameter values and evaluated objective values, leading to an optimal search space which giving off parameters leading to better objective values. More detailed explanation of how samplers suggest parameters is in `optuna.samplers.BaseSampler`.

Optuna provides the following sampling algorithms:

- Tree-structured Parzen Estimator algorithm implemented in `optuna.samplers.TPESampler`
- CMA-ES based algorithm implemented in `optuna.samplers.CmaEsSampler`
- Grid Search implemented in `optuna.samplers.GridSampler`
- Random Search implemented in `optuna.samplers.RandomSampler`

The default sampler is `optuna.samplers.TPESampler`.

Switching Samplers

```python
import optuna

study = optuna.create_study()
print(f"Sampler is {study.sampler.__class__.__name__}\")
```

Out:

```python
Sampler is TPESampler
```

If you want to use different samplers for example `RandomSampler` and `CmaEsSampler`,

```python
import optuna

study = optuna.create_study()
print(f"Sampler is {study.sampler.__class__.__name__}\")
```

Out:

```python
Sampler is RandomSampler
```
```python
study = optuna.create_study(sampler=optuna.samplers.RandomSampler())
print(f"Sampler is {study.sampler.__class__.__name__}\")

study = optuna.create_study(sampler=optuna.samplers.CmaEsSampler())
print(f"Sampler is {study.sampler.__class__.__name__}\")
```

Out:

```
Sampler is RandomSampler
Sampler is CmaEsSampler
```

**Pruning Algorithms**

Pruners automatically stop unpromising trials at the early stages of the training (a.k.a., automated early-stopping).

Optuna provides the following pruning algorithms:

- Asynchronous Successive Halving algorithm implemented in `optuna.pruners.SuccessiveHalvingPruner`
- Hyperband algorithm implemented in `optuna.pruners.HyperbandPruner`
- Median pruning algorithm implemented in `optuna.pruners.MedianPruner`
- Threshold pruning algorithm implemented in `optuna.pruners.ThresholdPruner`

We use `optuna.pruners.MedianPruner` in most examples, though basically it is outperformed by `optuna.pruners.SuccessiveHalvingPruner` and `optuna.pruners.HyperbandPruner` as in this benchmark result.

**Activating Pruners**

To turn on the pruning feature, you need to call `report()` and `should_prune()` after each step of the iterative training. `report()` periodically monitors the intermediate objective values. `should_prune()` decides termination of the trial that does not meet a predefined condition.

We would recommend using integration modules for major machine learning frameworks. Exclusive list is `optuna.integration` and usecases are available in `optuna/examples`.

```python
import logging
import sys
import sklearn.datasets
import sklearn.linear_model
import sklearn.model_selection

def objective(trial):
    iris = sklearn.datasets.load_iris()
    classes = list(set(iris.target))
    train_x, valid_x, train_y, valid_y = sklearn.model_selection.train_test_split(
        iris.data, iris.target, test_size=0.25, random_state=0
    )

    alpha = trial.suggest_float("alpha", 1e-5, 1e-1, log=True)
    clf = sklearn.linear_model.SGDClassifier(alpha=alpha)
```

(continues on next page)
```python
for step in range(100):
    clf.partial_fit(train_x, train_y, classes=classes)

    # Report intermediate objective value.
    intermediate_value = 1.0 - clf.score(valid_x, valid_y)
    trial.report(intermediate_value, step)

    # Handle pruning based on the intermediate value.
    if trial.should_prune():
        raise optuna.TrialPruned()

return 1.0 - clf.score(valid_x, valid_y)
```

Set up the median stopping rule as the pruning condition.

```python
# Add stream handler of stdout to show the messages
optuna.logging.get_logger("optuna").addHandler(logging.StreamHandler(sys.stdout))
study = optuna.create_study(pruner=optuna.pruners.MedianPruner())
study.optimize(objective, n_trials=20)
```

Out:

```
A new study created in memory with name: no-name-4423c12c-22e1-4eaf-ba60-caf0020403c6
Trial 0 finished with value: 0.07894736842105265 and parameters: {'alpha': 0.
˓
→00020629773477269024}. Best is trial 0 with value: 0.07894736842105265.
Trial 1 finished with value: 0.36842102631579 and parameters: {'alpha': 0.
˓
→005250149151047217}. Best is trial 0 with value: 0.07894736842105265.
Trial 2 finished with value: 0.052631578947368474 and parameters: {'alpha': 5.
˓
→9086862655635784e-05}. Best is trial 2 with value: 0.052631578947368474.
Trial 3 finished with value: 0.3421052631578947 and parameters: {'alpha': 0.
˓
→0717263583415294}. Best is trial 2 with value: 0.052631578947368474.
Trial 4 finished with value: 0.23684210526315785 and parameters: {'alpha': 1.
˓
→7451874636151302e-05}. Best is trial 2 with value: 0.052631578947368474.
Trial 5 pruned.
Trial 6 finished with value: 0.10526315789473684 and parameters: {'alpha': 1.
˓
→4943994817649e-05}. Best is trial 2 with value: 0.052631578947368474.
Trial 7 pruned.
Trial 8 pruned.
Trial 9 pruned.
Trial 10 pruned.
Trial 11 pruned.
Trial 12 pruned.
Trial 13 pruned.
Trial 14 pruned.
Trial 15 pruned.
Trial 16 finished with value: 0.07894736842105265 and parameters: {'alpha': 0.
˓
→006166329613687364}. Best is trial 2 with value: 0.052631578947368474.
Trial 17 pruned.
Trial 18 pruned.
Trial 19 pruned.

As you can see, several trials were pruned (stopped) before they finished all of the iterations. The format of message is "Trial <Trial Number> pruned.".
```
Which Sampler and Pruner Should be Used?

From the benchmark results which are available at optuna/optuna - wiki “Benchmarks with Kurobako”, at least for not deep learning tasks, we would say that

- For `optuna.samplers.RandomSampler`, `optuna.pruners.MedianPruner` is the best.
- For `optuna.samplers.TPESampler`, `optuna.pruners.Hyperband` is the best.

However, note that the benchmark is not deep learning. For deep learning tasks, consult the below table. This table is from the Ozaki et al., Hyperparameter Optimization Methods: Overview and Characteristics, in IEICE Trans, Vol.J103-D No.9 pp.615-631, 2020 paper, which is written in Japanese.

<table>
<thead>
<tr>
<th>Parallel Compute Resource</th>
<th>Categorical/Conditional Hyperparameters</th>
<th>Recommended Algorithms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited</td>
<td>No</td>
<td>TPE, GP-EI if search space is low-dimensional and continuous.</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>TPE, GP-EI if search space is low-dimensional and continuous</td>
</tr>
<tr>
<td>Sufficient</td>
<td>No</td>
<td>CMA-ES, Random Search</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>Random Search or Genetic Algorithm</td>
</tr>
</tbody>
</table>

Integration Modules for Pruning

To implement pruning mechanism in much simpler forms, Optuna provides integration modules for the following libraries.

For the complete list of Optuna’s integration modules, see `optuna.integration`.

For example, `XGBoostPruningCallback` introduces pruning without directly changing the logic of training iteration. (See also example for the entire script.)

```python
pruning_callback = optuna.integration.XGBoostPruningCallback(trial, 'validation-error →')
bst = xgb.train(param, dtrain, evals=[(dvalid, 'validation')], callbacks=[pruning_callback])
```

Total running time of the script: ( 0 minutes 1.274 seconds)

Easy Parallelization

It’s straightforward to parallelize `optuna.study.Study.optimize()`.

If you want to manually execute Optuna optimization:

1. start an RDB server (this example uses MySQL)
2. create a study with `--storage` argument
3. share the study among multiple nodes and processes

Of course, you can use Kubernetes as in the kubernetes examples.

To just see how parallel optimization works in Optuna, check the below video.
Create a Study

You can create a study using `optuna create-study` command. Alternatively, in Python script you can use `optuna.create_study()`.

```bash
$ mysql -u root -e "CREATE DATABASE IF NOT EXISTS example"
$ optuna create-study --study-name "distributed-example" --storage "mysql://root@localhost/example"
```

Then, write an optimization script. Let’s assume that `foo.py` contains the following code.

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", -10, 10)
    return (x - 2) ** 2

if __name__ == "__main__":
    study = optuna.load_study(
        study_name="distributed-example", storage="mysql://root@localhost/example"
    )
    study.optimize(objective, n_trials=100)
```

Share the Study among Multiple Nodes and Processes

Finally, run the shared study from multiple processes. For example, run `Process 1` in a terminal, and do `Process 2` in another one. They get parameter suggestions based on shared trials’ history.

**Process 1:**

```
$ python foo.py
[I 2020-07-21 13:45:02,973] Trial 0 finished with value: 45.35553104173011 and parameters: {'x': 8.73465151598285}. Best is trial 0 with value: 45.35553104173011.
[I 2020-07-21 13:45:04,013] Trial 2 finished with value: 4.6002397305938905 and parameters: {'x': 4.144816945707463}. Best is trial 1 with value: 0.
...```

**Process 2 (the same command as process 1):**

```
$ python foo.py
[I 2020-07-21 13:45:03,748] Trial 1 finished with value: 0.028194513284051464 and parameters: {'x': 1.8320877810162361}. Best is trial 1 with value: 0.
[I 2020-07-21 13:45:05,783] Trial 3 finished with value: 24.45966755098074 and parameters: {'x': 6.945671597566982}. Best is trial 1 with value: 0.
...```

**Note:** We do not recommend SQLite for distributed optimizations at scale because it may cause deadlocks and serious performance issues. Please consider to use another database engine like PostgreSQL or MySQL.
Quick Visualization for Hyperparameter Optimization Analysis

Optuna provides various visualization features in `optuna.visualization` to analyze optimization results visually.

This tutorial walks you through this module by visualizing the history of lightgbm model for breast cancer dataset.

```python
import lightgbm as lgb
import numpy as np
import sklearn.datasets
import sklearn.metrics
from sklearn.model_selection import train_test_split
import optuna
from optuna.visualization import plot_contour
from optuna.visualization import plot_edf
from optuna.visualization import plot_intermediate_values
from optuna.visualization import plot_optimization_history
from optuna.visualization import plot_parallel_coordinate
from optuna.visualization import plot_param_importances
from optuna.visualization import plot_slice

SEED = 42
np.random.seed(SEED)

Define the objective function.

```python
def objective(trial):
    data, target = sklearn.datasets.load_breast_cancer(return_X_y=True)
    train_x, valid_x, train_y, valid_y = train_test_split(data, target, test_size=0.25)
    dtrain = lgb.Dataset(train_x, label=train_y)
    dvalid = lgb.Dataset(valid_x, label=valid_y)

    param = {
        "objective": "binary",
        "metric": "auc",
        "verbosity": -1,
        "boosting_type": "gbdt",
        "bagging_fraction": trial.suggest_float("bagging_fraction", 0.4, 1.0),
        "bagging_freq": trial.suggest_int("bagging_freq", 1, 7),
        "min_child_samples": trial.suggest_int("min_child_samples", 5, 100),
    }

    # Add a callback for pruning.
    pruning_callback = optuna.integration.LightGBMPruningCallback(trial, "auc")
    gbm = lgb.train(
        param, dtrain, valid_sets=[dvalid], verbose_eval=False, callbacks=[pruning_callback]
    )
```
preds = gbm.predict(valid_x)
pred_labels = np.rint(preds)
accuracy = sklearn.metrics.accuracy_score(valid_y, pred_labels)

return accuracy

study = optuna.create_study(
    direction="maximize",
    sampler=optuna.samplers.TPESampler(seed=SEED),
    pruner=optuna.pruners.MedianPruner(n_warmup_steps=10),
)
study.optimize(objective, n_trials=100, timeout=600)

**Plot functions**

Visualize the optimization history. See `plot_optimization_history()` for the details.

```
plot_optimization_history(study)
```

Visualize the learning curves of the trials. See `plot_intermediate_values()` for the details.

```
plot_intermediate_values(study)
```

Visualize high-dimensional parameter relationships. See `plot_parallel_coordinate()` for the details.

```
plot_parallel_coordinate(study)
```

Select parameters to visualize.

```
plot_parallel_coordinate(study, params=["bagging_freq", "bagging_fraction"])
```

Visualize hyperparameter relationships. See `plot_contour()` for the details.

```
plot_contour(study)
```

Select parameters to visualize.

```
plot_contour(study, params=["bagging_freq", "bagging_fraction"])
```

Visualize individual hyperparameters as slice plot. See `plot_slice()` for the details.

```
plot_slice(study)
```

Select parameters to visualize.

```
plot_slice(study, params=["bagging_freq", "bagging_fraction"])
```

Visualize parameter importances. See `plot_param_importances()` for the details.

```
plot_param_importances(study)
```

Learn which hyperparameters are affecting the trial duration with hyperparameter importance.
```python
optuna.visualization.plot_param_importances(
    study, target=lambda t: t.duration.total_seconds(), target_name="duration"
)
```

Visualize empirical distribution function. See `plot_edf()` for the details.

```python
plot_edf(study)
```

**Total running time of the script:** (0 minutes 3.904 seconds)

### 6.2.2 Recipes

Showcases the recipes that might help you using Optuna with comfort.

**Saving/Resuming Study with RDB Backend**

An RDB backend enables persistent experiments (i.e., to save and resume a study) as well as access to history of studies. In addition, we can run multi-node optimization tasks with this feature, which is described in *Easy Parallelization*.

In this section, let’s try simple examples running on a local environment with SQLite DB.

**Note:** You can also utilize other RDB backends, e.g., PostgreSQL or MySQL, by setting the storage argument to the DB’s URL. Please refer to SQLAlchemy’s document for how to set up the URL.

**New Study**

We can create a persistent study by calling `create_study()` function as follows. An SQLite file `example.db` is automatically initialized with a new study record.

```python
import logging
import sys
import optuna

# Add stream handler of stdout to show the messages
optuna.logging.get_logger("optuna").addHandler(logging.StreamHandler(sys.stdout))
study_name = "example-study"  # Unique identifier of the study.
storage_name = "sqlite:///{}.db".format(study_name)
study = optuna.create_study(study_name=study_name, storage=storage_name)

Out:
A new study created in RDB with name: example-study

To run a study, call `optimize()` method passing an objective function.

```python
def objective(trial):
    x = trial.suggest_float("x", -10, 10)
    return (x - 2) ** 2

study.optimize(objective, n_trials=3)
```
Optuna Documentation, Release 2.10.0

Out:
Trial 0 finished with value: 112.50779117350417 and parameters: {'x': -8.
˓→606968990880674}. Best is trial 0 with value: 112.50779117350417.
Trial 1 finished with value: 0.3685348006116495 and parameters: {'x': 2.
˓→6070706718427843}. Best is trial 1 with value: 0.3685348006116495.
Trial 2 finished with value: 39.79103192690228 and parameters: {'x': -4.
˓→308013310615497}. Best is trial 1 with value: 0.3685348006116495.

Resume Study
To resume a study, instantiate a Study object passing the study name example-study and the DB URL
sqlite:///example-study.db.
study = optuna.create_study(study_name=study_name, storage=storage_name, load_if_
˓→exists=True)
study.optimize(objective, n_trials=3)

Out:
Using an existing study with name 'example-study' instead of creating a new one.
Trial 3 finished with value: 28.53230222965668 and parameters: {'x': -3.
˓→341563650248556}. Best is trial 1 with value: 0.3685348006116495.
Trial 4 finished with value: 27.889451362460168 and parameters: {'x': 7.
˓→281046426841954}. Best is trial 1 with value: 0.3685348006116495.
Trial 5 finished with value: 126.77220752873005 and parameters: {'x': -9.
˓→25931647697719}. Best is trial 1 with value: 0.3685348006116495.

Experimental History
We can access histories of studies and trials via the Study class.
example-study as:

For example, we can get all trials of

study = optuna.create_study(study_name=study_name, storage=storage_name, load_if_
˓→exists=True)
df = study.trials_dataframe(attrs=("number", "value", "params", "state"))

Out:
Using an existing study with name 'example-study' instead of creating a new one.

The method trials_dataframe() returns a pandas dataframe like:
print(df)

Out:
0
1
2
3
4
5

26

number
0
1
2
3
4
5

value
112.507791
0.368535
39.791032
28.532302
27.889451
126.772208

params_x
-8.606969
2.607071
-4.308013
-3.341564
7.281046
-9.259316

state
COMPLETE
COMPLETE
COMPLETE
COMPLETE
COMPLETE
COMPLETE

Chapter 6. Reference


A `Study` object also provides properties such as `trials`, `best_value`, `best_params` (see also Lightweight, versatile, and platform agnostic architecture).

```python
print("Best params: ", study.best_params)
print("Best value: ", study.best_value)
print("Best Trial: ", study.best_trial)
print("Trials: ", study.trials)
```

Out:

```
Best params: {'x': 2.6070706718427843}
Best value: 0.3685348006116495
Best Trial: FrozenTrial(number=1, values=[0.3685348006116495], datetime_start=datetime.datetime(2021, 10, 4, 6, 39, 17, 381628), datetime_complete=datetime.datetime(2021, 10, 4, 6, 39, 17, 393875), params={'x': 2.6070706718427843}, distributions={'x': UniformDistribution(high=10.0, low=-10.0)}, system_attrs={}, intermediate_values={}, trial_id=2, state=TrialState.COMPLETE, value=None)
Trials: [FrozenTrial(number=0, values=[112.50779117350417], datetime_start=datetime.datetime(2021, 10, 4, 6, 39, 17, 341791), datetime_complete=datetime.datetime(2021, 10, 4, 6, 39, 17, 357043), params={'x': -8.606968990880674}, distributions={'x': UniformDistribution(high=10.0, low=-10.0)}, system_attrs={}, intermediate_values={}, trial_id=1, state=TrialState.COMPLETE, value=None), FrozenTrial(number=1, values=[0.3685348006116495], datetime_start=datetime.datetime(2021, 10, 4, 6, 39, 17, 381628), datetime_complete=datetime.datetime(2021, 10, 4, 6, 39, 17, 393875), params={'x': 2.6070706718427843}, distributions={'x': UniformDistribution(high=10.0, low=-10.0)}, system_attrs={}, intermediate_values={}, trial_id=2, state=TrialState.COMPLETE, value=None), FrozenTrial(number=2, values=[39.79103192690228], datetime_start=datetime.datetime(2021, 10, 4, 6, 39, 17, 411811), datetime_complete=datetime.datetime(2021, 10, 4, 6, 39, 17, 423785), params={'x': -4.308013310615497}, distributions={'x': UniformDistribution(high=10.0, low=-10.0)}, system_attrs={}, intermediate_values={}, trial_id=3, state=TrialState.COMPLETE, value=None), FrozenTrial(number=3, values=[28.53230222965668], datetime_start=datetime.datetime(2021, 10, 4, 6, 39, 17, 472379), datetime_complete=datetime.datetime(2021, 10, 4, 6, 39, 17, 486029), params={'x': -3.341563650248556}, distributions={'x': UniformDistribution(high=10.0, low=-10.0)}, system_attrs={}, intermediate_values={}, trial_id=4, state=TrialState.COMPLETE, value=None), FrozenTrial(number=4, values=[27.889451362460168], datetime_start=datetime.datetime(2021, 10, 4, 6, 39, 17, 507569), datetime_complete=datetime.datetime(2021, 10, 4, 6, 39, 17, 521916), params={'x': 7.281046426841954}, distributions={'x': UniformDistribution(high=10.0, low=-10.0)}, system_attrs={}, intermediate_values={}, trial_id=5, state=TrialState.COMPLETE, value=None), FrozenTrial(number=5, values=[126.77220752873005], datetime_start=datetime.datetime(2021, 10, 4, 6, 39, 17, 548217), datetime_complete=datetime.datetime(2021, 10, 4, 6, 39, 17, 561916), params={'x': -9.25931647697719}, distributions={'x': UniformDistribution(high=10.0, low=-10.0)}, system_attrs={}, intermediate_values={}, trial_id=6, state=TrialState.COMPLETE, value=None)]
```

Total running time of the script: ( 0 minutes 0.460 seconds)
Multi-objective Optimization with Optuna

This tutorial showcases Optuna’s multi-objective optimization feature by optimizing the validation accuracy of Fashion MNIST dataset and the FLOPS of the model implemented in PyTorch.

We use `thop` to measure FLOPS.

```python
import thop
import torch
import torch.nn as nn
import torch.nn.functional as F
import torchvision
import optuna

DEVICE = torch.device("cuda") if torch.cuda.is_available() else torch.device("cpu")

DIR = ".."
BATCHSIZE = 128
N_TRAIN_EXAMPLES = BATCHSIZE * 30
N_VALID_EXAMPLES = BATCHSIZE * 10

def define_model(trial):
    n_layers = trial.suggest_int("n_layers", 1, 3)
    layers = []

    in_features = 28 * 28
    for i in range(n_layers):
        out_features = trial.suggest_int("n_units_{}/".format(i), 4, 128)
        layers.append(nn.Linear(in_features, out_features))
        layers.append(nn.ReLU())
        p = trial.suggest_float("dropout_{}/".format(i), 0.2, 0.5)
        layers.append(nn.Dropout(p))

        in_features = out_features
    layers.append(nn.Linear(in_features, 10))
    layers.append(nn.LogSoftmax(dim=1))

    return nn.Sequential(*layers)

# Defines training and evaluation.
def train_model(model, optimizer, train_loader):
    model.train()
    for batch_idx, (data, target) in enumerate(train_loader):
        data, target = data.view(-1, 28 * 28).to(DEVICE), target.to(DEVICE)
        optimizer.zero_grad()
        loss = F.nll_loss(model(data), target).backward()
        optimizer.step()

def eval_model(model, valid_loader):
    model.eval()
    correct = 0
    with torch.no_grad():
        for batch_idx, (data, target) in enumerate(valid_loader):
            output = model(data)
            pred = output.max(1, keepdim=True)[1]
            correct += pred.eq(target.view_as(pred)).sum().item()

    return correct / len(valid_loader)
```

(continues on next page)
Define multi-objective objective function. Objectives are FLOPS and accuracy.

```python
def objective(trial):
    train_dataset = torchvision.datasets.FashionMNIST(
        DIR, train=True, download=True, transform=torchvision.transforms.ToTensor()
    )
    train_loader = torch.utils.data.DataLoader(
        torch.utils.data.Subset(train_dataset, list(range(N_TRAIN_EXAMPLES))),
        batch_size=BATCHSIZE,
        shuffle=True,
    )
    val_dataset = torchvision.datasets.FashionMNIST(
        DIR, train=False, transform=torchvision.transforms.ToTensor()
    )
    val_loader = torch.utils.data.DataLoader(
        torch.utils.data.Subset(val_dataset, list(range(N_VALID_EXAMPLES))),
        batch_size=BATCHSIZE,
        shuffle=True,
    )
    model = define_model(trial).to(DEVICE)
    optimizer = torch.optim.Adam(
        model.parameters(), trial.suggest_float("lr", 1e-5, 1e-1, log=True)
    )
    for epoch in range(10):
        train_model(model, optimizer, train_loader)
        flops, accuracy = eval_model(model, val_loader)
        return flops, accuracy
```

Run multi-objective optimization

If your optimization problem is multi-objective, Optuna assumes that you will specify the optimization direction for each objective. Specifically, in this example, we want to minimize the FLOPS (we want a faster model) and maximize the accuracy. So we set directions to ["minimize", "maximize"].

```python
study = optuna.create_study(directions=['minimize', 'maximize'])
study.optimize(objective, n_trials=30, timeout=300)
print("Number of finished trials: ", len(study.trials))
```

Out:
Optuna Documentation, Release 2.10.0


<table>
<thead>
<tr>
<th>Percentage</th>
<th>Progress</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>0/2642188</td>
<td>00:00&lt;?, ?it/s</td>
</tr>
<tr>
<td>0%</td>
<td>39936/2642188</td>
<td>00:00&lt;01:20, 327729.88it/s</td>
</tr>
<tr>
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<td>00:00&lt;01:14, 352188.38it/s</td>
</tr>
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<td>305152/2642188</td>
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</tr>
<tr>
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<td>00:00&lt;00:15, 1645473.15it/s</td>
</tr>
<tr>
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</tr>
<tr>
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</tr>
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<tr>
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</tr>
<tr>
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<tr>
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<tr>
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<tr>
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</tr>
<tr>
<td>96%</td>
<td>2532048/2642188</td>
<td>00:00&lt;00:00, 1427047.83it/s</td>
</tr>
</tbody>
</table>

2642272it [00:02, 11987315.25it/s]

Extracting ../FashionMNIST/raw/train-images-idx3-ubyte.gz to ../FashionMNIST/raw

2642272it [00:02, 11987315.25it/s]

0% | 0/29515 [00:00<?, ?it/s]
29696it [00:00, 299984.23it/s]

Extracting ../FashionMNIST/raw/train-labels-idx1-ubyte.gz to ../FashionMNIST/raw

0% | 0/29515 [00:00<?, ?it/s]
29696it [00:00, 299984.23it/s]


0% | 0/29515 [00:00<?, ?it/s]
29696it [00:00, 299984.23it/s]

0% | 0/4422102 [00:00<?, ?it/s]
1% | 40960/4422102 [00:00<00:13, 321359.92it/s]
2% | 104448/4422102 [00:00<00:12, 357337.47it/s]
8% | 333824/4422102 [00:00<00:03, 1047568.48it/s]
18% | 788480/4422102 [00:00<00:01, 2228109.92it/s]
33% | 1474560/4422102 [00:00<00:00, 3734809.83it/s]
59% | 2608128/4422102 [00:00<00:00, 6145988.24it/s]
4422656it [00:00, 5556150.40it/s]

Extracting ../FashionMNIST/raw/t10k-images-idx3-ubyte.gz to ../FashionMNIST/raw

0% | 0/4422102 [00:00<?, ?it/s]
1% | 40960/4422102 [00:00<00:13, 321359.92it/s]
2% | 104448/4422102 [00:00<00:12, 357337.47it/s]
8% | 333824/4422102 [00:00<00:03, 1047568.48it/s]
18% | 788480/4422102 [00:00<00:01, 2228109.92it/s]
33% | 1474560/4422102 [00:00<00:00, 3734809.83it/s]
59% | 2608128/4422102 [00:00<00:00, 6145988.24it/s]
4422656it [00:00, 5556150.40it/s]

Extracting ../FashionMNIST/raw/t10k-images-idx3-ubyte.gz to ../FashionMNIST/raw

0% | 0/5148 [00:00<?, ?it/s]
6144it [00:00, 3691948.65it/s]

Extracting ../FashionMNIST/raw/t10k-labels-idx1-ubyte.gz to ../FashionMNIST/raw

Processing...

The given NumPy array is not writeable, and PyTorch does not support non-writeable NumPy array using the tensor. You may want to copy the array to protect its data or make it writeable before converting it to a tensor. This type of warning will be suppressed for the rest of this program. (Triggered internally at /pytorch/torch/csrc/utils/tensor_numpy.cpp:143.)
Done!
Number of finished trials: 30

Check trials on pareto front visually

```python
doctests.visualization.plot_pareto_front(study, target_names=['FLOPS', 'accuracy'])
```

Out:

/home/docs/checkouts/readthedocs.org/user_builds/optuna/checkouts/stable/tutorial/20_...
plot_pareto_front is experimental (supported from v2.4.0). The interface can change...

Learn which hyperparameters are affecting the flops most with hyperparameter importance.

```python
doctests.visualization.plot_param_importances(study, target=lambda t: t.values[0], target_name='flops')
```

Total running time of the script: 1 minutes 26.447 seconds

**User Attributes**

This feature is to annotate experiments with user-defined attributes.

**Adding User Attributes to Studies**

A `Study` object provides `set_user_attr()` method to register a pair of key and value as an user-defined attribute. A key is supposed to be a `str`, and a value be any object serializable with `json.dumps`.

```python
import sklearn.datasets
import sklearn.model_selection
import sklearn.svm
import optuna

study = optuna.create_study(storage='sqlite:///example.db')
study.set_user_attr('contributors', ['Akiba', 'Sano'])
study.set_user_attr('dataset', 'MNIST')
```

We can access annotated attributes with `user_attr` property.

```python
study.user_attrs  # {'contributors': ['Akiba', 'Sano'], 'dataset': 'MNIST'}
```

Out:

```python
{'contributors': ['Akiba', 'Sano'], 'dataset': 'MNIST'}
```

StudySummary object, which can be retrieved by `get_all_study_summaries()`, also contains user-defined attributes.
```python
study_summaries = optuna.get_all_study_summaries("sqlite:///example.db")
study_summaries[0].user_attrs # {"contributors": ["Akiba", "Sano"], "dataset": "MNIST"}
```

Out:

```python
dict["contributors": ['Akiba', 'Sano'], 'dataset': 'MNIST']
```

See also:

The `optuna study set-user-attr` command, which sets an attribute via command line interface.

### Adding User Attributes to Trials

As with `Study`, a `Trial` object provides `set_user_attr()` method. Attributes are set inside an objective function.

```python
def objective(trial):
    iris = sklearn.datasets.load_iris()
    x, y = iris.data, iris.target

    svc_c = trial.suggest_float("svc_c", 1e-10, 1e10, log=True)
    clf = sklearn.svm.SVC(C=svc_c)
    accuracy = sklearn.model_selection.cross_val_score(clf, x, y).mean()

    trial.set_user_attr("accuracy", accuracy)
    return 1.0 - accuracy  # return error for minimization
```

We can access annotated attributes as:

```python
study.trials[0].user_attrs
```

Out:

```python
dict["accuracy": 0.9266666666666667]
```

Note that, in this example, the attribute is not annotated to a `Study` but a single `Trial`.

**Total running time of the script:** (0 minutes 0.214 seconds)

### Command-Line Interface

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>create-study</td>
<td>Create a new study.</td>
</tr>
<tr>
<td>delete-study</td>
<td>Delete a specified study.</td>
</tr>
<tr>
<td>dashboard</td>
<td>Launch web dashboard (beta).</td>
</tr>
<tr>
<td>storage upgrade</td>
<td>Upgrade the schema of a storage.</td>
</tr>
<tr>
<td>studies</td>
<td>Show a list of studies.</td>
</tr>
<tr>
<td>study optimize</td>
<td>Start optimization of a study.</td>
</tr>
<tr>
<td>study set-user-attr</td>
<td>Set a user attribute to a study.</td>
</tr>
</tbody>
</table>
Optuna provides command-line interface as shown in the above table.

Let us assume you are not in IPython shell and writing Python script files instead. It is totally fine to write scripts like the following:

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", -10, 10)
    return (x - 2) ** 2

if __name__ == "__main__":
    study = optuna.create_study()
    study.optimize(objective, n_trials=100)
    print("Best value: {} (params: {})
          ".format(study.best_value, study.best_params))
```

Out:

```
Best value: 7.831437049424937e-05 (params: {'x': 1.991150459306029})
```

However, we can reduce boilerplate codes by using our `optuna` command. Let us assume that `foo.py` contains only the following code.

```python
def objective(trial):
    x = trial.suggest_float('x', -10, 10)
    return (x - 2) ** 2
```

Even so, we can invoke the optimization as follows. (Don’t care about `--storage sqlite:///example.db` for now, which is described in Saving/Resuming Study with RDB Backend.)

```bash
$ cat foo.py
def objective(trial):
    x = trial.suggest_float('x', -10, 10)
    return (x - 2) ** 2

$ STUDY_NAME=`optuna create-study --storage sqlite:///example.db`
$ optuna study optimize foo.py objective --study-name $STUDY_NAME --n-trials=100 --storage sqlite:///example.db

Current best value is 54.353767789264026 with parameters: {'x': -5.372500782588228}.

Current best value is 15.784266965526376 with parameters: {'x': 5.972941852774387}.

... 

Current best value is 2.28075809973617e-06 with parameters: {'x': 1.9984897821018828}.
```

Please note that `foo.py` only contains the definition of the objective function. By giving the script file name and the method name of objective function to `optuna study optimize` command, we can invoke the optimization.

**Total running time of the script:** (0 minutes 0.319 seconds)
User-Defined Sampler

Thanks to user-defined samplers, you can:

- experiment your own sampling algorithms,
- implement task-specific algorithms to refine the optimization performance, or
- wrap other optimization libraries to integrate them into Optuna pipelines (e.g., `SkoptSampler`).

This section describes the internal behavior of sampler classes and shows an example of implementing a user-defined sampler.

Overview of Sampler

A sampler has the responsibility to determine the parameter values to be evaluated in a trial. When a `suggest API` (e.g., `suggest_float()`) is called inside an objective function, the corresponding distribution object (e.g., `UniformDistribution`) is created internally. A sampler samples a parameter value from the distribution. The sampled value is returned to the caller of the `suggest API` and evaluated in the objective function.

To create a new sampler, you need to define a class that inherits `BaseSampler`. The base class has three abstract methods; `infer_relative_search_space()`, `sample_relative()`, and `sample_independent()`. As the method names imply, Optuna supports two types of sampling: one is relative sampling that can consider the correlation of the parameters in a trial, and the other is independent sampling that samples each parameter independently.

At the beginning of a trial, `infer_relative_search_space()` is called to provide the relative search space for the trial. Then, `sample_relative()` is invoked to sample relative parameters from the search space. During the execution of the objective function, `sample_independent()` is used to sample parameters that don’t belong to the relative search space.

Note: Please refer to the document of `BaseSampler` for further details.

An Example: Implementing SimulatedAnnealingSampler

For example, the following code defines a sampler based on Simulated Annealing (SA):

```python
import numpy as np
import optuna

class SimulatedAnnealingSampler(optuna.samplers.BaseSampler):
    def __init__(self, temperature=100):
        self._rng = np.random.RandomState()
        self._temperature = temperature  # Current temperature.
        self._current_trial = None  # Current state.

    def sample_relative(self, study, trial, search_space):
        if search_space == {}:
            return {}

        # Simulated Annealing algorithm.
        # 1. Calculate transition probability.
        prev_trial = study.trials[-2]
```

(continues on next page)
if self._current_trial is None or prev_trial.value <= self._current_trial.value:
    probability = 1.0
else:
    probability = np.exp((self._current_trial.value - prev_trial.value) / self._temperature)
self._temperature *= 0.9  # Decrease temperature.

# 2. Transit the current state if the previous result is accepted.
if self._rng.uniform(0, 1) < probability:
    self._current_trial = prev_trial

# 3. Sample parameters from the neighborhood of the current point.
# The sampled parameters will be used during the next execution of
# the objective function passed to the study.
params = {}
for param_name, param_distribution in search_space.items():
    if not isinstance(param_distribution, optuna.distributions.UniformDistribution):
        raise NotImplementedError("Only suggest_float() is supported")
    current_value = self._current_trial.params[param_name]
    width = (param_distribution.high - param_distribution.low) * 0.1
    neighbor_low = max(current_value - width, param_distribution.low)
    neighbor_high = min(current_value + width, param_distribution.high)
    params[param_name] = self._rng.uniform(neighbor_low, neighbor_high)

    return params

# The rest are unrelated to SA algorithm: boilerplate

def infer_relative_search_space(self, study, trial):
    return optuna.samplers.intersection_search_space(study)

def sample_independent(self, study, trial, param_name, param_distribution):
    independent_sampler = optuna.samplers.RandomSampler()
    return independent_sampler.sample_independent(study, trial, param_name, param_distribution)

Note: In favor of code simplicity, the above implementation doesn’t support some features (e.g., maximization). If you’re interested in how to support those features, please see examples/samplers/simulated_annealing.py.

You can use SimulatedAnnealingSampler in the same way as built-in samplers as follows:

```python
def objective(trial):
    x = trial.suggest_float("x", -10, 10)
    y = trial.suggest_float("y", -5, 5)
    return x ** 2 + y

sampler = SimulatedAnnealingSampler()
study = optuna.create_study(sampler=sampler)
study.optimize(objective, n_trials=100)
best_trial = study.best_trial
```

(continues on next page)
print("Best value: ", best_trial.value)
print("Parameters that achieve the best value: ", best_trial.params)

Out:
Best value: -4.603830738404337
Parameters that achieve the best value: {'x': 0.4204214914775637, 'y': -4.780584968900556}

In this optimization, the values of $x$ and $y$ parameters are sampled by using `SimulatedAnnealingSampler.sample_relative` method.

Note: Strictly speaking, in the first trial, `SimulatedAnnealingSampler.sample_independent` method is used to sample parameter values. Because `intersection_search_space()` used in `SimulatedAnnealingSampler.infer_relative_search_space` cannot infer the search space if there are no complete trials.

Total running time of the script: ( 0 minutes 0.284 seconds)

User-Defined Pruner

In `optuna.pruners`, we described how an objective function can optionally include calls to a pruning feature which allows Optuna to terminate an optimization trial when intermediate results do not appear promising. In this document, we describe how to implement your own pruner, i.e., a custom strategy for determining when to stop a trial.

Overview of Pruning Interface

The `create_study()` constructor takes, as an optional argument, a pruner inheriting from `BasePruner`. The pruner should implement the abstract method `prune()`, which takes arguments for the associated `Study` and `Trial` and returns a boolean value: `True` if the trial should be pruned and `False` otherwise. Using the `Study` and `Trial` objects, you can access all other trials through the `get_trial()` method and, from a trial, its reported intermediate values through the `intermediate_values()` (a dictionary which maps an integer `step` to a float value).

You can refer to the source code of the built-in Optuna pruners as templates for building your own. In this document, for illustration, we describe the construction and usage of a simple (but aggressive) pruner which prunes trials that are in last place compared to completed trials at the same step.

Note: Please refer to the documentation of `BasePruner` or, for example, `ThresholdPruner` or `PercentilePruner` for more robust examples of pruner implementation, including error checking and complex pruner-internal logic.
An Example: Implementing LastPlacePruner

We aim to optimize the loss and alpha hyperparameters for a stochastic gradient descent classifier (SGDClassifier) run on the sklearn iris dataset. We implement a pruner which terminates a trial at a certain step if it is in last place compared to completed trials at the same step. We begin considering pruning after a “warmup” of 1 training step and 5 completed trials. For demonstration purposes, we print() a diagnostic message from prune when it is about to return True (indicating pruning).

It may be important to note that the SGDClassifier score, as it is evaluated on a holdout set, decreases with enough training steps due to overfitting. This means that a trial could be pruned even if it had a favorable (high) value on a previous training set. After pruning, Optuna will take the intermediate value last reported as the value of the trial.

```python
import numpy as np
from sklearn.datasets import load_iris
from sklearn.model_selection import train_test_split
from sklearn.linear_model import SGDClassifier
import optuna
from optuna.pruners import BasePruner
from optuna.trial._state import TrialState

class LastPlacePruner(BasePruner):
    def __init__(self, warmup_steps, warmup_trials):
        self._warmup_steps = warmup_steps
        self._warmup_trials = warmup_trials

    def prune(self, study: 'optuna.study.Study', trial: 'optuna.trial.FrozenTrial') -> bool:
        # Get the latest score reported from this trial
        step = trial.last_step

        if step:
            # trial.last_step == None when no scores have been reported yet
            this_score = trial.intermediate_values[step]

        # Get scores from other trials in the study reported at the same step
        completed_trials = study.get_trials(deepcopy=False, states=(TrialState.COMPLETE,))
        other_scores = [t.intermediate_values[step] for t in completed_trials
                        if step in t.intermediate_values]
        other_scores = sorted(other_scores)

        # Prune if this trial at this step has a lower value than all completed trials
        if step >= self._warmup_steps and len(other_scores) > self._warmup_trials:
            if this_score < other_scores[0]:
                print(f"prune() True: Trial {trial.number}, Step {step}, Score < {this_score}"
                      return True

        return False
```

6.2. Tutorial
Lastly, let’s confirm the implementation is correct with the simple hyperparameter optimization.

```python
def objective(trial):
    iris = load_iris()
    classes = np.unique(iris.target)
    X_train, X_valid, y_train, y_valid = train_test_split(
        iris.data, iris.target, train_size=100, test_size=50, random_state=0
    )

    loss = trial.suggest_categorical("loss", ["hinge", "log", "perceptron"])
    alpha = trial.suggest_float("alpha", 0.00001, 0.001, log=True)
    clf = SGDClassifier(loss=loss, alpha=alpha, random_state=0)
    score = 0

    for step in range(0, 5):
        clf.partial_fit(X_train, y_train, classes=classes)
        score = clf.score(X_valid, y_valid)
        trial.report(score, step)
        if trial.should_prune():
            raise optuna.TrialPruned()

    return score
```

pruner = LastPlacePruner(warmup_steps=1, warmup_trials=5)
study = optuna.create_study(direction="maximize", pruner=pruner)
study.optimize(objective, n_trials=50)

Out:

```
prune() True: Trial 7, Step 1, Score 0.56
prune() True: Trial 10, Step 1, Score 0.62
prune() True: Trial 17, Step 1, Score 0.64
prune() True: Trial 26, Step 1, Score 0.62
prune() True: Trial 27, Step 1, Score 0.62
prune() True: Trial 47, Step 4, Score 0.64
```

**Total running time of the script:** ( 0 minutes 0.623 seconds)

**Callback for Study.optimize**

This tutorial showcases how to use & implement Optuna Callback for `optimize()`. Callback is called after every evaluation of `objective`, and it takes `Study` and `FrozenTrial` as arguments, and does some work.

`MLflowCallback` is a great example.
Stop optimization after some trials are pruned in a row

This example implements a stateful callback which stops the optimization if a certain number of trials are pruned in a row. The number of trials pruned in a row is specified by `threshold`.

```python
import optuna

class StopWhenTrialKeepBeingPrunedCallback:
    def __init__(self, threshold: int):
        self.threshold = threshold
        self._consequtive_pruned_count = 0

    def __call__(self, study: optuna.study.Study, trial: optuna.trial.FrozenTrial) -> None:
        if trial.state == optuna.trial.TrialState.PRUNED:
            self._consequtive_pruned_count += 1
        else:
            self._consequtive_pruned_count = 0
        if self._consequtive_pruned_count >= self.threshold:
            study.stop()

This objective prunes all the trials except for the first 5 trials (`trial.number` starts with 0).

```python
def objective(trial):
    if trial.number > 4:
        raise optuna.TrialPruned

    return trial.suggest_float("x", 0, 1)
```

Here, we set the threshold to 2: optimization finishes once two trials are pruned in a row. So, we expect this study to stop after 7 trials.

```python
import logging
import sys

# Add stream handler of stdout to show the messages
optuna.logging.get_logger("optuna").addHandler(logging.StreamHandler(sys.stdout))

study_stop_cb = StopWhenTrialKeepBeingPrunedCallback(2)
study = optuna.create_study()
study.optimize(objective, n_trials=10, callbacks=[study_stop_cb])
```

Out:

```
A new study created in memory with name: no-name-dc92ccf1-9285-4c64-8b84-8b38e70b51bc
Trial 0 finished with value: 0.7164382844358129 and parameters: {'x': 0.7164382844358129). Best is trial 0 with value: 0.7164382844358129.
Trial 1 finished with value: 0.9462759827487973 and parameters: {'x': 0.9462759827487973). Best is trial 0 with value: 0.7164382844358129.
Trial 2 finished with value: 0.8372419181202911 and parameters: {'x': 0.8372419181202911). Best is trial 0 with value: 0.7164382844358129.
Trial 3 finished with value: 0.4696901310379079 and parameters: {'x': 0.4696901310379079). Best is trial 3 with value: 0.4696901310379079.
Trial 4 finished with value: 0.23722141010585274 and parameters: {'x': 0.23722141010585274). Best is trial 4 with value: 0.23722141010585274.

(continues on next page)
```
Trial 5 pruned.
Trial 6 pruned.

As you can see in the log above, the study stopped after 7 trials as expected.

**Total running time of the script:** ( 0 minutes 0.007 seconds)

### Specify Hyperparameters Manually

It’s natural that you have some specific sets of hyperparameters to try first such as initial learning rate values and the number of leaves. Also, it’s also possible that you’ve already tried those sets before having Optuna find better sets of hyperparameters.

Optuna provides two APIs to support such cases:

1. Passing those sets of hyperparameters and let Optuna evaluate them - `enqueue_trial()`
2. Adding the results of those sets as completed Trials - `add_trial()`

### First Scenario: Have Optuna evaluate your hyperparameters

In this scenario, let’s assume you have some out-of-box sets of hyperparameters but have not evaluated them yet and decided to use Optuna to find better sets of hyperparameters.

Optuna has `optuna.study.Study.enqueue_trial()` which lets you pass those sets of hyperparameters to Optuna and Optuna will evaluate them.

This section walks you through how to use this lit API with LightGBM.

```python
import lightgbm as lgb
import numpy as np
import sklearn.datasets
import sklearn.metrics
from sklearn.model_selection import train_test_split
import optuna

Define the objective function.

```python
def objective(trial):
    data, target = sklearn.datasets.load_breast_cancer(return_X_y=True)
    train_x, valid_x, train_y, valid_y = train_test_split(data, target, test_size=0.25)
    dtrain = lgb.Dataset(train_x, label=train_y)
    dvalid = lgb.Dataset(valid_x, label=valid_y)

    param = {
        "objective": "binary",
        "metric": "auc",
        "verbosity": -1,
        "boosting_type": "gbdt",
        "bagging_fraction": min(trial.suggest_float("bagging_fraction", 0.4, 1.0 + 1e-12), 1),
        "bagging_freq": trial.suggest_int("bagging_freq", 0, 7),
        "min_child_samples": trial.suggest_int("min_child_samples", 5, 100),
    }
```

(continues on next page)
# Add a callback for pruning.
pruning_callback = optuna.integration.LightGBMPruningCallback(trial, "auc")

```
gbm = lgb.train(param, dtrain, valid_sets=[dvalid], verbose_eval=False, callbacks=[pruning_callback])
```

```
preds = gbm.predict(valid_x)
pred_labels = np.rint(preds)
accuracy = sklearn.metrics.accuracy_score(valid_y, pred_labels)
return accuracy
```

Then, construct Study for hyperparameter optimization.

```
study = optuna.create_study(direction="maximize", pruner=optuna.pruners.MedianPruner())
```

Here, we get Optuna evaluate some sets with larger "bagging_freq" value and the default values.

```
study.enqueue_trial(
    {
        "bagging_fraction": 1.0,
        "bagging_freq": 0,
        "min_child_samples": 20,
    }
)
study.enqueue_trial(
    {
        "bagging_fraction": 0.75,
        "bagging_freq": 5,
        "min_child_samples": 20,
    }
)
```

```
import logging
import sys
# Add stream handler of stdout to show the messages to see Optuna works expectedly.
optuna.logging.get_logger("optuna").addHandler(logging.StreamHandler(sys.stdout))

study.optimize(objective, n_trials=100, timeout=600)
```

Out:

```
/home/docs/checkouts/readthedocs.org/user_builds/optuna/checkouts/stable/tutorial/20_recipes/008_specify_params.py:77: ExperimentalWarning:
enqueue_trial is experimental (supported from v1.2.0). The interface can change in the future.

/home/docs/checkouts/readthedocs.org/user_builds/optuna/envs/stable/lib/python3.8/site-packages/optuna/study/study.py:857: ExperimentalWarning:
create_trial is experimental (supported from v2.0.0). The interface can change in the future.
```

(continues on next page)
add_trial is experimental (supported from v2.0.0). The interface can change in the future.

enqueue_trial is experimental (supported from v1.2.0). The interface can change in the future.

Trial 0 finished with value: 0.972027972027972 and parameters: {'bagging_fraction': 1.0, 'bagging_freq': 0, 'min_child_samples': 20}. Best is trial 0 with value: 0.972027972027972.

Trial 1 finished with value: 0.986013986013986 and parameters: {'bagging_fraction': 0.75, 'bagging_freq': 5, 'min_child_samples': 20}. Best is trial 1 with value: 0.986013986013986.

Trial 2 finished with value: 0.9300699300699301 and parameters: {'bagging_fraction': 0.5020874200284251, 'bagging_freq': 4, 'min_child_samples': 89}. Best is trial 1 with value: 0.986013986013986.

Trial 3 finished with value: 0.97027972027972 and parameters: {'bagging_fraction': 0.7370953063603155, 'bagging_freq': 4, 'min_child_samples': 10}. Best is trial 1 with value: 0.986013986013986.

Trial 4 finished with value: 0.972027972027972 and parameters: {'bagging_fraction': 0.73615588341067, 'bagging_freq': 7, 'min_child_samples': 41}. Best is trial 1 with value: 0.986013986013986.

Trial 5 pruned. Trial was pruned at iteration 67.

Trial 6 pruned. Trial was pruned at iteration 0.

Trial 7 pruned. Trial was pruned at iteration 0.

Trial 8 pruned. Trial was pruned at iteration 64.

Trial 9 pruned. Trial was pruned at iteration 0.

Trial 10 pruned. Trial was pruned at iteration 0.

Trial 11 finished with value: 0.9790209790209791 and parameters: {'bagging_fraction': 0.97820697813648, 'bagging_freq': 0, 'min_child_samples': 29}. Best is trial 1 with value: 0.986013986013986.

Trial 12 pruned. Trial was pruned at iteration 1.

Trial 13 finished with value: 0.9790209790209791 and parameters: {'bagging_fraction': 0.823504230292682, 'bagging_freq': 2, 'min_child_samples': 36}. Best is trial 1 with value: 0.986013986013986.

Trial 14 pruned. Trial was pruned at iteration 1.

Trial 15 pruned. Trial was pruned at iteration 2.

Trial 16 finished with value: 0.9790209790209791 and parameters: {'bagging_fraction': 0.7958309078829543, 'bagging_freq': 3, 'min_child_samples': 5}. Best is trial 1 with value: 0.986013986013986.

Trial 17 pruned. Trial was pruned at iteration 0.

Trial 18 pruned. Trial was pruned at iteration 1.

Trial 19 pruned. Trial was pruned at iteration 0.

Trial 20 pruned. Trial was pruned at iteration 0.

Trial 21 pruned. Trial was pruned at iteration 0.

Trial 22 finished with value: 0.972027972027972 and parameters: {'bagging_fraction': 0.9334354261479995, 'bagging_freq': 6, 'min_child_samples': 27}. Best is trial 1 with value: 0.986013986013986.

Trial 23 finished with value: 0.986013986013986 and parameters: {'bagging_fraction': 0.902844582356714, 'bagging_freq': 1, 'min_child_samples': 17}. Best is trial 1 with value: 0.986013986013986.

Trial 24 finished with value: 0.9790209790209791 and parameters: {'bagging_fraction': 0.8802888949191399, 'bagging_freq': 6, 'min_child_samples': 14}. Best with value: 0.986013986013986.
Trial 25 finished with value: 0.972027972027972 and parameters: {'bagging_fraction': 0.8865036005344626, 'bagging_freq': 6, 'min_child_samples': 19}. Best is trial 1 with value: 0.986013986013986.
Trial 26 pruned. Trial was pruned at iteration 0.
Trial 27 pruned. Trial was pruned at iteration 0.
Trial 28 pruned. Trial was pruned at iteration 0.
Trial 29 pruned. Trial was pruned at iteration 0.
Trial 30 finished with value: 0.993006993006993 and parameters: {'bagging_fraction': 0.8543507870326342, 'bagging_freq': 5, 'min_child_samples': 21}. Best is trial 30 with value: 0.993006993006993.
Trial 31 pruned. Trial was pruned at iteration 0.
Trial 32 pruned. Trial was pruned at iteration 0.
Trial 33 pruned. Trial was pruned at iteration 0.
Trial 34 pruned. Trial was pruned at iteration 0.
Trial 35 pruned. Trial was pruned at iteration 0.
Trial 36 pruned. Trial was pruned at iteration 0.
Trial 37 pruned. Trial was pruned at iteration 0.
Trial 38 pruned. Trial was pruned at iteration 0.
Trial 39 pruned. Trial was pruned at iteration 0.
Trial 40 pruned. Trial was pruned at iteration 0.
Trial 41 pruned. Trial was pruned at iteration 0.
Trial 42 pruned. Trial was pruned at iteration 0.
Trial 43 pruned. Trial was pruned at iteration 0.
Trial 44 pruned. Trial was pruned at iteration 0.
Trial 45 pruned. Trial was pruned at iteration 0.
Trial 46 pruned. Trial was pruned at iteration 0.
Trial 47 finished with value: 0.972027972027972 and parameters: {'bagging_fraction': 0.8440076581617026, 'bagging_freq': 7, 'min_child_samples': 16}. Best is trial 30 with value: 0.993006993006993.
Trial 48 pruned. Trial was pruned at iteration 0.
Trial 49 pruned. Trial was pruned at iteration 0.
Trial 50 pruned. Trial was pruned at iteration 0.
Trial 51 pruned. Trial was pruned at iteration 0.
Trial 52 finished with value: 0.972027972027972 and parameters: {'bagging_fraction': 0.847273937969274, 'bagging_freq': 2, 'min_child_samples': 8}. Best is trial 30 with value: 0.993006993006993.
Trial 53 pruned. Trial was pruned at iteration 0.
Trial 54 pruned. Trial was pruned at iteration 0.
Trial 55 finished with value: 0.986013986013986 and parameters: {'bagging_fraction': 0.9410512593928915, 'bagging_freq': 3, 'min_child_samples': 16}. Best is trial 30 with value: 0.993006993006993.
Trial 56 pruned. Trial was pruned at iteration 0.
Trial 57 pruned. Trial was pruned at iteration 2.
Trial 58 pruned. Trial was pruned at iteration 0.
Trial 59 pruned. Trial was pruned at iteration 0.
Trial 60 pruned. Trial was pruned at iteration 0.
Trial 61 pruned. Trial was pruned at iteration 0.
Trial 62 pruned. Trial was pruned at iteration 0.
Trial 63 pruned. Trial was pruned at iteration 0.
Trial 64 finished with value: 0.9790209790209791 and parameters: {'bagging_fraction': 0.9906277664874055, 'bagging_freq': 2, 'min_child_samples': 30}. Best is trial 30 with value: 0.993006993006993.
Trial 65 pruned. Trial was pruned at iteration 0.
Trial 66 pruned. Trial was pruned at iteration 0.
Trial 67 pruned. Trial was pruned at iteration 0.
Trial 68 pruned. Trial was pruned at iteration 0.
Trial 69 pruned. Trial was pruned at iteration 0.
Trial 70 pruned. Trial was pruned at iteration 0.
Trial 71 finished with value: 0.993006993006993 and parameters: {'bagging_fraction': 0.983831693228373, 'bagging_freq': 0, 'min_child_samples': 30}. Best is trial 30 with value: 0.993006993006993.
Trial 72 pruned. Trial was pruned at iteration 0.
Trial 73 pruned. Trial was pruned at iteration 0.
Trial 74 pruned. Trial was pruned at iteration 0.
Trial 75 pruned. Trial was pruned at iteration 0.
Trial 76 pruned. Trial was pruned at iteration 0.
Trial 77 pruned. Trial was pruned at iteration 50.
Trial 78 pruned. Trial was pruned at iteration 0.
Trial 79 pruned. Trial was pruned at iteration 0.
Trial 80 pruned. Trial was pruned at iteration 0.
Trial 81 pruned. Trial was pruned at iteration 0.
Trial 82 pruned. Trial was pruned at iteration 0.
Trial 83 pruned. Trial was pruned at iteration 0.
Trial 84 pruned. Trial was pruned at iteration 0.
Trial 85 pruned. Trial was pruned at iteration 0.
Trial 86 pruned. Trial was pruned at iteration 0.
Trial 87 pruned. Trial was pruned at iteration 0.
Trial 88 pruned. Trial was pruned at iteration 0.
Trial 89 pruned. Trial was pruned at iteration 0.
Trial 90 pruned. Trial was pruned at iteration 0.
Trial 91 pruned. Trial was pruned at iteration 0.
Trial 92 pruned. Trial was pruned at iteration 0.
Trial 93 pruned. Trial was pruned at iteration 0.
Trial 94 pruned. Trial was pruned at iteration 0.
Trial 95 pruned. Trial was pruned at iteration 0.
Trial 96 pruned. Trial was pruned at iteration 0.
Trial 97 pruned. Trial was pruned at iteration 0.
Trial 98 pruned. Trial was pruned at iteration 0.
Trial 99 pruned. Trial was pruned at iteration 1.

Second scenario: Have Optuna utilize already evaluated hyperparameters

In this scenario, let’s assume you have some out-of-box sets of hyperparameters and you have already evaluated them but the results are not desirable so that you are thinking of using Optuna.

Optuna has `optuna.study.Study.add_trial()` which lets you register those results to Optuna and then Optuna will sample hyperparameters taking them into account.

In this section, the objective is the same as the first scenario.

```python
study = optuna.create_study(direction="maximize", pruner=optuna.pruners.MedianPruner())
study.add_trial(oputna.trial.create_trial(params=
    "bagging_fraction": 1.0,
    "bagging_freq": 0,
    "min_child_samples": 20,
},
    distributions={
    "bagging_fraction": optuna.distributions.UniformDistribution(0.4, 1.0 + \(-1e-12)),
```
"bagging_freq": optuna.distributions.IntUniformDistribution(0, 7),
"min_child_samples": optuna.distributions.IntUniformDistribution(5, 100),
},
value=0.94,

study.add_trial(
    optuna.trial.create_trial(
        params={
            "bagging_fraction": 0.75,
            "bagging_freq": 5,
            "min_child_samples": 20,
        },
        distributions={
            "bagging_fraction": optuna.distributions.UniformDistribution(0.4, 1.0 + 1e-12),
            "bagging_freq": optuna.distributions.IntUniformDistribution(0, 7),
            "min_child_samples": optuna.distributions.IntUniformDistribution(5, 100),
        },
        value=0.95,
    )
)
study.optimize(objective, n_trials=100, timeout=600)

Out:

A new study created in memory with name: no-name-7e061f88-8c99-41ed-9b46-7c631c0fc79c
/home/docs/checkouts/readthedocs.org/user_builds/optuna/checkouts/stable/tutorial/20_recipes/008_specify_params.py:115: ExperimentalWarning:
create_trial is experimental (supported from v2.0.0). The interface can change in the future.

/home/docs/checkouts/readthedocs.org/user_builds/optuna/checkouts/stable/tutorial/20_recipes/008_specify_params.py:114: ExperimentalWarning:
add_trial is experimental (supported from v2.0.0). The interface can change in the future.

/home/docs/checkouts/readthedocs.org/user_builds/optuna/checkouts/stable/tutorial/20_recipes/008_specify_params.py:130: ExperimentalWarning:
create_trial is experimental (supported from v2.0.0). The interface can change in the future.

/home/docs/checkouts/readthedocs.org/user_builds/optuna/checkouts/stable/tutorial/20_recipes/008_specify_params.py:129: ExperimentalWarning:
add_trial is experimental (supported from v2.0.0). The interface can change in the future.

Trial 2 finished with value: 0.972027972027972 and parameters: {'bagging_fraction': 0.8815873835077461, 'bagging_freq': 1, 'min_child_samples': 28}. Best is trial 2 with value: 0.972027972027972.

Trial 3 finished with value: 0.986013986013986 and parameters: {'bagging_fraction': 0.8196393995302161, 'bagging_freq': 0, 'min_child_samples': 84}. Best is trial 3 with value: 0.986013986013986.
Trial 4 finished with value: 0.9790209790209791 and parameters: {'bagging_fraction': 0.7795497001254322, 'bagging_freq': 1, 'min_child_samples': 10}. Best is trial 3 with value: 0.986013986013986.

Trial 5 pruned. Trial was pruned at iteration 18.
Trial 6 pruned. Trial was pruned at iteration 0.
Trial 7 pruned. Trial was pruned at iteration 1.
Trial 8 pruned. Trial was pruned at iteration 1.
Trial 9 pruned. Trial was pruned at iteration 0.
Trial 10 pruned. Trial was pruned at iteration 0.
Trial 11 pruned. Trial was pruned at iteration 0.
Trial 12 pruned. Trial was pruned at iteration 0.
Trial 13 pruned. Trial was pruned at iteration 0.
Trial 14 pruned. Trial was pruned at iteration 0.
Trial 15 pruned. Trial was pruned at iteration 0.
Trial 16 pruned. Trial was pruned at iteration 0.
Trial 17 pruned. Trial was pruned at iteration 1.
Trial 18 pruned. Trial was pruned at iteration 0.
Trial 19 pruned. Trial was pruned at iteration 0.
Trial 20 pruned. Trial was pruned at iteration 0.
Trial 21 pruned. Trial was pruned at iteration 5.
Trial 22 pruned. Trial was pruned at iteration 5.
Trial 23 pruned. Trial was pruned at iteration 0.
Trial 24 pruned. Trial was pruned at iteration 0.
Trial 25 pruned. Trial was pruned at iteration 0.
Trial 26 finished with value: 0.986013986013986 and parameters: {'bagging_fraction': 0.8455220501918473, 'bagging_freq': 1, 'min_child_samples': 14}. Best is trial 3 with value: 0.986013986013986.

Trial 27 pruned. Trial was pruned at iteration 26.
Trial 28 pruned. Trial was pruned at iteration 0.
Trial 29 pruned. Trial was pruned at iteration 0.
Trial 30 pruned. Trial was pruned at iteration 0.
Trial 31 pruned. Trial was pruned at iteration 0.
Trial 32 finished with value: 0.986013986013986 and parameters: {'bagging_fraction': 0.8937338244303624, 'bagging_freq': 1, 'min_child_samples': 27}. Best is trial 3 with value: 0.986013986013986.

Trial 33 pruned. Trial was pruned at iteration 0.
Trial 34 pruned. Trial was pruned at iteration 1.
Trial 35 pruned. Trial was pruned at iteration 1.
Trial 36 pruned. Trial was pruned at iteration 0.
Trial 37 pruned. Trial was pruned at iteration 1.
Trial 38 pruned. Trial was pruned at iteration 0.
Trial 39 pruned. Trial was pruned at iteration 0.
Trial 40 pruned. Trial was pruned at iteration 0.
Trial 41 pruned. Trial was pruned at iteration 0.
Trial 42 pruned. Trial was pruned at iteration 0.
Trial 43 pruned. Trial was pruned at iteration 0.
Trial 44 pruned. Trial was pruned at iteration 0.
Trial 45 pruned. Trial was pruned at iteration 0.
Trial 46 pruned. Trial was pruned at iteration 0.
Trial 47 pruned. Trial was pruned at iteration 0.
Trial 48 pruned. Trial was pruned at iteration 0.
Trial 49 pruned. Trial was pruned at iteration 0.
Trial 50 pruned. Trial was pruned at iteration 0.
Trial 51 pruned. Trial was pruned at iteration 0.
Trial 52 pruned. Trial was pruned at iteration 0.
Trial 53 pruned. Trial was pruned at iteration 0.
Trial 54 pruned. Trial was pruned at iteration 0.
Trial 55 pruned. Trial was pruned at iteration 0.
Trial 56 pruned. Trial was pruned at iteration 0.
Trial 57 pruned. Trial was pruned at iteration 0.
Trial 58 pruned. Trial was pruned at iteration 0.
Trial 59 pruned. Trial was pruned at iteration 0.
Trial 60 pruned. Trial was pruned at iteration 0.
Trial 61 pruned. Trial was pruned at iteration 0.
Trial 62 pruned. Trial was pruned at iteration 1.
Trial 63 pruned. Trial was pruned at iteration 0.
Trial 64 pruned. Trial was pruned at iteration 0.
Trial 65 pruned. Trial was pruned at iteration 0.
Trial 66 pruned. Trial was pruned at iteration 1.
Trial 67 pruned. Trial was pruned at iteration 0.
Trial 68 pruned. Trial was pruned at iteration 0.
Trial 69 pruned. Trial was pruned at iteration 0.
Trial 70 pruned. Trial was pruned at iteration 0.
Trial 71 pruned. Trial was pruned at iteration 47.
Trial 72 pruned. Trial was pruned at iteration 0.
Trial 73 pruned. Trial was pruned at iteration 0.
Trial 74 finished with value: 0.993006993006993 and parameters: {'bagging_fraction': 0.8503565214550296, 'bagging_freq': 1, 'min_child_samples': 29}. Best is trial 74 with value: 0.993006993006993.
Trial 75 pruned. Trial was pruned at iteration 0.
Trial 76 pruned. Trial was pruned at iteration 1.
Trial 77 pruned. Trial was pruned at iteration 0.
Trial 78 pruned. Trial was pruned at iteration 0.
Trial 79 pruned. Trial was pruned at iteration 0.
Trial 80 pruned. Trial was pruned at iteration 1.
Trial 81 pruned. Trial was pruned at iteration 0.
Trial 82 pruned. Trial was pruned at iteration 0.
Trial 83 pruned. Trial was pruned at iteration 2.
Trial 84 pruned. Trial was pruned at iteration 0.
Trial 85 pruned. Trial was pruned at iteration 0.
Trial 86 pruned. Trial was pruned at iteration 0.
Trial 87 pruned. Trial was pruned at iteration 0.
Trial 88 pruned. Trial was pruned at iteration 0.
Trial 89 pruned. Trial was pruned at iteration 0.
Trial 90 pruned. Trial was pruned at iteration 0.
Trial 91 pruned. Trial was pruned at iteration 0.
Trial 92 pruned. Trial was pruned at iteration 1.
Trial 93 finished with value: 0.993006993006993 and parameters: {'bagging_fraction': 0.8601433618867627, 'bagging_freq': 2, 'min_child_samples': 12}. Best is trial 74 with value: 0.993006993006993.
Trial 94 pruned. Trial was pruned at iteration 0.
Trial 95 pruned. Trial was pruned at iteration 0.
Trial 96 pruned. Trial was pruned at iteration 0.
Trial 97 pruned. Trial was pruned at iteration 0.
Trial 98 pruned. Trial was pruned at iteration 0.
Trial 99 pruned. Trial was pruned at iteration 0.
Trial 100 pruned. Trial was pruned at iteration 0.
Trial 101 pruned. Trial was pruned at iteration 1.

Total running time of the script: ( 0 minutes 6.986 seconds)
Optuna Documentation, Release 2.10.0

Ask-and-Tell Interface

Optuna has an *Ask-and-Tell* interface, which provides a more flexible interface for hyperparameter optimization. This tutorial explains three use-cases when the ask-and-tell interface is beneficial:

- *Apply Optuna to an existing optimization problem with minimum modifications*
- *Define-and-Run*
- *Batch Optimization*

### Apply Optuna to an existing optimization problem with minimum modifications

Let’s consider the traditional supervised classification problem; you aim to maximize the validation accuracy. To do so, you train *LogisticRegression* as a simple model.

```python
import numpy as np
from sklearn.datasets import make_classification
from sklearn.linear_model import LogisticRegression
from sklearn.model_selection import train_test_split
import optuna

X, y = make_classification(n_features=10)
X_train, X_test, y_train, y_test = train_test_split(X, y)

C = 0.01
clf = LogisticRegression(C=C)
clf.fit(X_train, y_train)
val_accuracy = clf.score(X_test, y_test) # the objective
```

Then you try to optimize hyperparameters $C$ and *solver* of the classifier by using optuna. When you introduce optuna naively, you define an *objective* function such that it takes *trial* and calls *suggest_* methods of *trial* to sample the hyperparameters:

```python
def objective(trial):
    X, y = make_classification(n_features=10)
    X_train, X_test, y_train, y_test = train_test_split(X, y)

    C = trial.suggest_loguniform("C", 1e-7, 10.0)
    solver = trial.suggest_categorical("solver", ("lbfgs", "saga"))

    clf = LogisticRegression(C=C, solver=solver)
    clf.fit(X_train, y_train)
    val_accuracy = clf.score(X_test, y_test)

    return val_accuracy
```

```python
study = optuna.create_study(direction="maximize")
study.optimize(objective, n_trials=10)
```

Out:
This interface is not flexible enough. For example, if objective requires additional arguments other than trial, you need to define a class as in How to define objective functions that have own arguments?. The ask-and-tell interface provides a more flexible syntax to optimize hyperparameters. The following example is equivalent to the previous code block.

```python
study = optuna.create_study(direction="maximize")
for _ in range(n_trials):
    trial = study.ask()  # `trial` is a `Trial` and not a `FrozenTrial`.
    C = trial.suggest_loguniform("C", 1e-7, 10.0)
    solver = trial.suggest_categorical("solver", ("lbfgs", "saga"))
    clf = LogisticRegression(C=C, solver=solver)
    clf.fit(X_train, y_train)
    val_accuracy = clf.score(X_test, y_test)
    study.tell(trial, val_accuracy)  # tell the pair of trial and objective value
```

The main difference is to use two methods: `optuna.study.Study.ask()` and `optuna.study.Study.tell()`. `optuna.study.Study.ask()` creates a trial that can sample hyperparameters, and `optuna.study.Study.tell()` finishes the trial by passing trial and an objective value. You can apply Optuna’s hyperparameter optimization to your original code without an objective function.

If you want to make your optimization faster with a pruner, you need to explicitly pass the state of trial to the argument of `optuna.study.Study.tell()` method as follows:

```python
import numpy as np
from sklearn.datasets import load_iris
from sklearn.linear_model import SGDClassifier
from sklearn.model_selection import train_test_split
import optuna

X, y = load_iris(return_X_y=True)
X_train, X_valid, y_train, y_valid = train_test_split(X, y)
classes = np.unique(y)
n_train_iter = 100

# define study with hyperband pruner.
study = optuna.create_study(
    direction="maximize",
    pruner=optuna.pruners.HyperbandPruner(
        min_resource=1, max_resource=n_train_iter, reduction_factor=3
    ),
)
for _ in range(20):
    trial = study.ask()
```

(continues on next page)
alpha = trial.suggest_uniform("alpha", 0.0, 1.0)
clf = SGDClassifier(alpha=alpha)
pruned_trial = False

for step in range(n_train_iter):
    clf.partial_fit(X_train, y_train, classes=classes)

    intermediate_value = clf.score(X_valid, y_valid)
    trial.report(intermediate_value, step)

    if trial.should_prune():
        pruned_trial = True
        break

if pruned_trial:
    study.tell(trial, state=optuna.trial.TrialState.PRUNED)  # tell the pruned
else:
    score = clf.score(X_valid, y_valid)
    study.tell(trial, score)  # tell objective value

---

**Note:** `optuna.study.Study.tell()` method can take a trial number rather than the trial object. `study.tell(trial.number, y)` is equivalent to `study.tell(trial, y)`.

### Define-and-Run

The ask-and-tell interface supports both *define-by-run* and *define-and-run* APIs. This section shows the example of the *define-and-run* API in addition to the define-by-run example above.

Define distributions for the hyperparameters before calling the `optuna.study.Study.ask()` method for define-and-run API. For example,

```
distributions = {
    "C": optuna.distributions.LogUniformDistribution(1e-7, 10.0),
    "solver": optuna.distributions.CategoricalDistribution(["lbfgs", "saga")},
}
```

Pass `distributions` to `optuna.study.Study.ask()` method at each call. The returned `trial` contains the suggested hyperparameters.

```
study = optuna.create_study(direction="maximize")
n_trials = 10
for _ in range(n_trials):
    trial = study.ask(distributions)  # pass the pre-defined distributions.

    # two hyperparameters are already sampled from the pre-defined distributions
    C = trial.params["C"]
    solver = trial.params["solver"]

    clf = LogisticRegression(C=C, solver=solver)
    clf.fit(X_train, y_train)
    val_accuracy = clf.score(X_test, y_test)
```

(continues on next page)
Batch Optimization

The ask-and-tell interface enables us to optimize a batched objective for faster optimization. For example, parallelizable evaluation, operation over vectors, etc.

The following objective takes batched hyperparameters $xs$ and $ys$ instead of a single pair of hyperparameters $x$ and $y$ and calculates the objective over the full vectors.

```python
def batched_objective(xs: np.ndarray, ys: np.ndarray):
    return xs ** 2 + ys
```

In the following example, the number of pairs of hyperparameters in a batch is 10, and batched_objective is evaluated three times. Thus, the number of trials is 30. Note that you need to store either `trial_ids` or `trial` to call `optuna.study.Study.tell()` method after the batched evaluations.

```python
batch_size = 10
study = optuna.create_study(sampler=optuna.samplers.CmaEsSampler())
for _ in range(3):
    # create batch
    trial_ids = []
    x_batch = []
    y_batch = []
    for _ in range(batch_size):
        trial = study.ask()
        trial_ids.append(trial.number)
        x_batch.append(trial.suggest_float("x", -10, 10))
        y_batch.append(trial.suggest_float("y", -10, 10))

    # evaluate batched objective
    x_batch = np.array(x_batch)
    y_batch = np.array(y_batch)
    objectives = batched_objective(x_batch, y_batch)

    # finish all trials in the batch
    for trial_id, objective in zip(trial_ids, objectives):
        study.tell(trial_id, objective)
```

Total running time of the script: (0 minutes 0.130 seconds)
Re-use the best values

In some cases, you may want to re-evaluate the objective function with the best hyperparameters again after the hyperparameter optimization.

For example,

- You have found good hyperparameters with Optuna and want to run a similar objective function using the best hyperparameters found so far to further analyze the results, or
- You have optimized with Optuna using a partial dataset to reduce training time. After the hyperparameter tuning, you want to train the model using the whole dataset with the best hyperparameter values found.

`best_trial` provides an interface to re-evaluate the objective function with the current best hyperparameter values.

This tutorial shows an example of how to re-run a different objective function with the current best values, like the first example above.

Investigating the best model further

Let’s consider a classical supervised classification problem with Optuna as follows:

```python
import optuna

def objective(trial):
    X, y = make_classification(n_features=10, random_state=1)
    X_train, X_test, y_train, y_test = train_test_split(X, y, random_state=1)

    C = trial.suggest_loguniform("C", 1e-7, 10.0)

    clf = LogisticRegression(C=C)
    clf.fit(X_train, y_train)

    return clf.score(X_test, y_test)

study = optuna.create_study(direction="maximize")
study.optimize(objective, n_trials=10)

print(study.best_trial.value)  # Show the best value.
```

Out:

```
0.88
```

Suppose after the hyperparameter optimization, you want to calculate other evaluation metrics such as recall, precision, and F1-score on the same dataset. You can define another objective function that shares most of the objective function to reproduce the model with the best hyperparameters.
```python
def detailed_objective(trial):
    # Use same code objective to reproduce the best model
    X, y = make_classification(n_features=10, random_state=1)
    X_train, X_test, y_train, y_test = train_test_split(X, y, random_state=1)

    C = trial.suggest_loguniform("C", 1e-7, 10.0)
    clf = LogisticRegression(C=C)
    clf.fit(X_train, y_train)

    # calculate more evaluation metrics
    pred = clf.predict(X_test)
    acc = metrics.accuracy_score(pred, y_test)
    recall = metrics.recall_score(pred, y_test)
    precision = metrics.precision_score(pred, y_test)
    f1 = metrics.f1_score(pred, y_test)

    return acc, f1, recall, precision
```

Pass `study.best_trial` as the argument of `detailed_objective`.

```python
detailed_objective(study.best_trial)  # calculate acc, f1, recall, and precision
```

Out:

```
(0.88, 0.88, 1.0, 0.7857142857142857)
```

**The difference between `best_trial` and ordinal trials**

This uses `best_trial`, which returns the `best_trial` as a `FrozenTrial`. The `FrozenTrial` is different from an active trial and behaves differently from `Trial` in some situations. For example, pruning does not work because `should_prune` always returns `False`.

**Total running time of the script:** (0 minutes 0.055 seconds)

### 6.3 API Reference

#### 6.3.1 optuna

The `optuna` module is primarily used as an alias for basic Optuna functionality coded in other modules. Currently, two modules are aliased: (1) from `optuna.study`, functions regarding the Study lifecycle, and (2) from `optuna.exceptions`, the TrialPruned Exception raised when a trial is pruned.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>optuna.create_study</code></td>
<td>Create a new <code>Study</code>.</td>
</tr>
<tr>
<td><code>optuna.load_study</code></td>
<td>Load the existing <code>Study</code> that has the specified name.</td>
</tr>
<tr>
<td><code>optuna.delete_study</code></td>
<td>Delete a <code>Study</code> object.</td>
</tr>
<tr>
<td><code>optuna.copy_study</code></td>
<td>Copy study from one storage to another.</td>
</tr>
<tr>
<td><code>optuna.get_all_study_summaries</code></td>
<td>Get all history of studies stored in a specified storage.</td>
</tr>
<tr>
<td><code>optuna.TrialPruned</code></td>
<td>Exception for pruned trials.</td>
</tr>
</tbody>
</table>
Optuna Documentation, Release 2.10.0

optuna.create_study

```
optuna.create_study(
    storage=None, sampler=None, pruner=None, study_name=None, direction=None, load_if_exists=False, *, directions=None)
```

Create a new `Study`.

**Example**

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", 0, 10)
    return x ** 2

study = optuna.create_study()
study.optimize(objective, n_trials=3)
```

**Parameters**

- **storage** *(Optional[Union[str, optuna.storages._base.BaseStorage]])* – Database URL. If this argument is set to None, in-memory storage is used, and the `Study` will not be persistent.

  **Note:**
  
  When a database URL is passed, Optuna internally uses SQLAlchemy to handle the database. Please refer to SQLAlchemy's document for further details. If you want to specify non-default options to SQLAlchemy Engine, you can instantiate `RDBStorage` with your desired options and pass it to the `storage` argument instead of a URL.

- **sampler** *(Optional[optuna.samplers._base.BaseSampler]*) – A sampler object that implements background algorithm for value suggestion. If `None` is specified, `TPESampler` is used during single-objective optimization and `NSGAIISampler` during multi-objective optimization. See also `samplers`.

- **pruner** *(Optional[optuna.pruners._base.BasePruner]*) – A pruner object that decides early stopping of unpromising trials. If `None` is specified, `MedianPruner` is used as the default. See also `pruners`.

- **study_name** *(Optional[str]*) – Study’s name. If this argument is set to `None`, a unique name is generated automatically.

- **direction** *(Optional[Union[str, optuna.study._study_direction.StudyDirection]])* – Direction of optimization. Set `minimize` for minimization and `maximize` for maximization. You can also pass the corresponding `StudyDirection` object.

  **Note:** If none of `direction` and `directions` are specified, the direction of the study is set to “minimize”.
• **load_if_exists** *(bool)* – Flag to control the behavior to handle a conflict of study names. In the case where a study named `study_name` already exists in the storage, a `DuplicatedStudyError` is raised if `load_if_exists` is set to `False`. Otherwise, the creation of the study is skipped, and the existing one is returned.

• **directions** *(Optional[Sequence[Union[str, optuna.study._study_direction.StudyDirection]]])* – A sequence of directions during multi-objective optimization.

Returns A `Study` object.

Raises `ValueError` – If the length of `directions` is zero. Or, if `direction` is neither ‘minimize’ nor ‘maximize’ when it is a string. Or, if the element of `directions` is neither `minimize` nor `maximize`. Or, if both `direction` and `directions` are specified.

Return type `optuna.study.study.Study`

See also:

`optuna.create_study()` is an alias of `optuna.study.create_study()`.

### `optuna.load_study`

`optuna.load_study` *(study_name: Optional[str], storage: Union[str, optuna.storages._base.BaseStorage], sampler=None, pruner=None)*

Load the existing `Study` that has the specified name.

#### Example

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", 0, 10)
    return x ** 2

study = optuna.create_study(storage="sqlite:///example.db", study_name="my_study")
study.optimize(objective, n_trials=3)

loaded_study = optuna.load_study(study_name="my_study", storage="sqlite:///example.db")
assert len(loaded_study.trials) == len(study.trials)
```

#### Parameters

• **study_name** *(Optional[str])* – Study’s name. Each study has a unique name as an identifier. If `None`, checks whether the storage contains a single study, and if so loads that study.

• **storage** *(Union[str, optuna.storages._base.BaseStorage])* – Database URL such as `sqlite:///example.db`. Please see also the documentation of `create_study()` for further details.

• **sampler** *(Optional[optuna.samplers._base.BaseSampler])* – A sampler object that implements background algorithm for value suggestion. If `None` is specified, `TPESampler` is used as the default. See also `samplers`.

---

6.3. API Reference 55
• **pruner** (*Optional*[`optuna.pruners._base.BasePruner]*) – A pruner object that decides early stopping of unpromising trials. If *None* is specified, *MedianPruner* is used as the default. See also *pruners*.

Raises **ValueError** – If *study_name* is *None* and the storage contains more than 1 study.

Return type  *optuna.study.study.Study*

See also:  *

*optuna.load_study()* is an alias of *optuna.study.load_study()*.

### optuna.delete_study

**optuna.delete_study** (*study_name*, *storage*)

Delete a *Study* object.

**Example**

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", -10, 10)
    return (x - 2) ** 2

study = optuna.create_study(study_name="example-study", storage="sqlite:///example.db")
study.optimize(objective, n_trials=3)

optuna.delete_study(study_name="example-study", storage="sqlite:///example.db")
```

**Parameters**

• *study_name* (*str*) – Study’s name.

• *storage* (*Union*[str, `optuna.storages._base.BaseStorage]*) – Database URL such as sqlite:///example.db. Please see also the documentation of *create_study()* for further details.

Return type  *None*

See also:  *

*optuna.delete_study()* is an alias of *optuna.study.delete_study()*.
**optuna.copy_study**

**optuna.copy_study**(from_study_name, from_storage, to_storage, to_study_name=None)

Copy study from one storage to another.

The direction(s) of the objective(s) in the study, trials, user attributes and system attributes are copied.

**Example**

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", -10, 10)
    return (x - 2) ** 2

study = optuna.create_study(
    study_name="example-study",
    storage="sqlite:///example.db",
)
study.optimize(objective, n_trials=3)
optuna.copy_study(
    from_study_name="example-study",
    from_storage="sqlite:///example.db",
    to_storage="sqlite:///example_copy.db",
)
study = optuna.load_study(
    study_name=None,
    storage="sqlite:///example_copy.db",
)
```

**Parameters**

- **from_study_name**(str) – Name of study.
- **from_storage**(Union[str, optuna.storages._base.BaseStorage]) – Source database URL such as sqlite:///example.db. Please see also the documentation of create_study() for further details.
- **to_storage**(Union[str, optuna.storages._base.BaseStorage]) – Destination database URL.
- **to_study_name**(Optional[str]) – Name of the created study. If omitted, from_study_name is used.

**Raises**  
DuplicateStudyError – If a study with a conflicting name already exists in the destination storage.

**Return type** None

**Note:** Added in v2.8.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.8.0.
**optuna.get_all_study_summaries**

Get all history of studies stored in a specified storage.

**Example**

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", -10, 10)
    return (x - 2) ** 2

study = optuna.create_study(study_name="example-study", storage="sqlite:///example.db")
study.optimize(objective, n_trials=3)

study_summaries = optuna.study.get_all_study_summaries(storage="sqlite:///example.db")
assert len(study_summaries) == 1
study_summary = study_summaries[0]
assert study_summary.study_name == "example-study"
```

**Parameters**

- `storage` *(Union[str, optuna.storages._base.BaseStorage]*) - Database URL such as sqlite:///example.db. Please see also the documentation of `create_study()` for further details.

**Returns** List of study history summarized as `StudySummary` objects.

**Return type** List[optuna.study._study_summary.StudySummary]

See also:

- `optuna.get_all_study_summaries()` is an alias of `optuna.study.get_all_study_summaries()`.

---

**optuna.TrialPruned**

Exception for pruned trials.

This error tells a trainer that the current `Trial` was pruned. It is supposed to be raised after `optuna.trial.Trial.should_prune()` as shown in the following example.

See also:

- `optuna.TrialPruned` is an alias of `optuna.exceptions.TrialPruned`.
Example

```python
import numpy as np
from sklearn.datasets import load_iris
from sklearn.linear_model import SGDClassifier
from sklearn.model_selection import train_test_split

import optuna

X, y = load_iris(return_X_y=True)
X_train, X_valid, y_train, y_valid = train_test_split(X, y)
classes = np.unique(y)

def objective(trial):
    alpha = trial.suggest_float("alpha", 0.0, 1.0)
    clf = SGDClassifier(alpha=alpha)
    n_train_iter = 100
    for step in range(n_train_iter):
        clf.partial_fit(X_train, y_train, classes=classes)
        intermediate_value = clf.score(X_valid, y_valid)
        trial.report(intermediate_value, step)
        if trial.should_prune():
            raise optuna.TrialPruned()
    return clf.score(X_valid, y_valid)

study = optuna.create_study(direction="maximize")
study.optimize(objective, n_trials=20)
```

6.3.2 optuna.cli

The `cli` module implements Optuna’s command-line functionality using the cliff framework.

```
optuna
  
  [--version]
  [-v | -q]
  [--log-file LOG_FILE]
  [--debug]
  [--storage STORAGE]

--version
  show program’s version number and exit

-v, --verbose
  Increase verbosity of output. Can be repeated.

-q, --quiet
  Suppress output except warnings and errors.

--log-file <LOG_FILE>
  Specify a file to log output. Disabled by default.
```
---debug
Show tracebacks on errors.

---storage <STORAGE>
DB URL. (e.g. sqlite:///example.db)

ask
Create a new trial and suggest parameters.

```bash
optuna ask
  [--study-name STUDY_NAME]
  [--direction {minimize,maximize}]  
  [--directions {minimize,maximize} [{minimize,maximize} ...]]
  [--sampler SAMPLER]
  [--sampler-kwargs SAMPLER_KWARGS]
  [--search-space SEARCH_SPACE]
  [-f {json,table,yaml}]
  [--flatten]
```

---study-name <STUDY_NAME>
Name of study.

---direction <DIRECTION>
Direction of optimization.

---directions <DIRECTIONS>
Directions of optimization, if there are multiple objectives.

---sampler <SAMPLER>
Class name of sampler object to create.

---sampler-kwargs <SAMPLER_KWARGS>
Sampler object initialization keyword arguments as JSON.

---search-space <SEARCH_SPACE>
Search space as JSON. Keys are names and values are outputs from distribution_to_json().

-f <FORMAT>,  --format <FORMAT>
Output format.

--flatten
Flatten nested columns such as params.

This command is provided by the optuna plugin.

best-trial
Show the best trial.

```bash
optuna best-trial
  --study-name STUDY_NAME
  [-f {json,table,yaml}]
  [--flatten]
```

---study-name <STUDY_NAME>
The name of the study to get the best trial.
-f <FORMAT>, --format <FORMAT>
  Output format.

--flatten
  Flatten nested columns such as params and user_attrs.

This command is provided by the optuna plugin.

best-trials

Show a list of trials located at the Pareto front.

```
optuna best-trials
  --study-name STUDY_NAME
  [-f {json,table,yaml}]
  [--flatten]
```

--study-name <STUDY_NAME>
  The name of the study to get the best trials (trials at the Pareto front).

-f <FORMAT>, --format <FORMAT>
  Output format.

--flatten
  Flatten nested columns such as params and user_attrs.

This command is provided by the optuna plugin.

create-study

Create a new study.

```
optuna create-study
  [--study-name STUDY_NAME]
  [--direction {minimize,maximize}] [--skip-if-exists]
  [--directions {minimize,maximize} [{minimize,maximize} ...]]
```

--study-name <STUDY_NAME>
  A human-readable name of a study to distinguish it from others.

--direction <DIRECTION>
  Set direction of optimization to a new study. Set ‘minimize’ for minimization and ‘maximize’ for maximization.

--skip-if-exists
  If specified, the creation of the study is skipped without any error when the study name is duplicated.

--directions <DIRECTIONS>
  Set directions of optimization to a new study. Put whitespace between directions. Each direction should be either “minimize” or “maximize”.

This command is provided by the optuna plugin.
**dashboard**

Launch web dashboard (beta).

This feature is deprecated since version 2.7.0. Please use `optuna-dashboard` instead.

```
optuna dashboard
    [--study STUDY]
    [--study-name STUDY_NAME]
    [--out OUT]
    [--allow-websocket-origin BOKEH_ALLOW_WEB_SOCKET_ORIGINS]
```

```
--study <STUDY>
    This argument is deprecated. Use --study-name instead.

--study-name <STUDY_NAME>
    The name of the study to show on the dashboard.

--out <OUT>, -o <OUT>
    Output HTML file path. If it is not given, a HTTP server starts and the dashboard is served.

--allow-websocket-origin <BOKEH_ALLOW_WEB_SOCKET_ORIGINS>
    Allow websocket access from the specified host(s). Internally, it is used as the value of bokeh’s
    subcommands/serve.html for more details.
```

This command is provided by the optuna plugin.

**delete-study**

Delete a specified study.

```
optuna delete-study [--study-name STUDY_NAME]
```

```
--study-name <STUDY_NAME>
    The name of the study to delete.
```

This command is provided by the optuna plugin.

**storage upgrade**

Upgrade the schema of a storage.

```
optuna storage upgrade
```

This command is provided by the optuna plugin.
### studies

Show a list of studies.

```bash
optuna studies [-f {json,table,yaml}] [--flatten]
```

- `-f <FORMAT>, --format <FORMAT>`
  - Output format.
- `--flatten`
  - Flatten nested columns such as directions.

This command is provided by the optuna plugin.

### study optimize

Start optimization of a study. Deprecated since version 2.0.0.

```bash
optuna study optimize
[--n-trials N_TRIALS]
[--timeout TIMEOUT]
[--n-jobs N_JOBS]
[--study STUDY]
[--study-name STUDY_NAME]
file
method
```

- `--n-trials <N_TRIALS>`
  - The number of trials. If this argument is not given, as many trials run as possible.
- `--timeout <TIMEOUT>`
  - Stop study after the given number of second(s). If this argument is not given, as many trials run as possible.
- `--n-jobs <N_JOBS>`
  - The number of parallel jobs. If this argument is set to -1, the number is set to CPU counts.
- `--study <STUDY>`
  - This argument is deprecated. Use --study-name instead.
- `--study-name <STUDY_NAME>`
  - The name of the study to start optimization on.
- `file`
  - Python script file where the objective function resides.
- `method`
  - The method name of the objective function.

This command is provided by the optuna plugin.
**study set-user-attr**

Set a user attribute to a study.

```bash
optuna study set-user-attr
    [--study STUDY]
    [--study-name STUDY_NAME]
    --key KEY
    --value VALUE
```

`--study` `<STUDY>`
This argument is deprecated. Use `--study-name` instead.

`--study-name` `<STUDY_NAME>`
The name of the study to set the user attribute to.

`--key` `<KEY>`, `-k` `<KEY>`
Key of the user attribute.

`--value` `<VALUE>`, `-v` `<VALUE>`
Value to be set.

This command is provided by the optuna plugin.

**tell**

Finish a trial created with the ask command.

```bash
optuna tell
    [--study-name STUDY_NAME]
    [--trial-number TRIAL_NUMBER]
    [--values VALUES [VALUES ...]]
    [--state STATE]
```

`--study-name` `<STUDY_NAME>`
Name of study.

`--trial-number` `<TRIAL_NUMBER>`
Trial number.

`--values` `<VALUES>`
Objective values.

`--state` `<STATE>`
Trial state.

This command is provided by the optuna plugin.
trials

Show a list of trials.

```
optuna trials
   --study-name STUDY_NAME
   [-f {json,table,yaml}]
   [--flatten]
```

```
--study-name <STUDY_NAME>
   The name of the study which includes trials.

-f <FORMAT>, --format <FORMAT>
   Output format.

--flatten
   Flatten nested columns such as params and user_attrs.
```

This command is provided by the optuna plugin.

### 6.3.3 optuna.distributions

The `distributions` module defines various classes representing probability distributions, mainly used to suggest initial hyperparameter values for an optimization trial. Distribution classes inherit from a library-internal `BaseDistribution`, and is initialized with specific parameters, such as the `low` and `high` endpoints for a `UniformDistribution`.

Optuna users should not use distribution classes directly, but instead use utility functions provided by `Trial` such as `suggest_int()`.

<table>
<thead>
<tr>
<th><code>optuna.distributions</code></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>UniformDistribution</code></td>
<td>A uniform distribution in the linear domain.</td>
</tr>
<tr>
<td><code>LogUniformDistribution</code></td>
<td>A uniform distribution in the log domain.</td>
</tr>
<tr>
<td><code>DiscreteUniformDistribution</code></td>
<td>A discretized uniform distribution in the linear domain.</td>
</tr>
<tr>
<td><code>IntUniformDistribution</code></td>
<td>A uniform distribution on integers.</td>
</tr>
<tr>
<td><code>IntLogUniformDistribution</code></td>
<td>A uniform distribution on integers in the log domain.</td>
</tr>
<tr>
<td><code>CategoricalDistribution</code></td>
<td>A categorical distribution.</td>
</tr>
</tbody>
</table>

| `optuna.distributions.distribution_to_json` | Serialize a distribution to JSON format. |
| `optuna.distributions.json_to_distribution` | Deserialize a distribution in JSON format. |
| `optuna.distributions.check_distribution_compatibility` | A function to check compatibility of two distributions. |
optuna.distributions.UniformDistribution

class optuna.distributions.UniformDistribution(low, high)
    A uniform distribution in the linear domain.

    This object is instantiated by suggest_uniform(), and passed to samplers in general.

    low
        Lower endpoint of the range of the distribution. low is included in the range.

    high
        Upper endpoint of the range of the distribution. high is included from the range.

    Raises ValueError – If low value is larger than high value.

Methods

    single()
        Test whether the range of this distribution contains just a single value.

        Returns True if the range of this distribution contains just a single value, otherwise False.

        Return type bool

    to_external_repr(param_value_in_internal_repr)
        Convert internal representation of a parameter value into external representation.

    to_internal_repr(param_value_in_external_repr)
        Convert external representation of a parameter value into internal representation.
**optuna.distributions.LogUniformDistribution**

```python
class optuna.distributions.LogUniformDistribution(low, high)
A uniform distribution in the log domain.

This object is instantiated by `suggest_float()` with `log=True` and `suggest_loguniform()`, and passed to samplers in general.

**low**
Lower endpoint of the range of the distribution. `low` is included in the range.

**high**
Upper endpoint of the range of the distribution. `high` is included from the range.

**Raises** `ValueError` – If `low` value is larger than `high` value, or `low` value is smaller than or equal to 0.

**Methods**

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>single()</td>
<td>Test whether the range of this distribution contains just a single value.</td>
</tr>
<tr>
<td>to_external_repr</td>
<td>Convert internal representation of a parameter value into external representation.</td>
</tr>
<tr>
<td>to_internal_repr</td>
<td>Convert external representation of a parameter value into internal representation.</td>
</tr>
</tbody>
</table>

**single()**
Test whether the range of this distribution contains just a single value.

- **Returns**: `True` if the range of this distribution contains just a single value, otherwise `False`.
- **Return type**: `bool`

**to_external_repr** *(param_value_in_internal_repr)*
Convert internal representation of a parameter value into external representation.

- **Parameters**: `param_value_in_internal_repr` *(float)* – Optuna’s internal representation of a parameter value.
- **Returns**: Optuna’s external representation of a parameter value.
- **Return type**: *Any*

**to_internal_repr** *(param_value_in_external_repr)*
Convert external representation of a parameter value into internal representation.

- **Parameters**: `param_value_in_external_repr` *(Any)* – Optuna’s external representation of a parameter value.
- **Returns**: Optuna’s internal representation of a parameter value.
- **Return type**: *float*
class optuna.distributions.DiscreteUniformDistribution

A discretized uniform distribution in the linear domain.

This object is instantiated by suggest_uniform() with step argument and
suggest_discrete_uniform(), and passed to samplers in general.

Note: If the range \([\text{low}, \text{high}]\) is not divisible by \(q\), \text{high} will be replaced with the maximum of \(kq + \text{low} < \text{high}\), where \(k\) is an integer.

\text{low}
Lower endpoint of the range of the distribution. \text{low} is included in the range.

\text{high}
Upper endpoint of the range of the distribution. \text{high} is included in the range.

\(q\)
A discretization step.

Raises \text{ValueError} – If \text{low} value is larger than \text{high} value.

Methods

single()
Test whether the range of this distribution contains just a single value.

Returns True if the range of this distribution contains just a single value, otherwise False.

Return type bool
to_external_repr(param_value_in_internal_repr)
Convert internal representation of a parameter value into external representation.

Parameters

param_value_in_internal_repr (float) – Optuna’s internal representation of a parameter value.

Returns Optuna’s external representation of a parameter value.

Return type Any
to_internal_repr(param_value_in_external_repr)
Convert external representation of a parameter value into internal representation.

Parameters

param_value_in_external_repr (Any) – Optuna’s external representation of a parameter value.

Returns Optuna’s internal representation of a parameter value.

Return type float
### optuna.distributions.IntUniformDistribution

**class** optuna.distributions.IntUniformDistribution (low, high, step=1)

A uniform distribution on integers.

This object is instantiated by `suggest_int()`, and passed to samplers in general.

**Note:** If the range \([low, high]\) is not divisible by `step`, `high` will be replaced with the maximum of \(k \times step + low < high\), where \(k\) is an integer.

- **low**
  - Lower endpoint of the range of the distribution. `low` is included in the range.

- **high**
  - Upper endpoint of the range of the distribution. `high` is included in the range.

- **step**
  - A step for spacing between values.

**Raises** `ValueError` – If `low` value is larger than `high` value, or `step` value is smaller or equal to 0.

**Methods**

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>single()</td>
<td>Test whether the range of this distribution contains just a single value.</td>
</tr>
<tr>
<td>to_external_repr()</td>
<td>Convert internal representation of a parameter value into external representation.</td>
</tr>
<tr>
<td>to_internal_repr()</td>
<td>Convert external representation of a parameter value into internal representation.</td>
</tr>
</tbody>
</table>

**single()**

Test whether the range of this distribution contains just a single value.

Returns **True** if the range of this distribution contains just a single value, otherwise **False**.

Return type **bool**

**to_external_repr** *(param_value_in_internal_repr)*

Convert internal representation of a parameter value into external representation.

Parameters

- **param_value_in_internal_repr** *(float)* – Optuna’s internal representation of a parameter value.

Returns Optuna’s external representation of a parameter value.

Return type **int**

**to_internal_repr** *(param_value_in_external_repr)*

Convert external representation of a parameter value into internal representation.

Parameters

- **param_value_in_external_repr** *(int)* – Optuna’s external representation of a parameter value.

Returns Optuna’s internal representation of a parameter value.

Return type **float**
optuna.distributions.IntLogUniformDistribution

class optuna.distributions.IntLogUniformDistribution (low, high, step=1)
    A uniform distribution on integers in the log domain.

    This object is instantiated by suggest_int(), and passed to samplers in general.

    low
    Lower endpoint of the range of the distribution. low is included in the range.

    high
    Upper endpoint of the range of the distribution. high is included in the range.

    step
    A step for spacing between values.

    Warning: Deprecated in v2.0.0. step argument will be removed in the future. The removal of this feature is currently scheduled for v4.0.0, but this schedule is subject to change.

    Samplers and other components in Optuna relying on this distribution will ignore this value and assume that step is always 1. User-defined samplers may continue to use other values besides 1 during the deprecation.

    Raises ValueError – If low value is larger than high value, or low value is smaller than 1.

Methods

    single()
    Test whether the range of this distribution contains just a single value.

    to_external_repr(param_value_in_internal_repr)
    Convert internal representation of a parameter value into external representation.

    to_internal_repr(param_value_in_external_repr)
    Convert external representation of a parameter value into internal representation.

Attributes

    step

    single()
    Test whether the range of this distribution contains just a single value.

        Returns True if the range of this distribution contains just a single value, otherwise False.

        Return type bool

    to_external_repr(param_value_in_internal_repr)
    Convert internal representation of a parameter value into external representation.

        Parameters param_value_in_internal_repr (float) – Optuna’s internal representation of a parameter value.

        Returns Optuna’s external representation of a parameter value.
Return type  int

**to_internal_repr** *(param_value_in_external_repr)*
Convert external representation of a parameter value into internal representation.

**Parameters**  
*param_value_in_external_repr* *(int)* – Optuna’s external representation of a parameter value.

**Returns**  
Optuna’s internal representation of a parameter value.

**Return type**  float

---

**optuna.distributions.CategoricalDistribution**

**class**  
*optuna.distributions.CategoricalDistribution* *(choices)*  
A categorical distribution.

This object is instantiated by *suggest_categorical()* and passed to *samplers* in general.

**Parameters**  
*choices* – Parameter value candidates.

**Note:** Not all types are guaranteed to be compatible with all storages. It is recommended to restrict the types of the choices to *None, bool, int, float* and *str*.

**choices**  
Parameter value candidates.

**Raises**  
*ValueError* – If *choices* do not contain any elements.

**Methods**

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>single()</strong></td>
<td>Test whether the range of this distribution contains just a single value.</td>
</tr>
<tr>
<td><strong>to_external_repr</strong></td>
<td>Convert internal representation of a parameter value into external representation.</td>
</tr>
<tr>
<td><strong>to_internal_repr</strong></td>
<td>Convert external representation of a parameter value into internal representation.</td>
</tr>
</tbody>
</table>

**single()**  
Test whether the range of this distribution contains just a single value.

**Returns**  
*True* if the range of this distribution contains just a single value, otherwise *False*.

**Return type**  *bool*

**to_external_repr** *(param_value_in_internal_repr)*  
Convert internal representation of a parameter value into external representation.

**Parameters**  
*param_value_in_internal_repr* *(float)* – Optuna’s internal representation of a parameter value.

**Returns**  
Optuna’s external representation of a parameter value.

**Return type**  *Union[None, bool, int, float, str]*

**to_internal_repr** *(param_value_in_external_repr)*  
Convert external representation of a parameter value into internal representation.
Parameters param_value_in_external_repr (Union[None, bool, int, float, str]) – Optuna’s external representation of a parameter value.

Returns Optuna’s internal representation of a parameter value.

Return type float

dist = optuna.distributions.distribution_to_json(dist)

Serialize a distribution to JSON format.

Parameters dist (optuna.distributions.BaseDistribution) – A distribution to be serialized.

Returns A JSON string of a given distribution.

Return type str

dist = optuna.distributions.json_to_distribution(json_str)

Deserialize a distribution in JSON format.

Parameters json_str (str) – A JSON-serialized distribution.

Returns A deserialized distribution.

Raises ValueError – If the unknown class is specified.

Return type optuna.distributions.BaseDistribution

dist = optuna.distributions.check_distribution_compatibility(dist_old, dist_new)

A function to check compatibility of two distributions.

Parameters

• dist_old (optuna.distributions.BaseDistribution) – A distribution previously recorded in storage.

• dist_new (optuna.distributions.BaseDistribution) – A distribution newly added to storage.

Raises ValueError – If different distribution kinds are set to dist_old and dist_new, or dist_old.choices doesn’t match dist_new.choices for CategoricalDistribution.

Return type None
6.3.4 optuna.exceptions

The `exceptions` module defines Optuna-specific exceptions deriving from a base `OptunaError` class. Of special importance for library users is the `TrialPruned` exception to be raised if `optuna.trial.Trial.should_prune()` returns `True` for a trial that should be pruned.

<table>
<thead>
<tr>
<th>Exception</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>optuna.exceptions.OptunaError</code></td>
<td>Base class for Optuna specific errors.</td>
</tr>
<tr>
<td><code>optuna.exceptions.TrialPruned</code></td>
<td>Exception for pruned trials.</td>
</tr>
<tr>
<td><code>optuna.exceptions.CLIUsageError</code></td>
<td>Exception for CLI.</td>
</tr>
<tr>
<td><code>optuna.exceptions.StorageInternalError</code></td>
<td>Exception for storage operation.</td>
</tr>
<tr>
<td><code>optuna.exceptions.DuplicatedStudyError</code></td>
<td>Exception for a duplicated study name.</td>
</tr>
</tbody>
</table>

**Example**

```python
import numpy as np
from sklearn.datasets import load_iris
from sklearn.linear_model import SGDClassifier
from sklearn.model_selection import train_test_split

import optuna

X, y = load_iris(return_X_y=True)
X_train, X_valid, y_train, y_valid = train_test_split(X, y)
classes = np.unique(y)

def objective(trial):
    alpha = trial.suggest_float("alpha", 0.0, 1.0)
    clf = SGDClassifier(alpha=alpha)
    n_train_iter = 100
    
    for step in range(n_train_iter):
        clf.partial_fit(X_train, y_train, classes=classes)
```

(continues on next page)
```python
intermediate_value = clf.score(X_valid, y_valid)
trial.report(intermediate_value, step)

if trial.should_prune():
    raise optuna.TrialPruned()

return clf.score(X_valid, y_valid)
```

```python
study = optuna.create_study(direction="maximize")
study.optimize(objective, n_trials=20)
```

### optuna.exceptions.CLIUsageError

element optuna.exceptions.CLIUsageError

Exception for CLI.

CLI raises this exception when it receives invalid configuration.

### optuna.exceptions.StorageInternalError

element optuna.exceptions.StorageInternalError

Exception for storage operation.

This error is raised when an operation failed in backend DB of storage.

### optuna.exceptions.DuplicatedStudyError

element optuna.exceptions.DuplicatedStudyError

Exception for a duplicated study name.

This error is raised when a specified study name already exists in the storage.

### 6.3.5 optuna.importance

The `importance` module provides functionality for evaluating hyperparameter importances based on completed trials in a given study. The utility function `get_param_importances()` takes a Study and optional evaluator as two of its inputs. The evaluator must derive from `BaseImportanceEvaluator`, and is initialized as a `FanovaImportanceEvaluator` by default when not passed in. Users implementing custom evaluators should refer to either `FanovaImportanceEvaluator` or `MeanDecreaseImpurityImportanceEvaluator` as a guide, paying close attention to the format of the return value from the Evaluator's `evaluate()` function.

<table>
<thead>
<tr>
<th>optuna.importance</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>get_param_importances</code></td>
<td>Evaluate parameter importances based on completed trials in the given study.</td>
</tr>
<tr>
<td><code>FanovaImportanceEvaluator</code></td>
<td>TANOVA importance evaluator.</td>
</tr>
<tr>
<td><code>MeanDecreaseImpurityImportanceEvaluator</code></td>
<td>Mean Decrease Impurity (MDI) parameter importance evaluator.</td>
</tr>
</tbody>
</table>
optuna.importance.get_param_importances

optuna.importance.get_param_importances(study, *, evaluator=None, params=None, target=None)

Evaluate parameter importances based on completed trials in the given study.

The parameter importances are returned as a dictionary where the keys consist of parameter names and their values importances. The importances are represented by floating point numbers that sum to 1.0 over the entire dictionary. The higher the value, the more important. The returned dictionary is of type collections.OrderedDict and is ordered by its values in a descending order.

If `params` is `None`, all parameter that are present in all of the completed trials are assessed. This implies that conditional parameters will be excluded from the evaluation. To assess the importances of conditional parameters, a list of parameter names can be specified via `params`. If specified, only completed trials that contain all of the parameters will be considered. If no such trials are found, an error will be raised.

If the given study does not contain completed trials, an error will be raised.

**Note:** If `params` is specified as an empty list, an empty dictionary is returned.

See also:

See `plot_param_importances()` to plot importances.

**Parameters**

- **study** (`optuna.study.study.Study`) – An optimized study.
- **evaluator** (`Optional[optuna.importance._base.BaseImportanceEvaluator]`) – An importance evaluator object that specifies which algorithm to base the importance assessment on. Defaults to `FanovaImportanceEvaluator`.
- **params** (`Optional[List[str]]`) – A list of names of parameters to assess. If `None`, all parameters that are present in all of the completed trials are assessed.
- **target** (`Optional[Callable[[optuna.trial._frozen.FrozenTrial], float]]`) – A function to specify the value to evaluate importances. If it is `None` and `study` is being used for single-objective optimization, the objective values are used. **Note:** Specify this argument if `study` is being used for multi-objective optimization. For example, to get the hyperparameter importance of the first objective, use `target=lambda t: t.values[0]` for the target parameter.

**Returns** An `collections.OrderedDict` where the keys are parameter names and the values are assessed importances.

**Raises** `ValueError` – If `target` is `None` and `study` is being used for multi-objective optimization.

**Return type** `Dict[str, float]`
**optuna.importance.FanovaImportanceEvaluator**

```python
class optuna.importance.FanovaImportanceEvaluator(*, n_trees=64, max_depth=64, seed=None)
```

fANOV A importance evaluator.

Implements the fANOV A hyperparameter importance evaluation algorithm in An Efficient Approach for Assessing Hyperparameter Importance.

Given a study, fANOV A fits a random forest regression model that predicts the objective value given a parameter configuration. The more accurate this model is, the more reliable the importances assessed by this class are.

**Note:** Requires the sklearn Python package.

**Note:** Pairwise and higher order importances are not supported through this class. They can be computed using _Fanova directly but is not recommended as interfaces may change without prior notice.

**Note:** The performance of fANOV A depends on the prediction performance of the underlying random forest model. In order to obtain high prediction performance, it is necessary to cover a wide range of the hyperparameter search space. It is recommended to use an exploration-oriented sampler such as RandomSampler.

**Note:** For how to cite the original work, please refer to https://automl.github.io/fanova/cite.html.

**Parameters**

- **n_trees** – The number of trees in the forest.
- **max_depth** – The maximum depth of the trees in the forest.
- **seed** – Controls the randomness of the forest. For deterministic behavior, specify a value other than None.

**Methods**

**evaluate**(study[, params, target])

Evaluate parameter importances based on completed trials in the given study.

**evaluate**(study, params=None, *, target=None)

Evaluate parameter importances based on completed trials in the given study.

**Note:** This method is not meant to be called by library users.

**See also:**

Please refer to `get_param_importances()` for how a concrete evaluator should implement this method.

**Parameters**
- **study** *(optuna.study.study.Study)* – An optimized study.

- **params** *(Optional[List[str]])* – A list of names of parameters to assess. If *None*, all parameters that are present in all of the completed trials are assessed.

- **target** *(Optional[Callable[[optuna.trial._frozen.FrozenTrial], float]])* – A function to specify the value to evaluate importances. If it is *None* and *study* is being used for single-objective optimization, the objective values are used. Can also be used for other trial attributes, such as the duration, like *target=lambda t: t.duration.total_seconds()*.

  **Note:** Specify this argument if *study* is being used for multi-objective optimization. For example, to get the hyperparameter importance of the first objective, use *target=lambda t: t.values[0]* for the target parameter.

  Returns: An *collections.OrderedDict* where the keys are parameter names and the values are assessed importances.

  Raises *ValueError* – If *target* is *None* and *study* is being used for multi-objective optimization.

  Return type: *Dict[str, float]*

**optuna.importance.MeanDecreaseImpurityImportanceEvaluator**

```python
class optuna.importance.MeanDecreaseImpurityImportanceEvaluator(*, n_trees=64, max_depth=64, seed=None)
```

Mean Decrease Impurity (MDI) parameter importance evaluator.

This evaluator fits a random forest that predicts objective values given hyperparameter configurations. Feature importances are then computed using MDI.

**Note:** This evaluator requires the *sklearn* Python package and is based on *sklearn.ensemble.RandomForestClassifier.feature_importances_*.

### Parameters

- **n_trees** – Number of trees in the random forest.
- **max_depth** – The maximum depth of each tree in the random forest.
- **seed** – Seed for the random forest.

### Methods

- **evaluate**(study[, params, target]) Evaluate parameter importances based on completed trials in the given study.

```python
evaluate(study, params=None, *, target=None)
```

Evaluate parameter importances based on completed trials in the given study.
Note: This method is not meant to be called by library users.

See also:
Please refer to get_param_importances() for how a concrete evaluator should implement this method.

Parameters

- **study (optuna.study.study.Study)** – An optimized study.
- **params (Optional[List[str]])** – A list of names of parameters to assess. If None, all parameters that are present in all of the completed trials are assessed.
- **target (Optional[Callable[[optuna.trial._frozen.FrozenTrial], float]])** – A function to specify the value to evaluate importances. If it is None and study is being used for single-objective optimization, the objective values are used. Can also be used for other trial attributes, such as the duration, like target=lambda t: t.duration.total_seconds().

Note: Specify this argument if study is being used for multi-objective optimization. For example, to get the hyperparameter importance of the first objective, use target=lambda t: t.values[0] for the target parameter.

Returns An collections.OrderedDict where the keys are parameter names and the values are assessed importances.

Raises ValueError – If target is None and study is being used for multi-objective optimization.

Return type Dict[str, float]

6.3.6 optuna.integration

The integration module contains classes used to integrate Optuna with external machine learning frameworks.

For most of the ML frameworks supported by Optuna, the corresponding Optuna integration class serves only to implement a callback object and functions, compliant with the framework’s specific callback API, to be called with each intermediate step in the model training. The functionality implemented in these callbacks across the different ML frameworks includes:

1. Reporting intermediate model scores back to the Optuna trial using optuna.trial.report(),
2. According to the results of optuna.trial.Trial.should_prune(), pruning the current model by raising optuna.TrialPruned(), and
3. Reporting intermediate Optuna data such as the current trial number back to the framework, as done in MLflowCallback.

For scikit-learn, an integrated OptunaSearchCV estimator is available that combines scikit-learn BaseEstimator functionality with access to a class-level Study object.
AllenNLP

<table>
<thead>
<tr>
<th>Method/Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>optuna.integration.allennlp.dump_best_config</td>
<td>Save JSON config file with environment variables and best performing hyperparameters.</td>
</tr>
<tr>
<td>optuna.integration.AllenNLPPruningCallback</td>
<td>AllenNLP callback to prune unpromising trials.</td>
</tr>
</tbody>
</table>

**optuna.integration.AllenNLPExecutor**

class optuna.integration.AllenNLPExecutor(trial, config_file, serialization_dir, metrics='best_validation_accuracy', *, include_package=None, force=False, file_friendly_logging=False)

AllenNLP extension to use optuna with Jsonnet config file.

This feature is experimental since AllenNLP major release will come soon. The interface may change without prior notice to correspond to the update.

See the examples of objective function.

You can also see the tutorial of our AllenNLP integration on AllenNLP Guide.

**Note:** From Optuna v2.1.0, users have to cast their parameters by using methods in Jsonnet. Call std.parseInt for integer, or std.parseJson for floating point. Please see the example configuration.

**Note:** In AllenNLPExecutor, you can pass parameters to AllenNLP by either defining a search space using Optuna suggest methods or setting environment variables just like AllenNLP CLI. If a value is set in both a search space in Optuna and the environment variables, the executor will use the value specified in the search space in Optuna.

**Parameters**

- **trial** – A Trial corresponding to the current evaluation of the objective function.
- **config_file** – Config file for AllenNLP. Hyperparameters should be masked with std.extVar. Please refer to the config example.
- **serialization_dir** – A path which model weights and logs are saved.
- **metrics** – An evaluation metric for the result of objective.
- **force** – If True, an executor overwrites the output directory if it exists.
- **file_friendly_logging** – If True, tqdm status is printed on separate lines and slows tqdm refresh rate.
- **include_package** – Additional packages to include. For more information, please see AllenNLP documentation.
Note: Added in v1.4.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v1.4.0.

Methods

```
 run()  # Train a model using AllenNLP.
```

```
run()  # Train a model using AllenNLP.

Return type  float
```

```
optuna.integration.allennlp.dump_best_config
```

```
optuna.integration.allennlp.dump_best_config(input_config_file, output_config_file, study)
```

Save JSON config file with environment variables and best performing hyperparameters.

Parameters

- `input_config_file` (str) – Input Jsonnet config file used with `AllenNLPExecutor`.
- `output_config_file` (str) – Output JSON config file.
- `study` (optuna.study.study.Study) – Instance of `Study`. Note that `optimize()` must have been called.

Return type  None

```
optuna.integration.AllenNLPPruningCallback
```

```
class optuna.integration.AllenNLPPruningCallback(trial=None, monitor=None)
```

AllenNLP callback to prune unpromising trials.

See the example if you want to add a pruning callback which observes a metric.

You can also see the tutorial of our AllenNLP integration on AllenNLP Guide.

Note: When `AllenNLPPruningCallback` is instantiated in Python script, trial and monitor are mandatory.

On the other hand, when `AllenNLPPruningCallback` is used with `AllenNLPExecutor`, trial and monitor would be None. `AllenNLPExecutor` sets environment variables for a study name, trial id, monitor, and storage. Then `AllenNLPPruningCallback` loads them to restore trial and monitor.

Note: Currently, build-in pruners are supported except for `PatientPruner`.

Parameters
• **trial** – A *Trial* corresponding to the current evaluation of the objective function.

• **monitor** – An evaluation metric for pruning, e.g. `validation_loss` or `validation_accuracy`.

**Note:** Added in v2.0.0 as an experimental feature. The interface may change in newer versions without prior notice. See [https://github.com/optuna/optuna/releases/tag/v2.0.0](https://github.com/optuna/optuna/releases/tag/v2.0.0).

### Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>on_epoch(trainer, metrics, epoch[, is_primary])</code></td>
<td>Check if a training reaches saturation.</td>
</tr>
<tr>
<td><code>register(*args, **kwargs)</code></td>
<td>Stub method for <code>TrainerCallback.register</code>.</td>
</tr>
</tbody>
</table>

```python
don_epoch(trainer, metrics, epoch, is_primary=True, **kwargs)
```

Check if a training reaches saturation.

**Parameters**

- **trainer** (`GradientDescentTrainer`) – AllenNLP’s trainer
- **epoch** (`int`) – Number of current epoch.
- **is_primary** (`bool`) – A flag for AllenNLP internal.
- **kwargs** (`Any`) –

**Return type** None

```python
classmethod register(*args, **kwargs)
```

Stub method for `TrainerCallback.register`.

This method has the same signature as `Registrable.register` in AllenNLP.

**Parameters**

- **args** (`Any`) –
- **kwargs** (`Any`) –

**Return type** Callable

### BoTorch

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>optuna.integration.BoTorchSampler</code></td>
<td>A sampler that uses BoTorch, a Bayesian optimization library built on top of PyTorch.</td>
</tr>
<tr>
<td><code>optuna.integration.botorch.qei_candidates_func</code></td>
<td>Quasi MC-based batch Expected Improvement (qEI).</td>
</tr>
<tr>
<td><code>optuna.integration.botorch.gehvi_candidates_func</code></td>
<td>Quasi MC-based batch Expected Hypervolume Improvement (qEHVI).</td>
</tr>
<tr>
<td><code>optuna.integration.botorch.qparego_candidates_func</code></td>
<td>Quasi MC-based extended ParEGO (qParEGO) for constrained multi-objective optimization.</td>
</tr>
</tbody>
</table>
optuna.integration.BoTorchSampler

class optuna.integration.BoTorchSampler(*, candidates_func=None, constraints_func=None, n_startup_trials=10, independent_sampler=None)

A sampler that uses BoTorch, a Bayesian optimization library built on top of PyTorch.

This sampler allows using BoTorch’s optimization algorithms from Optuna to suggest parameter configurations. Parameters are transformed to continuous space and passed to BoTorch, and then transformed back to Optuna’s representations. Categorical parameters are one-hot encoded.

See also:

See an example how to use the sampler.

See also:

See the BoTorch homepage for details and for how to implement your own candidates_func.

Note: An instance of this sampler should not be used with different studies when used with constraints. Instead, a new instance should be created for each new study. The reason for this is that the sampler is stateful keeping all the computed constraints.

Parameters

- **candidates_func** – An optional function that suggests the next candidates. It must take the training data, the objectives, the constraints, the search space bounds and return the next candidates. The arguments are of type torch.Tensor. The return value must be a torch.Tensor. However, if constraints_func is omitted, constraints will be None. For any constraints that failed to compute, the tensor will contain NaN.
  
  If omitted, it is determined automatically based on the number of objectives. If the number of objectives is one, Quasi MC-based batch Expected Improvement (qEI) is used. If the number of objectives is either two or three, Quasi MC-based batch Expected Hypervolume Improvement (qEHVI) is used. Otherwise, for larger number of objectives, the faster Quasi MC-based extended ParEGO (qParEGO) is used.
  
  The function should assume maximization of the objective.
  
  See also:
  
  See optuna.integration.botorch.qei_candidates_func() for an example.

- **constraints_func** – An optional function that computes the objective constraints. It must take a FrozenTrial and return the constraints. The return value must be a sequence of float. A value strictly larger than 0 means that a constraint is violated. A value equal to or smaller than 0 is considered feasible.
  
  If omitted, no constraints will be passed to candidates_func nor taken into account during suggestion.

- **n_startup_trials** – Number of initial trials, that is the number of trials to resort to independent sampling.

- **independent_sampler** – An independent sampler to use for the initial trials and for parameters that are conditional.
Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>after_trial(study, trial, state, values)</code></td>
<td>Trial post-processing. This method is called after the objective function returns and right</td>
</tr>
<tr>
<td></td>
<td>before the trials is finished and its state is stored.</td>
</tr>
<tr>
<td><code>infer_relative_search_space(study, trial)</code></td>
<td>Infer the search space that will be used by relative sampling in the target trial.</td>
</tr>
<tr>
<td><code>reseed_rng()</code></td>
<td>Reseed sampler’s random number generator.</td>
</tr>
<tr>
<td><code>sample_independent(study, trial, param_name, ...)</code></td>
<td>Sample a parameter for a given distribution.</td>
</tr>
<tr>
<td><code>sample_relative(study, trial, search_space)</code></td>
<td>Sample parameters in a given search space.</td>
</tr>
</tbody>
</table>

**Parameters**

- `study` (`optuna.study.study.Study`) – Target study object.
- `trial` (`optuna.trial._frozen.FrozenTrial`) – Target trial object. Take a copy before modifying this object.
- `state` (`optuna.trial._state.TrialState`) – Resulting trial state.
- `values` (`Optional[Sequence[float]]`) – Resulting trial values. Guaranteed to not be `None` if trial succeeded.

**Return type**  
None

**infer_relative_search_space(study, trial)**  
Infer the search space that will be used by relative sampling in the target trial.  
This method is called right before `sample_relative()` method, and the search space returned by this method is passed to it. The parameters not contained in the search space will be sampled by using `sample_independent()` method.

**Parameters**

- `study` (`optuna.study.study.Study`) – Target study object.
- `trial` (`optuna.trial._frozen.FrozenTrial`) – Target trial object. Take a copy before modifying this object.

**Returns**  
A dictionary containing the parameter names and parameter’s distributions.

**Return type**  
`Dict[str, optuna.distributions.BaseDistribution]`
See also:

Please refer to `intersection_search_space()` as an implementation of `infer_relative_search_space()`.

**reseed_rng()**

Reseed sampler’s random number generator.

This method is called by the `Study` instance if trials are executed in parallel with the option `n_jobs>1`. In that case, the sampler instance will be replicated including the state of the random number generator, and they may suggest the same values. To prevent this issue, this method assigns a different seed to each random number generator.

**Return type** None

**sample_independent(study, trial, param_name, param_distribution)**

Sample a parameter for a given distribution.

This method is called only for the parameters not contained in the search space returned by `sample_relative()` method. This method is suitable for sampling algorithms that do not use relationship between parameters such as random sampling and TPE.

**Note:** The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

**Parameters**

- **study** (`optuna.study.Study`) – Target study object.
- **trial** (`optuna.trial.FrozenTrial`) – Target trial object. Take a copy before modifying this object.
- **param_name** (`str`) – Name of the sampled parameter.
- **param_distribution** (`optuna.distributions.BaseDistribution`) – Distribution object that specifies a prior and/or scale of the sampling algorithm.

**Returns** A parameter value.

**Return type** Any

**sample_relative(study, trial, search_space)**

Sample parameters in a given search space.

This method is called once at the beginning of each trial, i.e., right before the evaluation of the objective function. This method is suitable for sampling algorithms that use relationship between parameters such as Gaussian Process and CMA-ES.

**Note:** The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

**Parameters**

- **study** (`optuna.study.Study`) – Target study object.
- **trial** (`optuna.trial.FrozenTrial`) – Target trial object. Take a copy before modifying this object.
• **search_space** *(Dict[str, optuna.distributions.BaseDistribution])* – The search space returned by `infer_relative_search_space()`.

**Returns** A dictionary containing the parameter names and the values.

**Return type** Dict[str, Any]

```python
optuna.integration.botorch.qei_candidates_func
```

```python
optuna.integration.botorch.qei_candidates_func(train_x, train_obj, train_con, bounds)
```

Quasi MC-based batch Expected Improvement (qEI).

The default value of candidates_func in BoTorchSampler with single-objective optimization.

**Parameters**

- **train_x** *(torch.Tensor)* – Previous parameter configurations. A torch.Tensor of shape *(n_trials, n_params)*. *n_trials* is the number of already observed trials and *n_params* is the number of parameters. *n_params* may be larger than the actual number of parameters if categorical parameters are included in the search space, since these parameters are one-hot encoded. Values are not normalized.

- **train_obj** *(torch.Tensor)* – Previously observed objectives. A torch.Tensor of shape *(n_trials, n_objectives)*. *n_trials* is identical to that of *train_x*. *n_objectives* is the number of objectives. Observations are not normalized.

- **train_con** *(Optional[torch.Tensor])* – Objective constraints. A torch.Tensor of shape *(n_trials, n_constraints)*. *n_trials* is identical to that of *train_x*. *n_constraints* is the number of constraints. A constraint is violated if strictly larger than 0. If no constraints are involved in the optimization, this argument will be None.

- **bounds** *(torch.Tensor)* – Search space bounds. A torch.Tensor of shape *(2, n_params)*. *n_params* is identical to that of *train_x*. The first and the second rows correspond to the lower and upper bounds for each parameter respectively.

**Returns** Next set of candidates. Usually the return value of BoTorch’s `optimize_acqf`.

**Return type** torch.Tensor

---

**Note:** Added in v2.4.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.4.0.

```python
optuna.integration.botorch.qehvi_candidates_func
```

```python
optuna.integration.botorch.qehvi_candidates_func(train_x, train_obj, train_con, bounds)
```

Quasi MC-based batch Expected Hypervolume Improvement (qEHVI).

The default value of candidates_func in BoTorchSampler with multi-objective optimization when the number of objectives is three or less.

**See also:**

`qei_candidates_func()` for argument and return value descriptions.
Note: Added in v2.4.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.4.0.

Parameters

- **train_x**(torch.Tensor)
- **train_obj**(torch.Tensor)
- **train_con**(Optional[torch.Tensor])
- **bounds**(torch.Tensor)

Return type torch.Tensor

**optuna.integration.botorch.qparego_candidates_func**

optuna.integration.botorch.qparego_candidates_func(train_x, train_obj, train_con, bounds)

Quasi MC-based extended ParEGO (qParEGO) for constrained multi-objective optimization.

The default value of candidates_func in BoTorchSampler with multi-objective optimization when the number of objectives is larger than three.

See also:

qei_candidates_func() for argument and return value descriptions.

Note: Added in v2.4.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.4.0.

Parameters

- **train_x**(torch.Tensor)
- **train_obj**(torch.Tensor)
- **train_con**(Optional[torch.Tensor])
- **bounds**(torch.Tensor)

Return type torch.Tensor

Catalyst

optuna.integration.CatalystPruningCallback

Catalyst callback to prune unpromising trials.
optuna.integration.CatalystPruningCallback

class optuna.integration.CatalystPruningCallback(*args, **kwargs)
Catalyst callback to prune unpromising trials.

This class is an alias to Catalyst’s OptunaPruningCallback.
See the Catalyst’s documentation for the detailed description.

Warning: Deprecated in v2.7.0. This feature will be removed in the future. The removal of this feature is currently scheduled for v4.0.0, but this schedule is subject to change. See https://github.com/optuna/optuna/releases/tag/v2.7.0.

Chainer

optuna.integration.ChainerPruningExtension
A wrapper of Study to incorporate Optuna with ChainerMN.

optuna.integration.ChainerMNStudy
A wrapper of Study to incorporate Optuna with ChainerMN.

Parameters

• trial – A Trial corresponding to the current evaluation of the objective function.

• observation_key – An evaluation metric for pruning, e.g., main/loss and validation/main/accuracy. Please refer to chainer.Reporter reference for further details.

• pruner_trigger – A trigger to execute pruning. pruner_trigger is an instance of IntervalTrigger or ManualScheduleTrigger. IntervalTrigger can be specified by a tuple of the interval length and its unit like (1, 'epoch').

optuna.integration.ChainerMNStudy

class optuna.integration.ChainerMNStudy(study, comm)
A wrapper of Study to incorporate Optuna with ChainerMN.

See also:
ChainerMNStudy provides the same interface as Study. Please refer to optuna.study.Study for further details.

See the example if you want to optimize an objective function that trains neural network written with ChainerMN.

Parameters
• **study** – A *Study* object.
• **comm** – A ChainerMN communicator.

Methods

```python
optimize(func[, n_trials, timeout, catch])
```
Optimize an objective function.

```python
optimize (func, n_trials=None, timeout=None, catch=())
```
Optimize an objective function.

This method provides the same interface as `optuna.study.Study.optimize()` except the absence of `n_jobs` argument.

**Parameters**

- **func** (`Callable[[ChainerMNTrial, CommunicatorBase], float]`) –
- **n_trials** (`Optional[int]`) –
- **timeout** (`Optional[float]`) –
- **catch** (`Tuple[Type[Exception], ..]`) –

**Return type** None

**fast.ai**

```python
optuna.integration.FastAIV1PruningCallback
```
FastAI callback to prune unpromising trials for fastai.

```python
optuna.integration.FastAIV2PruningCallback
```
FastAI callback to prune unpromising trials for fastai.

```python
optuna.integration.FastAIPruningCallback
```
alias of `optuna.integration.fastaiv2.FastAIV2PruningCallback`

**optuna.integration.FastAIV1PruningCallback**

class `optuna.integration.FastAIV1PruningCallback(learn, trial, monitor)`
FastAI callback to prune unpromising trials for fastai.

**Note:** This callback is for fastai<2.0.

See the example if you want to add a pruning callback which monitors validation loss of a Learner.
Example

Register a pruning callback to learn.fit and learn.fit_one_cycle.

```python
learn.fit(n_epochs, callbacks=[FastAIPruningCallback(learn, trial, "valid_loss")])
learn.fit_one_cycle(
    n_epochs,
    cyc_len,
    max_lr,
    callbacks=[FastAIPruningCallback(learn, trial, "valid_loss")],
)
```

Parameters

- **learn** – fastai.basic_train.Learner.
- **trial** – A Trial corresponding to the current evaluation of the objective function.
- **monitor** – An evaluation metric for pruning, e.g. valid_loss and Accuracy. Please refer to fastai.callbacks.TrackerCallback reference for further details.

Warning: Deprecated in v2.4.0. This feature will be removed in the future. The removal of this feature is currently scheduled for v4.0.0, but this schedule is subject to change. See https://github.com/optuna/optuna/releases/tag/v2.4.0.

Methods

```python
on_epoch_end(epoch, **kwargs)
```

**optuna.integration.FastAIV2PruningCallback**

```python
class optuna.integration.FastAIV2PruningCallback(trial, monitor='valid_loss')
```

FastAI callback to prune unpromising trials for fastai.

Note: This callback is for fastai>=2.0.

See the example if you want to add a pruning callback which monitors validation loss of a Learner.

Example

Register a pruning callback to learn.fit and learn.fit_one_cycle.

```python
learn = cnn_learner(dls, resnet18, metrics=[error_rate])
learn.fit(n_epochs, cbs=[FastAIPruningCallback(trial)]) # Monitor "valid_loss"
learn.fit_one_cycle(
    n_epochs,
    lr_max,
)
```

(continues on next page)
cbs=[FastAIPruningCallback(trial, monitor="error_rate")],  # Monitor "error_rate"

Parameters

- **trial** – A `Trial` corresponding to the current evaluation of the objective function.
- **monitor** – An evaluation metric for pruning, e.g. `valid_loss` or `accuracy`. Please refer to `fastai.callback.TrackerCallback` reference for further details.

Methods

```python
after_epoch()

after_fit()
```

**optuna.integration.FastAIPruningCallback**

*alias of optuna.integration.fastaiv2.FastAIV2PruningCallback*

**Keras**

```python
optuna.integration.KerasPruningCallback
```

Keras callback to prune unpromising trials.

**optuna.integration.KerasPruningCallback**

```python
class optuna.integration.KerasPruningCallback (trial, monitor, interval=1)
```

Keras callback to prune unpromising trials.

See the example if you want to add a pruning callback which observes validation accuracy.

Parameters

- **trial** – A `Trial` corresponding to the current evaluation of the objective function.
- **monitor** – An evaluation metric for pruning, e.g. `val_loss` and `val_accuracy`. Please refer to `keras.Callback` reference for further details.
- **interval** – Check if trial should be pruned every n-th epoch. By default `interval=1` and pruning is performed after every epoch. Increase `interval` to run several epochs faster before applying pruning.

**Warning:** Deprecated in v2.1.0. This feature will be removed in the future. The removal of this feature is currently scheduled for v4.0.0, but this schedule is subject to change. See [https://github.com/optuna/optuna/releases/tag/v2.1.0](https://github.com/optuna/optuna/releases/tag/v2.1.0).
Recent Keras release (2.4.0) simply redirects all APIs in the standalone keras package to point to tf.keras. There is now only one Keras: tf.keras. There may be some breaking changes for some workflows by upgrading to keras 2.4.0. Test before upgrading. REF: [https://github.com/keras-team/keras/releases/tag/2.4.0](https://github.com/keras-team/keras/releases/tag/2.4.0).

There is an alternative callback function that can be used instead: `TFKerasPruningCallback`

**Methods**

```python
on_epoch_end(epoch[, logs])
```

**LightGBM**

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>optuna.integration.LightGBMPruningCallback</code></td>
<td>Callback for LightGBM to prune unpromising trials.</td>
</tr>
<tr>
<td><code>optuna.integration.lightgbm.train</code></td>
<td>Wrapper of LightGBM Training API to tune hyperparameters.</td>
</tr>
<tr>
<td><code>optuna.integration.lightgbm.LightGBMTuner</code></td>
<td>Hyperparameter tuner for LightGBM.</td>
</tr>
<tr>
<td><code>optuna.integration.lightgbm.LightGBMTunerCV</code></td>
<td>Hyperparameter tuner for LightGBM with cross-validation.</td>
</tr>
</tbody>
</table>

**optuna.integration.LightGBMPruningCallback**

```python
class optuna.integration.LightGBMPruningCallback(trial, metric, valid_name='valid_0')
```

Callback for LightGBM to prune unpromising trials.

See the example if you want to add a pruning callback which observes AUC of a LightGBM model.

**Parameters**

- **trial** – A `Trial` corresponding to the current evaluation of the objective function.
- **metric** – An evaluation metric for pruning, e.g., `binary_error` and `multi_error`. Please refer to LightGBM reference for further details.
- **valid_name** – The name of the target validation. Validation names are specified by `valid_names` option of `train method`. If omitted, `valid_0` is used which is the default name of the first validation. Note that this argument will be ignored if you are calling `cv method` instead of `train method`. 

6.3. API Reference
**optuna.integration.lightgbm.train**

`optuna.integration.lightgbm.train(*args, **kwargs)`

Wrapper of LightGBM Training API to tune hyperparameters.

It tunes important hyperparameters (e.g., `min_child_samples` and `feature_fraction`) in a stepwise manner. It is a drop-in replacement for `lightgbm.train()`. See a simple example of LightGBM Tuner which optimizes the validation log loss of cancer detection.

`train()` is a wrapper function of `LightGBMTuner`. To use feature in Optuna such as suspended/resumed optimization and/or parallelization, refer to `LightGBMTuner` instead of this function.

Arguments and keyword arguments for `lightgbm.train()` can be passed.

**Parameters**

- `args` *(Any)* –
- `kwargs` *(Any)* –

**Return type** *Any*

**optuna.integration.lightgbm.LightGBMTuner**

```python
class optuna.integration.lightgbm.LightGBMTuner(params, train_set, num_boost_round=1000, valid_sets=None, valid_names=None, fobj=None, feval=None, feature_name='auto', categorical_feature='auto', early_stopping_rounds=None, evals_result=None, verbose_eval=True, learning_rates=None, keep_training_booster=False, callbacks=None, time_budget=None, sample_size=None, study=None, optuna_callbacks=None, model_dir=None, verbosity=None, show_progress_bar=True, *, optuna_seed=None)
```

Hyperparameter tuner for LightGBM.

It optimizes the following hyperparameters in a stepwise manner: `lambda_l1`, `lambda_l2`, `num_leaves`, `feature_fraction`, `bagging_fraction`, `bagging_freq` and `min_child_samples`.

You can find the details of the algorithm and benchmark results in this blog article by Kohei Ozaki, a Kaggle Grandmaster.

Arguments and keyword arguments for `lightgbm.train()` can be passed. The arguments that only `LightGBMTuner` has are listed below:

**Parameters**

- `time_budget` – A time budget for parameter tuning in seconds.
- `study` – A `Study` instance to store optimization results. The `Trial` instances in it has the following user attributes: `elapsed_secs` is the elapsed time since the optimization starts.
- `sample_size` – The average iteration time to train the booster model.
in the trial. \texttt{lgbm_params} is a JSON-serialized dictionary of LightGBM parameters used in the trial.

- **\texttt{optuna_callbacks}** – List of Optuna callback functions that are invoked at the end of each trial. Each function must accept two parameters with the following types in this order: \texttt{Study} and \texttt{FrozenTrial}. Please note that this is not a \texttt{callbacks} argument of \texttt{lightgbm.train()}.

- **\texttt{model_dir}** – A directory to save boosters. By default, it is set to \texttt{None} and no boosters are saved. Please set shared directory (e.g., directories on NFS) if you want to access \texttt{get_best_booster()} in distributed environments. Otherwise, it may raise \texttt{ValueError}. If the directory does not exist, it will be created. The filenames of the boosters will be \texttt{{model_dir}/{trial_number}.pkl} (e.g., \texttt{./boosters/0.pkl}).

- **\texttt{verbosity}** – A verbosity level to change Optuna’s logging level. The level is aligned to LightGBM’s verbosity.

  Warning: Deprecated in v2.0.0. \texttt{verbosity} argument will be removed in the future. The removal of this feature is currently scheduled for v4.0.0, but this schedule is subject to change.

  Please use \texttt{set_verbosity()} instead.

- **\texttt{show_progress_bar}** – Flag to show progress bars or not. To disable progress bar, set this \texttt{False}.

  Note: Progress bars will be fragmented by logging messages of LightGBM and Optuna. Please suppress such messages to show the progress bars properly.

- **\texttt{optuna_seed}** – seed of \texttt{TPESampler} for random number generator that affects sampling for \texttt{num_leaves}, \texttt{bagging_fraction}, \texttt{bagging_freq}, \texttt{lambda_l1}, and \texttt{lambda_l2}.

  Note: The deterministic parameter of LightGBM makes training reproducible. Please enable it when you use this argument.

Methods

- \texttt{compare_validation_metrics(val_score, best_score)}
- \texttt{get_best_booster()} Return the best booster.
- \texttt{higher_is_better()}
- \texttt{run()} Perform the hyperparameter-tuning with given parameters.
- \texttt{sample_train_set()} Make subset of \texttt{self.train_set} Dataset object.
- \texttt{tune_bagging([n_trials])}
### Table 28 – continued from previous page

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>tune_feature_fraction([n_trials])</code></td>
<td></td>
</tr>
<tr>
<td><code>tune_feature_fraction_stage2([n_trials])</code></td>
<td></td>
</tr>
<tr>
<td><code>tune_min_data_in_leaf()</code></td>
<td></td>
</tr>
<tr>
<td><code>tune_num_leaves([n_trials])</code></td>
<td></td>
</tr>
<tr>
<td><code>tune_regularization_factors([n_trials])</code></td>
<td></td>
</tr>
</tbody>
</table>

### Attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>best_booster</code></td>
<td>Return the best booster.</td>
</tr>
<tr>
<td><code>best_params</code></td>
<td>Return parameters of the best booster.</td>
</tr>
<tr>
<td><code>best_score</code></td>
<td>Return the score of the best booster.</td>
</tr>
</tbody>
</table>

#### property best_booster
Return the best booster.

**Warning:** Deprecated in v1.4.0. This feature will be removed in the future. The removal of this feature is currently scheduled for v3.0.0, but this schedule is subject to change. See https://github.com/optuna/optuna/releases/tag/v1.4.0.

Please get the best booster via `get_best_booster` instead.

#### property best_params
Return parameters of the best booster.

#### property best_score
Return the score of the best booster.

#### `get_best_booster()`
Return the best booster.

If the best booster cannot be found, `ValueError` will be raised. To prevent the errors, please save boosters by specifying the `model_dir` argument of `__init__()`, when you resume tuning or you run tuning in parallel.

**Return type** lightgbm.basic.Booster

#### `run()`
Perform the hyperparameter-tuning with given parameters.

**Return type** None

#### `sample_train_set()`
Make subset of `self.train_set` Dataset object.

**Return type** None
**optuna.integration.lightgbm.LightGBMTunerCV**

```python
class optuna.integration.lightgbm.LightGBMTunerCV(params, train_set, num_boost_round=1000, folds=None, nfold=5, stratified=True, shuffle=True, fobj=None, feval=None, feature_name='auto', categorical_feature='auto', early_stopping_rounds=None, fpreproc=None, verbose_eval=True, show_stdv=True, seed=0, callbacks=None, time_budget=None, sample_size=None, study=None, optuna_callbacks=None, verbosity=None, show_progress_bar=True, model_dir=None, return_cvbooster=None, *, optuna_seed=None)
```

Hyperparameter tuner for LightGBM with cross-validation.

It employs the same stepwise approach as `LightGBMTuner`. `LightGBMTunerCV` invokes `lightgbm.cv()` to train and validate boosters while `LightGBMTuner` invokes `lightgbm.train()`. See a simple example which optimizes the validation log loss of cancer detection.

Arguments and keyword arguments for `lightgbm.cv()` can be passed except `metrics`, `init_model` and `eval_train_metric`. The arguments that only `LightGBMTunerCV` has are listed below:

**Parameters**

- **time_budget** – A time budget for parameter tuning in seconds.
- **study** – A `Study` instance to store optimization results. The `Trial` instances in it has the following user attributes: `elapsed_secs` is the elapsed time since the optimization starts. `average_iteration_time` is the average time of iteration to train the booster model in the trial. `lgbm_params` is a JSON-serialized dictionary of LightGBM parameters used in the trial.
- **optuna_callbacks** – List of Optuna callback functions that are invoked at the end of each trial. Each function must accept two parameters with the following types in this order: `Study` and `FrozenTrial`. Please note that this is not a `callbacks` argument of `lightgbm.train()`.
- **model_dir** – A directory to save boosters. By default, it is set to `None` and no boosters are saved. Please set shared directory (e.g., directories on NFS) if you want to access `get_best_booster()` in distributed environments. Otherwise, it may raise `ValueError`. If the directory does not exist, it will be created. The filenames of the boosters will be `{model_dir}/{trial_number}.pkl` (e.g., `/boosters/0.pkl`).
- **verbosity** – A verbosity level to change Optuna’s logging level. The level is aligned to LightGBM’s verbosity.

**Warning:** Deprecated in v2.0.0. `verbosity` argument will be removed in the future. The removal of this feature is currently scheduled for v4.0.0, but this schedule is subject to change.
Please use `set_verbosity()` instead.

- **show_progress_bar** – Flag to show progress bars or not. To disable progress bar, set this `False`.

  **Note:** Progress bars will be fragmented by logging messages of LightGBM and Optuna. Please suppress such messages to show the progress bars properly.

- **return_cvbooster** – Flag to enable `get_best_booster()`.

- **optuna_seed** – seed of `TPESampler` for random number generator that affects sampling for `num_leaves`, `bagging_fraction`, `bagging_freq`, `lambda_l1`, and `lambda_l2`.

  **Note:** The deterministic parameter of LightGBM makes training reproducible. Please enable it when you use this argument.

### Methods

```python
compare_validation_metrics(val_score, best_score)
get_best_booster() Return the best cvbooster.
higher_is_better()
run() Perform the hyperparameter-tuning with given parameters.
sample_train_set() Make subset of `self.train_set` Dataset object.
tune_bagging([n_trials])
tune_feature_fraction([n_trials])
tune_feature_fraction_stage2([n_trials])
tune_min_data_in_leaf()
tune_num_leaves([n_trials])
tune_regularization_factors([n_trials])
```
Attributes

<table>
<thead>
<tr>
<th>best_params</th>
<th>Return parameters of the best booster.</th>
</tr>
</thead>
<tbody>
<tr>
<td>best_score</td>
<td>Return the score of the best booster.</td>
</tr>
</tbody>
</table>

**property best_params**

Return parameters of the best booster.

**property best_score**

Return the score of the best booster.

**get_best_booster()**

Return the best cvbooster.

If the best booster cannot be found, `ValueError` will be raised. To prevent the errors, please save boosters by specifying both of the `model_dir` and the `return_cvbooster` arguments of `__init__()`, when you resume tuning or you run tuning in parallel.

**Return type** lightgbm.engine.CVBooster

**run()**

Perform the hyperparameter-tuning with given parameters.

**Return type** None

**sample_train_set()**

Make subset of `self.train_set` Dataset object.

**Return type** None

### MLflow

**optuna.integration.MLflowCallback**

Callback to track Optuna trials with MLflow.

**class optuna.integration.MLflowCallback**(tracking_uri=None, metric_name='value', nest_trials=False, tag_study_user_attrs=False)

Callback to track Optuna trials with MLflow.

This callback adds relevant information that is tracked by Optuna to MLflow. The MLflow experiment will be named after the Optuna study name.

**Example**

Add MLflow callback to Optuna optimization.

```python
import optuna
from optuna.integration.mlflow import MLflowCallback

def objective(trial):
    x = trial.suggest_float("x", -10, 10)
    return (x - 2) ** 2
```

(continues on next page)
mlflc = MLflowCallback(
    tracking_uri=YOUR_TRACKING_URI,
    metric_name="my metric score",
)

study = optuna.create_study(study_name="my_study")
study.optimize(objective, n_trials=10, callbacks=[mlflc])

Add additional logging to MLflow

import optuna
import mlflow
from optuna.integration.mlflow import MLflowCallback

mlflc = MLflowCallback(
    tracking_uri=YOUR_TRACKING_URI,
    metric_name="my metric score",
)

@mlflc.track_in_mlflow()
def objective(trial):
    x = trial.suggest_float("x", -10, 10)
    mlflow.log_param("power", 2)
    mlflow.log_metric("base of metric", x - 2)
    return (x - 2) ** 2

study = optuna.create_study(study_name="my_other_study")
study.optimize(objective, n_trials=10, callbacks=[mlflc])

Parameters

- **tracking_uri** – The URI of the MLflow tracking server.
  Please refer to mlflow.set_tracking_uri for more details.
- **metric_name** – Name assigned to optimized metric. In case of multi-objective optimization, list of names can be passed. Those names will be assigned to metrics in the order returned by objective function. If single name is provided, or this argument is left to default value, it will be broadcasted to each objective with a number suffix in order returned by objective function e.g. two objectives and default metric name will be logged as value_0 and value_1.
- **nest_trials** – Flag indicating whether or not trials should be logged as nested runs. This is often helpful for aggregating trials to a particular study, under a given experiment.
- **tag_study_user_attrs** – Flag indicating whether or not to add the study’s user attrs to the mlflow trial as tags. Please note that when this flag is set, key value pairs in user_attrs will supersede existing tags.

Note: Added in v1.4.0 as an experimental feature. The interface may change in newer versions without prior
Methods

---

**track_in_mlflow()**

Decorator for using MLflow logging in the objective function.

This decorator enables the extension of MLflow logging provided by the callback. All information logged in the decorated objective function will be added to the MLflow run for the trial created by the callback.

**Returns**

Objective function with tracking to MLflow enabled.

**Return type**

ObjectiveFuncType

**Note:** Added in v2.9.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.9.0.

---

Weights & Biases

---

**optuna.integration.WeightsAndBiasesCallback**

Callback to track Optuna trials with Weights & Biases.

**class optuna.integration.WeightsAndBiasesCallback** *(metric_name='value', wandb_kwargs=None)*

Callback to track Optuna trials with Weights & Biases. This callback enables tracking of Optuna study in Weights & Biases. The study is tracked as a single experiment run, where all suggested hyperparameters and optimized metrics are logged and plotted as a function of optimizer steps.

**Note:** User needs to be logged in to Weights & Biases before using this callback in online mode. For more information, please refer to wandb setup.

**Note:** Users who want to run multiple Optuna studies within the same process should call *wandb.finish()* between subsequent calls to *study.optimize()* . Calling *wandb.finish()* is not necessary if you are running one Optuna study per process.

**Note:** To ensure correct trial order in Weights & Biases, this callback should only be used with *study*.  

6.3. API Reference
Example

Add Weights & Biases callback to Optuna optimization.

```python
import optuna
from optuna.integration.wandb import WeightsAndBiasesCallback

def objective(trial):
    x = trial.suggest_float("x", -10, 10)
    return (x - 2) ** 2

wandb_kwargs = {
    "project": "my-project"
}
wandbc = WeightsAndBiasesCallback(wandb_kwargs=wandb_kwargs)

study = optuna.create_study(study_name="my_study")
study.optimize(objective, n_trials=10, callbacks=[wandbc])
```

Parameters

- **metric_name** – Name assigned to optimized metric. In case of multi-objective optimization, list of names can be passed. Those names will be assigned to metrics in the order returned by objective function. If single name is provided, or this argument is left to default value, it will be broadcasted to each objective with a number suffix in order returned by objective function e.g. two objectives and default metric name will be logged as value_0 and value_1.

- **wandb_kwargs** – Set of arguments passed when initializing Weights & Biases run. Please refer to Weights & Biases API documentation for more details.

Raises

- **ValueError** – If there are missing or extra metric names in multi-objective optimization.

- **TypeError** – When metric names are not passed as sequence.

Note: Added in v2.9.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.9.0.
optuna.integration.MXNetPruningCallback

class optuna.integration.MXNetPruningCallback(trial, eval_metric)
MXNet callback to prune unpromising trials.
See the example if you want to add a pruning callback which observes accuracy.

Parameters

- trial – A Trial corresponding to the current evaluation of the objective function.
- eval_metric – An evaluation metric name for pruning, e.g., cross-entropy and accuracy. If using default metrics like mxnet.metrics.Accuracy, use it’s default metric name. For custom metrics, use the metric_name provided to constructor. Please refer to mxnet.metrics reference for further details.

pycma

optuna.integration.PyCmaSampler
A Sampler using cma library as the backend.

optuna.integration.CmaEsSampler
Wrapper class of PyCmaSampler for backward compatibility.

optuna.integration.PyCmaSampler

class optuna.integration.PyCmaSampler(x0=None, sigma0=None, cma_stds=None, seed=None, cma_opts=None, n_startup_trials=1, independent_sampler=None, warn_independent_sampling=True)
A Sampler using cma library as the backend.

Example

Optimize a simple quadratic function by using PyCmaSampler.

```
import optuna

def objective(trial):
    x = trial.suggest_float("x", -1, 1)
    y = trial.suggest_int("y", -1, 1)
    return x ** 2 + y

sampler = optuna.integration.PyCmaSampler()
study = optuna.create_study(sampler=sampler)
study.optimize(objective, n_trials=20)
```

Note that parallel execution of trials may affect the optimization performance of CMA-ES, especially if the number of trials running in parallel exceeds the population size.

Note: CmaEsSampler is deprecated and renamed to PyCmaSampler in v2.0.0. Please use PyCmaSampler instead of CmaEsSampler.
Parameters

- **x0** – A dictionary of an initial parameter values for CMA-ES. By default, the mean of `low` and `high` for each distribution is used. Please refer to `cma.CMAEvolutionStrategy` for further details of `x0`.

- **sigma0** – Initial standard deviation of CMA-ES. By default, `sigma0` is set to `min_range / 6`, where `min_range` denotes the minimum range of the distributions in the search space. If distribution is categorical, `min_range` is `len(choices) - 1`. Please refer to `cma.CMAEvolutionStrategy` for further details of `sigma0`.

- **cma_stds** – A dictionary of multipliers of `sigma0` for each parameters. The default value is 1.0. Please refer to `cma.CMAEvolutionStrategy` for further details of `cma_stds`.

- **seed** – A random seed for CMA-ES.

- **cma_opts** – Options passed to the constructor of `cma.CMAEvolutionStrategy` class. Note that `BoundaryHandler`, `bounds`, `CMA_stds` and `seed` arguments in `cma_opts` will be ignored because it is added by `PyCmaSampler` automatically.

- **n_startup_trials** – The independent sampling is used instead of the CMA-ES algorithm until the given number of trials finish in the same study.

- **independent_sampler** – A `BaseSampler` instance that is used for independent sampling. The parameters not contained in the relative search space are sampled by this sampler. The search space for `PyCmaSampler` is determined by `intersection_search_space()`.

  If `None` is specified, `RandomSampler` is used as the default.

  See also:

  - `optuna.samplers` module provides built-in independent samplers such as `RandomSampler` and `TPESampler`.

- **warn_independent_sampling** – If this is `True`, a warning message is emitted when the value of a parameter is sampled by using an independent sampler.

  Note that the parameters of the first trial in a study are always sampled via an independent sampler, so no warning messages are emitted in this case.

Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>after_trial(study, trial, state, values)</code></td>
<td>Trial post-processing.</td>
</tr>
<tr>
<td><code>infer_relative_search_space(study, trial)</code></td>
<td>Infer the search space that will be used by relative sampling in the target trial.</td>
</tr>
<tr>
<td><code>reseed_rng()</code></td>
<td>Reseed sampler’s random number generator.</td>
</tr>
<tr>
<td><code>sample_independent(study, trial, param_name, …)</code></td>
<td>Sample a parameter for a given distribution.</td>
</tr>
<tr>
<td><code>sample_relative(study, trial, search_space)</code></td>
<td>Sample parameters in a given search space.</td>
</tr>
</tbody>
</table>

**after_trial** `(study, trial, state, values)`

Trial post-processing.

This method is called after the objective function returns and right before the trials is finished and its state is stored.
Note: Added in v2.4.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.4.0.

Parameters

- **study** (optuna.study.study.Study) – Target study object.
- **trial** (optuna.trial._frozen.FrozenTrial) – Target trial object. Take a copy before modifying this object.
- **state** (optuna.trial._state.TrialState) – Resulting trial state.
- **values** (Optional[Sequence[float]]) – Resulting trial values. Guaranteed to not be None if trial succeeded.

Return type None

`infer_relative_search_space(study, trial)`

Infer the search space that will be used by relative sampling in the target trial.

This method is called right before `sample_relative()` method, and the search space returned by this method is passed to it. The parameters not contained in the search space will be sampled by using `sample_independent()` method.

Parameters

- **study** (optuna.study.study.Study) – Target study object.
- **trial** (optuna.trial._frozen.FrozenTrial) – Target trial object. Take a copy before modifying this object.

Returns A dictionary containing the parameter names and parameter’s distributions.

Return type Dict[str, optuna.distributions.BaseDistribution]

See also:

Please refer to `intersection_search_space()` as an implementation of `infer_relative_search_space()`.

`reseed_rng()`

Reseed sampler’s random number generator.

This method is called by the `Study` instance if trials are executed in parallel with the option `n_jobs>1`. In that case, the sampler instance will be replicated including the state of the random number generator, and they may suggest the same values. To prevent this issue, this method assigns a different seed to each random number generator.

Return type None

`sample_independent(study, trial, param_name, param_distribution)`

Sample a parameter for a given distribution.

This method is called only for the parameters not contained in the search space returned by `sample_relative()` method. This method is suitable for sampling algorithms that do not use relationship between parameters such as random sampling and TPE.

Note: The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.
Parameters

- **study** ([`optuna.study.Study`]) – Target study object.
- **trial** ([`optuna.trial.FrozenTrial`]) – Target trial object. Take a copy before modifying this object.
- **param_name** (`str`) – Name of the sampled parameter.
- **param_distribution** ([`optuna.distributions.BaseDistribution`]) – Distribution object that specifies a prior and/or scale of the sampling algorithm.

Returns A parameter value.

Return type float

```python
sample_relative(study, trial, search_space)
```

Sample parameters in a given search space.

This method is called once at the beginning of each trial, i.e., right before the evaluation of the objective function. This method is suitable for sampling algorithms that use relationship between parameters such as Gaussian Process and CMA-ES.

**Note:** The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

Parameters

- **study** ([`optuna.study.Study`]) – Target study object.
- **trial** ([`optuna.trial.FrozenTrial`]) – Target trial object. Take a copy before modifying this object.
- **search_space** (`Dict[str, optuna.distributions.BaseDistribution]`) – The search space returned by `infer_relative_search_space()`.

Returns A dictionary containing the parameter names and the values.

Return type Dict[str, float]

```python
optuna.integration.CmaEsSampler
```

**Warning:** Deprecated in v2.0.0. This feature will be removed in the future. The removal of this feature is currently scheduled for v4.0.0, but this schedule is subject to change. See [https://github.com/optuna/optuna/releases/tag/v2.0.0](https://github.com/optuna/optuna/releases/tag/v2.0.0).

This class is renamed to `PyCmaSampler`.

```
```
Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>after_trial(study, trial, state, values)</code></td>
<td>Trial post-processing. This method is called after the objective function</td>
</tr>
<tr>
<td></td>
<td>returns and right before the trials is finished and its state is stored.</td>
</tr>
<tr>
<td></td>
<td>Note: Added in v2.4.0 as an experimental feature. The interface may change</td>
</tr>
<tr>
<td></td>
<td>in newer versions without prior notice. See <a href="https://github.com/optuna/optuna/releas">https://github.com/optuna/optuna/releas</a></td>
</tr>
<tr>
<td></td>
<td>s/tag/v2.4.0.</td>
</tr>
<tr>
<td><code>infer_relative_search_space(study, trial)</code></td>
<td>Infer the search space that will be used by relative sampling in the target</td>
</tr>
<tr>
<td></td>
<td>trial.</td>
</tr>
<tr>
<td><code>reseed_rng()</code></td>
<td>Reseed sampler’s random number generator.</td>
</tr>
<tr>
<td><code>sample_independent(study, trial, param_name, ...)</code></td>
<td>Sample a parameter for a given distribution.</td>
</tr>
<tr>
<td><code>sample_relative(study, trial, search_space)</code></td>
<td>Sample parameters in a given search space.</td>
</tr>
</tbody>
</table>

**after_trial** *(study, trial, state, values)*

Trial post-processing.

This method is called after the objective function returns and right before the trials is finished and its state is stored.

**Note:** Added in v2.4.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.4.0.

**Parameters**

- **study** *(optuna.study.study.Study)* – Target study object.
- **trial** *(optuna.trial._frozen.FrozenTrial)* – Target trial object. Take a copy before modifying this object.
- **state** *(optuna.trial._state.TrialState)* – Resulting trial state.
- **values** *(Optional[Sequence[float]])* – Resulting trial values. Guaranteed to not be `None` if trial succeeded.

**Return type** `None`

**infer_relative_search_space** *(study, trial)*

Infer the search space that will be used by relative sampling in the target trial.

This method is called right before `sample_relative()` method, and the search space returned by this method is passed to it. The parameters not contained in the search space will be sampled by using `sample_independent()` method.

**Parameters**

- **study** *(optuna.study.study.Study)* – Target study object.
- **trial** *(optuna.trial._frozen.FrozenTrial)* – Target trial object. Take a copy before modifying this object.

**Returns** A dictionary containing the parameter names and parameter’s distributions.

**Return type** `Dict[str, optuna.distributions.BaseDistribution]`

**See also:**
Please refer to `intersection_search_space()` as an implementation of `infer_relative_search_space()`.

**reseed_rng()**
Reseed sampler’s random number generator.
This method is called by the `Study` instance if trials are executed in parallel with the option `n_jobs>1`. In that case, the sampler instance will be replicated including the state of the random number generator, and they may suggest the same values. To prevent this issue, this method assigns a different seed to each random number generator.

**Return type**  None

**sample_independent** *(study, trial, param_name, param_distribution)*

Sample a parameter for a given distribution.

This method is called only for the parameters not contained in the search space returned by `sample_relative()` method. This method is suitable for sampling algorithms that do not use relationship between parameters such as random sampling and TPE.

**Note:** The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

**Parameters**

- `study` *(optuna.study.study.Study)* – Target study object.
- `trial` *(optuna.trial._frozen.FrozenTrial)* – Target trial object. Take a copy before modifying this object.
- `param_name` *(str)* – Name of the sampled parameter.
- `param_distribution` *(optuna.distributions.BaseDistribution)* – Distribution object that specifies a prior and/or scale of the sampling algorithm.

**Returns**  A parameter value.

**Return type**  float

**sample_relative** *(study, trial, search_space)*

Sample parameters in a given search space.

This method is called once at the beginning of each trial, i.e., right before the evaluation of the objective function. This method is suitable for sampling algorithms that use relationship between parameters such as Gaussian Process and CMA-ES.

**Note:** The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

**Parameters**

- `study` *(optuna.study.study.Study)* – Target study object.
- `trial` *(optuna.trial._frozen.FrozenTrial)* – Target trial object. Take a copy before modifying this object.
- `search_space` *(Dict[str, optuna.distributions.BaseDistribution])* – The search space returned by `infer_relative_search_space()`.

**Returns**  A dictionary containing the parameter names and the values.

**Return type**  Dict[str, float]
**PyTorch**

<table>
<thead>
<tr>
<th>Module</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>optuna.integration.PyTorchLightningPruningCallback</code></td>
<td>PyTorch Lightning callback to prune unpromising trials.</td>
</tr>
<tr>
<td><code>optuna.integration.TorchDistributedTrial</code></td>
<td>A wrapper of <code>Trial</code> to incorporate Optuna with PyTorch distributed.</td>
</tr>
</tbody>
</table>

### optuna.integration.PyTorchIgnitePruningHandler

**class** `optuna.integration.PyTorchIgnitePruningHandler(trial, metric, trainer)`

PyTorch Ignite handler to prune unpromising trials.

See the example if you want to add a pruning handler which observes validation accuracy.

**Parameters**

- `trial` – A `Trial` corresponding to the current evaluation of the objective function.
- `metric` – A name of metric for pruning, e.g., `accuracy` and `loss`.

### optuna.integration.PyTorchLightningPruningCallback

**class** `optuna.integration.PyTorchLightningPruningCallback(trial, monitor)`

PyTorch Lightning callback to prune unpromising trials.

See the example if you want to add a pruning callback which observes accuracy.

**Parameters**

- `trial` – A `Trial` corresponding to the current evaluation of the objective function.
- `monitor` – An evaluation metric for pruning, e.g., `val_loss` or `val_acc`. The metrics are obtained from the returned dictionaries from e.g. `pytorch_lightning.LightningModule.training_step` or `pytorch_lightning.LightningModule.validation_epoch_end` and the names thus depend on how this dictionary is formatted.

**Methods**

- `on_validation_end(trainer, pl_module)`
A wrapper of Trial to incorporate Optuna with PyTorch distributed.

See also:

TorchDistributedTrial provides the same interface as Trial. Please refer to optuna.trial.Trial for further details.

See the example if you want to optimize an objective function that trains neural network written with PyTorch distributed data parallel.

Parameters

- **trial** – A Trial object or None. Please set trial object in rank-0 node and set None in the other rank node.
- **device** – A torch.device to communicate with the other nodes. Please set a CUDA device assigned to the current node if you use “nccl” as torch.distributed backend.

Note: The methods of TorchDistributedTrial are expected to be called by all workers at once. They invoke synchronous data transmission to share processing results and synchronize timing.

Note: Added in v2.6.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.6.0.

Methods

- report(value, step)
- set_system_attr(key, value)
- set_user_attr(key, value)
- should_prune()
- suggest_categorical(name, choices)
- suggest_discrete_uniform(name, low, high, q)
- suggest_float(name, low, high, *, step, log)
- suggest_int(name, low, high, *, step, log)
- suggest_loguniform(name, low, high)
- suggest_uniform(name, low, high)
### Attributes

- `datetime_start`
- `distributions`
- `number`
- `params`
- `system_attrs`
- `user_attrs`

### scikit-learn

```python
optuna.integration.OptunaSearchCV
```

Hyperparameter search with cross-validation.

### optuna.integration.OptunaSearchCV

```python
class optuna.integration.OptunaSearchCV(estimator, param_distributions, cv=5, enable_pruning=False, error_score=nan, max_iter=1000, n_jobs=1, n_trials=10, random_state=None, refit=True, return_train_score=False, scoring=None, study=None, subsample=1.0, timeout=None, verbose=0)
```

Hyperparameter search with cross-validation.

#### Parameters

- **estimator** – Object to use to fit the data. This is assumed to implement the scikit-learn estimator interface. Either this needs to provide `score`, or `scoring` must be passed.

- **param_distributions** – Dictionary where keys are parameters and values are distributions. Distributions are assumed to implement the optuna distribution interface.

- **cv** – Cross-validation strategy. Possible inputs for cv are:
  - integer to specify the number of folds in a CV splitter,
  - a CV splitter,
  - an iterable yielding (train, validation) splits as arrays of indices.

  For integer, if `estimator` is a classifier and `y` is either binary or multiclass, `sklearn.model_selection.StratifiedKFold` is used. otherwise, `sklearn.model_selection.KFold` is used.

- **enable_pruning** – If `True`, pruning is performed in the case where the underlying estimator supports `partial_fit`.

- **error_score** – Value to assign to the score if an error occurs in fitting. If ‘raise’, the error is raised. If numeric, `sklearn.exceptions.FitFailedWarning` is raised.
This does not affect the refit step, which will always raise the error.

- **max_iter** – Maximum number of epochs. This is only used if the underlying estimator supports `partial_fit`.

- **n_jobs** – Number of `threading` based parallel jobs. `-1` means using the number is set to CPU count.

  **Note:** `n_jobs` allows parallelization using `threading` and may suffer from Python’s GIL. It is recommended to use `process-based parallelization` if `func` is CPU bound.

**Warning:** Deprecated in v2.7.0. This feature will be removed in the future. It is recommended to use `process-based parallelization`. The removal of this feature is currently scheduled for v4.0.0, but this schedule is subject to change. See https://github.com/optuna/optuna/releases/tag/v2.7.0.

- **n_trials** – Number of trials. If `None`, there is no limitation on the number of trials. If `timeout` is also set to `None`, the study continues to create trials until it receives a termination signal such as Ctrl+C or SIGTERM. This trades off runtime vs quality of the solution.

- **random_state** – Seed of the pseudo random number generator. If `int`, this is the seed used by the random number generator. If `numpy.random.RandomState` object, this is the random number generator. If `None`, the global random state from `numpy.random` is used.

- **refit** – If `True`, refit the estimator with the best found hyperparameters. The refitted estimator is made available at the `best_estimator_` attribute and permits using `predict` directly.

- **return_train_score** – If `True`, training scores will be included. Computing training scores is used to get insights on how different hyperparameter settings impact the overfitting/underfitting trade-off. However computing training scores can be computationally expensive and is not strictly required to select the hyperparameters that yield the best generalization performance.

- **scoring** – String or callable to evaluate the predictions on the validation data. If `None`, `score` on the estimator is used.

- **study** – Study corresponds to the optimization task. If `None`, a new study is created.

- **subsample** – Proportion of samples that are used during hyperparameter search.
  - If `int`, then draw `subsample` samples.
  - If `float`, then draw `subsample * X.shape[0]` samples.

- **timeout** – Time limit in seconds for the search of appropriate models. If `None`, the study is executed without time limitation. If `n_trials` is also set to `None`, the study continues to create trials until it receives a termination signal such as Ctrl+C or SIGTERM. This trades off runtime vs quality of the solution.

- **verbose** – Verbosity level. The higher, the more messages.

**best_estimator_**

Estimator that was chosen by the search. This is present only if `refit` is set to `True`. 
n_splits_
Number of cross-validation splits.

refit_time_
Time for refitting the best estimator. This is present only if refit is set to True.

sample_indices_
Indices of samples that are used during hyperparameter search.

scorer_
Scorer function.

study_
Actual study.

Examples

```python
import optuna
from sklearn.datasets import load_iris
from sklearn.svm import SVC
clf = SVC(gamma="auto")
param_distributions = {"C": optuna.distributions.LogUniformDistribution(1e-10, 1e10)}
optuna_search = optuna.integration.OptunaSearchCV(clf, param_distributions)
X, y = load_iris(return_X_y=True)
optuna_search.fit(X, y)
y_pred = optuna_search.predict(X)
```

Note: Added in v0.17.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v0.17.0.

Methods

- **fit**(X, y, groups) Run fit with all sets of parameters.
- **get_params**(deep) Get parameters for this estimator.
- **score**(X, y) Return the score on the given data.
- **set_params**(**params) Set the parameters of this estimator.

Attributes

- **best_index_** Index which corresponds to the best candidate parameter setting.
- **best_params_** Parameters of the best trial in the Study.
- **best_score_** Mean cross-validated score of the best estimator.
- **best_trial_** Best trial in the Study.
- **classes_** Class labels.
- **decision_function** Call decision_function on the best estimator.
- **inverse_transform** Call inverse_transform on the best estimator.

continues on next page
Table 45 – continued from previous page

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>n_trials_</td>
<td>Actual number of trials.</td>
</tr>
<tr>
<td>predict</td>
<td>Call <code>predict</code> on the best estimator.</td>
</tr>
<tr>
<td>predict_log_proba</td>
<td>Call <code>predict_log_proba</code> on the best estimator.</td>
</tr>
<tr>
<td>predict_proba</td>
<td>Call <code>predict_proba</code> on the best estimator.</td>
</tr>
<tr>
<td>score_samples</td>
<td>Call <code>score_samples</code> on the best estimator.</td>
</tr>
<tr>
<td>set_user_attr</td>
<td>Call <code>set_user_attr</code> on the <code>Study</code>.</td>
</tr>
<tr>
<td>transform</td>
<td>Call <code>transform</code> on the best estimator.</td>
</tr>
<tr>
<td>trials_</td>
<td>All trials in the <code>Study</code>.</td>
</tr>
<tr>
<td>trials_dataframe</td>
<td>Call <code>trials_dataframe</code> on the <code>Study</code>.</td>
</tr>
<tr>
<td>user_attrs_</td>
<td>User attributes in the <code>Study</code>.</td>
</tr>
</tbody>
</table>

**property best_index_**

- Index which corresponds to the best candidate parameter setting.

**property best_params_**

- Parameters of the best trial in the `Study`.

**property best_score_**

- Mean cross-validated score of the best estimator.

**property best_trial_**

- Best trial in the `Study`.

**property classes_**

- Class labels.

**property decision_function**

- Call `decision_function` on the best estimator.

  This is available only if the underlying estimator supports `decision_function` and `refit` is set to `True`.

**fit**(X, y=None, groups=None, **fit_params)**

- Run fit with all sets of parameters.

  **Parameters**


  - groups (Optional[Union[List[float], numpy.ndarray, pandas.core.series.Series]]) – Group labels for the samples used while splitting the dataset into train/validation set.

  - **fit_params** – Parameters passed to `fit` on the estimator.

  - fit_params (Any) –

**Returns** Return self.

**Return type** self

**get_params**(deep=True)

- Get parameters for this estimator.

  **Parameters**

  - deep (bool, default=True) – If True, will return the parameters for this estimator and contained subobjects that are estimators.
Returns `params` – Parameter names mapped to their values.

Return type `dict`

**property inverse_transform**

Call `inverse_transform` on the best estimator.

This is available only if the underlying estimator supports `inverse_transform` and `refit` is set to `True`.

**property n_trials_**

Actual number of trials.

**property predict**

Call `predict` on the best estimator.

This is available only if the underlying estimator supports `predict` and `refit` is set to `True`.

**property predict_log_proba**

Call `predict_log_proba` on the best estimator.

This is available only if the underlying estimator supports `predict_log_proba` and `refit` is set to `True`.

**property predict_proba**

Call `predict_proba` on the best estimator.

This is available only if the underlying estimator supports `predict_proba` and `refit` is set to `True`.

**score** *(X, y=None)*

Return the score on the given data.

Parameters


Returns Scaler score.

Return type score

**property score_samples**

Call `score_samples` on the best estimator.

This is available only if the underlying estimator supports `score_samples` and `refit` is set to `True`.

**set_params** (**params**)

Set the parameters of this estimator.

The method works on simple estimators as well as on nested objects (such as `Pipeline`). The latter have parameters of the form `<component>__<parameter>` so that it’s possible to update each component of a nested object.

Parameters **params** *(dict)* – Estimator parameters.

Returns self – Estimator instance.

Return type estimator instance

**property set_user_attr**

Call `set_user_attr` on the `Study`.
property `transform`
Call `transform` on the best estimator.
This is available only if the underlying estimator supports `transform` and `refit` is set to `True`.

property `trials_`
All trials in the `Study`.

property `trials_dataframe`
Call `trials_dataframe` on the `Study`.

property `user_attrs_`
User attributes in the `Study`.

scikit-optimize

```python
optuna.integration.SkoptSampler
Sampler using Scikit-Optimize as the backend.

class optuna.integration.SkoptSampler
Sampler using Scikit-Optimize as the backend.

Example
```
Optimize a simple quadratic function by using `SkoptSampler`.
```
```python
import optuna
def objective(trial):
x = trial.suggest_float("x", -10, 10)
y = trial.suggest_int("y", 0, 10)
return x ** 2 + y

sampler = optuna.integration.SkoptSampler()
study = optuna.create_study(sampler=sampler)
study.optimize(objective, n_trials=10)
```

Parameters

- **independent_sampler** – A `BaseSampler` instance that is used for independent sampling. The parameters not contained in the relative search space are sampled by this sampler. The search space for `SkoptSampler` is determined by `intersection_search_space()`.

If `None` is specified, `RandomSampler` is used as the default.

See also:
```
`optuna.samplers` module provides built-in independent samplers such as
```
Optuna Documentation, Release 2.10.0

RandomSampler and TPESampler.

• **warn_independent_sampling** – If this is `True`, a warning message is emitted when the value of a parameter is sampled by using an independent sampler.

  Note that the parameters of the first trial in a study are always sampled via an independent sampler, so no warning messages are emitted in this case.

• **skopt_kwargs** – Keyword arguments passed to the constructor of skopt.Optimizer class.

  Note that dimensions argument in skopt_kwargs will be ignored because it is added by SkoptSampler automatically.

• **n_startup_trials** – The independent sampling is used until the given number of trials finish in the same study.

• **consider_pruned_trials** – If this is `True`, the PRUNED trials are considered for sampling.

  Note: Added in v2.0.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.0.0.

  Note: As the number of trials \( n \) increases, each sampling takes longer and longer on a scale of \( O(n^3) \). And, if this is `True`, the number of trials will increase. So, it is suggested to set this flag `False` when each evaluation of the objective function is relatively faster than each sampling. On the other hand, it is suggested to set this flag `True` when each evaluation of the objective function is relatively slower than each sampling.

**Methods**

<table>
<thead>
<tr>
<th>Method Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>after_trial(study, trial, state, values)</code></td>
<td>Trial post-processing.</td>
</tr>
<tr>
<td><code>infer_relative_search_space(study, trial)</code></td>
<td>Infer the search space that will be used by relative sampling in the target trial.</td>
</tr>
<tr>
<td><code>reseed_rng()</code></td>
<td>Reseed sampler’s random number generator.</td>
</tr>
<tr>
<td><code>sample_independent(study, param_name, ...)</code></td>
<td>Sample a parameter for a given distribution.</td>
</tr>
<tr>
<td><code>sample_relative(study, trial, search_space)</code></td>
<td>Sample parameters in a given search space.</td>
</tr>
</tbody>
</table>

**after_trial**

Trial post-processing.

This method is called after the objective function returns and right before the trials is finished and its state is stored.

Note: Added in v2.4.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.4.0.

**Parameters**

- **study** *(optuna.study.Study)* – Target study object.
- **trial** *(optuna.trial.FrozenTrial)* – Target trial object. Take a
**copy before modifying this object.**

- **state (optuna.trial._state.TrialState)** – Resulting trial state.
- **values (Optional[Sequence[float]])** – Resulting trial values. Guaranteed to not be None if trial succeeded.

**Return type** None

---

**infer_relative_search_space (study, trial)**

Infer the search space that will be used by relative sampling in the target trial.

This method is called right before sample_relative() method, and the search space returned by this method is passed to it. The parameters not contained in the search space will be sampled by using sample_independent() method.

**Parameters**

- **study (optuna.study.study.Study)** – Target study object.
- **trial (optuna.trial._frozen.FrozenTrial)** – Target trial object. Take a copy before modifying this object.

**Returns** A dictionary containing the parameter names and parameter’s distributions.

**Return type** Dict[str, optuna.distributions.BaseDistribution]

---

**See also:**

Please refer to intersection_search_space() as an implementation of infer_relative_search_space().

---

**reseed_rng ()**

Reseed sampler’s random number generator.

This method is called by the Study instance if trials are executed in parallel with the option n_jobs>1. In that case, the sampler instance will be replicated including the state of the random number generator, and they may suggest the same values. To prevent this issue, this method assigns a different seed to each random number generator.

**Return type** None

---

**sample_independent (study, trial, param_name, param_distribution)**

Sample a parameter for a given distribution.

This method is called only for the parameters not contained in the search space returned by sample_relative() method. This method is suitable for sampling algorithms that do not use relationship between parameters such as random sampling and TPE.

---

**Note:** The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

---

**Parameters**

- **study (optuna.study.study.Study)** – Target study object.
- **trial (optuna.trial._frozen.FrozenTrial)** – Target trial object. Take a copy before modifying this object.
- **param_name (str)** – Name of the sampled parameter.
• **param_distribution** *(optuna.distributions.BaseDistribution)* – Distribution object that specifies a prior and/or scale of the sampling algorithm.

**Returns** A parameter value.

**Return type** Any

---

**sample_relative** *(study, trial, search_space)*

Sample parameters in a given search space.

This method is called once at the beginning of each trial, i.e., right before the evaluation of the objective function. This method is suitable for sampling algorithms that use relationship between parameters such as Gaussian Process and CMA-ES.

**Note:** The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

---

**Parameters**

- **study** *(optuna.study.study.Study)* – Target study object.
- **trial** *(optuna.trial._frozen.FrozenTrial)* – Target trial object. Take a copy before modifying this object.
- **search_space** *(Dict[str, optuna.distributions.BaseDistribution])* – The search space returned by *infer_relative_search_space()*.

**Returns** A dictionary containing the parameter names and the values.

**Return type** Dict[str, Any]

---

**skorch**

<table>
<thead>
<tr>
<th>optuna.integration. SkorchPruningCallback</th>
<th>Skorch callback to prune unpromising trials.</th>
</tr>
</thead>
</table>

**class** optuna.integration.SkorchPruningCallback *(trial, monitor)*

Skorch callback to prune unpromising trials.

New in version 2.1.0.

**Parameters**

- **trial** – A *Trial* corresponding to the current evaluation of the objective function.
- **monitor** – An evaluation metric for pruning, e.g. *val_loss* or *val_acc*. The metrics are obtained from the returned dictionaries, i.e., *net.histroy*. The names thus depend on how this dictionary is formatted.
Methods

```python
.on_epoch_end(net, **kwargs)
```

### TensorFlow

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>optuna.integration.TensorBoardCallback</code></td>
<td>Callback to track Optuna trials with TensorBoard.</td>
</tr>
<tr>
<td><code>optuna.integration.TFKerasPruningCallback</code></td>
<td>tf.keras callback to prune unpromising trials.</td>
</tr>
</tbody>
</table>

#### optuna.integration.TensorBoardCallback

```python
class optuna.integration.TensorBoardCallback (dirname, metric_name)
```

Callback to track Optuna trials with TensorBoard.

This callback adds relevant information that is tracked by Optuna to TensorBoard.

See the example.

**Parameters**

- **dirname** – Directory to store TensorBoard logs.
- **metric_name** – Name of the metric. Since the metric itself is just a number, `metric_name` can be used to give it a name. So you know later if it was roc-auc or accuracy.

**Note:** Added in v2.0.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.0.0.

#### optuna.integration.TensorFlowPruningHook

```python
class optuna.integration.TensorFlowPruningHook (trial, estimator, metric, run_every_steps)
```

TensorFlow SessionRunHook to prune unpromising trials.

See the example if you want to add a pruning hook to TensorFlow’s estimator.

**Parameters**

- **trial** – A `Trial` corresponding to the current evaluation of the objective function.
- **estimator** – An estimator which you will use.
- **metric** – An evaluation metric for pruning, e.g., `accuracy` and `loss`.
- **run_every_steps** – An interval to watch the summary file.
Methods

after_run(run_context, run_values)

before_run(run_context)

begin()

optuna.integration.TFKerasPruningCallback
class optuna.integration.TFKerasPruningCallback(trial, monitor)
tf.keras callback to prune unpromising trials.
This callback is intend to be compatible for Tensorflow v1 and v2, but only tested with TensorFlow v2.
See the example if you want to add a pruning callback which observes the validation accuracy.

Parameters

• trial – A Trial corresponding to the current evaluation of the objective function.
• monitor – An evaluation metric for pruning, e.g., val_loss or val_acc.

Methods

on_epoch_end(epoch[, logs])

XGBoost
class optuna.integration.XGBoostPruningCallback(trial, observation_key)
Callback for XGBoost to prune unpromising trials.

See the example if you want to add a pruning callback which observes validation AUC of a XGBoost model.

Parameters

• trial – A Trial corresponding to the current evaluation of the objective function.
• observation_key – An evaluation metric for pruning, e.g., validation-error and validation-merror. When using the Scikit-Learn API, the index number of eval_set must be included in the observation_key, e.g., validation_0-error and validation_0-merror. Please refer to eval_metric in XGBoost reference for further details.
6.3.7 optuna.logging

The logging module implements logging using the Python logging package. Library users may be especially interested in setting verbosity levels using set_verbosity() to one of optuna.logging.CRITICAL (aka optuna.logging.FATAL), optuna.logging.ERROR, optuna.logging.WARNING (aka optuna.logging.WARN), optuna.logging.INFO, or optuna.logging.DEBUG.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>optuna.logging.get_verbosity</td>
<td>Return the current level for the Optuna's root logger.</td>
</tr>
<tr>
<td>optuna.logging.set_verbosity</td>
<td>Set the level for the Optuna's root logger.</td>
</tr>
<tr>
<td>optuna.logging.disable_default_handler</td>
<td>Disable the default handler of the Optuna's root logger.</td>
</tr>
<tr>
<td>optuna.logging.enable_default_handler</td>
<td>Enable the default handler of the Optuna's root logger.</td>
</tr>
<tr>
<td>optuna.logging.disable_propagation</td>
<td>Disable propagation of the library log outputs.</td>
</tr>
<tr>
<td>optuna.logging.enable_propagation</td>
<td>Enable propagation of the library log outputs.</td>
</tr>
</tbody>
</table>

**optuna.logging.get_verbosity**

**optuna.logging.get_verbosity()**

Return the current level for the Optuna’s root logger.

**Returns** Logging level, e.g., optuna.logging.DEBUG and optuna.logging.INFO.

**Return type** int

**Note:** Optuna has following logging levels:

- optuna.logging.CRITICAL, optuna.logging.FATAL
- optuna.logging.ERROR
- optuna.logging.WARNING, optuna.logging.WARN
- optuna.logging.INFO
- optuna.logging.DEBUG

**optuna.logging.set_verbosity**

**optuna.logging.set_verbosity(verbosity)**

Set the level for the Optuna's root logger.

**Parameters** verbosity (int) – Logging level, e.g., optuna.logging.DEBUG and optuna.logging.INFO.

**Return type** None

**Note:** Optuna has following logging levels:

- optuna.logging.CRITICAL, optuna.logging.FATAL
- optuna.logging.ERROR
- optuna.logging.WARNING, optuna.logging.WARN
- optuna.logging.INFO
- optuna.logging.DEBUG
**optuna.logging.disable_default_handler**

`optuna.logging.disable_default_handler()`

Disable the default handler of the Optuna's root logger.

**Example**

Stop and then resume logging to `sys.stderr`.

```python
import optuna

study = optuna.create_study()

# There are no logs in sys.stderr.
optuna.logging.disable_default_handler()
study.optimize(objective, n_trials=10)

# There are logs in sys.stderr.
optuna.logging.enable_default_handler()
study.optimize(objective, n_trials=10)
```

**Return type**  None

**optuna.logging.enable_default_handler**

`optuna.logging.enable_default_handler()`

Enable the default handler of the Optuna's root logger.

Please refer to the example shown in `disable_default_handler()`.

**Return type**  None

**optuna.logging.disablePropagation**

`optuna.logging.disablePropagation()`

Disable propagation of the library log outputs.

Note that log propagation is disabled by default. You only need to use this function to stop log propagation when you use `enable_propogation()`.

**Example**

Stop propagating logs to the root logger on the second optimize call.

```python
import optuna
import logging

optuna.logging.disable_default_handler()  # Disable the default handler.
logger = logging.getLogger()
```
logger.setLevel(logging.INFO)  # Setup the root logger.
logger.addHandler(logging.FileHandler("foo.log", mode="w"))

optuna.logging.enable_propagation()  # Propagate logs to the root logger.

study = optuna.create_study()  # Setup the root logger.
study.optimize(objective, n_trials=10)  # Propagate logs to the root logger.

optuna.logging.disable_propagation()  # Stop propagating logs to the root logger.

logger.info("Logs from first optimize call")  # The logs are saved in the logs file.

logger.info("Logs from second optimize call")  # The new logs for second optimize call are not saved.

with open("foo.log") as f:
    assert f.readline().startswith("A new study created")
    assert f.readline() == "Logs from first optimize call\n"  # Check for logs after second optimize call.
    assert f.read().split("Logs from second optimize call\n")[-1] == ""

Return type None

optuna.logging.enable_propagation

**Example**

Propagate all log output to the root logger in order to save them to the file.

```python
import optuna
import logging

logger = logging.getLogger()

logger.setLevel(logging.INFO)  # Setup the root logger.
logger.addHandler(logging.FileHandler("foo.log", mode="w"))

optuna.logging.enable_propagation()  # Propagate logs to the root logger.
optuna.logging.disable_default_handler()  # Stop showing logs in sys.stderr.

study = optuna.create_study()

logger.info("Start optimization.")
study.optimize(objective, n_trials=10)

with open("foo.log") as f:
```

(continues on next page)
<table>
<thead>
<tr>
<th>Function/Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>assert f.readline().startswith(&quot;A new study created&quot;)</code></td>
<td>Checks if the first line of the file starts with a specific string.</td>
</tr>
<tr>
<td><code>assert f.readline() == &quot;Start optimization.\n&quot;</code></td>
<td>Checks if the first line of the file is equal to a specific string.</td>
</tr>
</tbody>
</table>

**Return type**: None

### 6.3.8 optuna.multi_objective

This module is deprecated, with former functionality moved to `optuna.samplers`, `optuna.study`, `optuna.trial` and `optuna.visualization`.

**optuna.multi_objective.samplers**

<table>
<thead>
<tr>
<th>Class/Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>BaseMultiObjectiveSampler</code></td>
<td>Base class for multi-objective samplers.</td>
</tr>
<tr>
<td><code>NSGAIIMultiObjectiveSampler</code></td>
<td>Multi-objective sampler using the NSGA-II algorithm.</td>
</tr>
<tr>
<td><code>RandomMultiObjectiveSampler</code></td>
<td>Multi-objective sampler using random sampling.</td>
</tr>
<tr>
<td><code>MOTPEMultiObjectiveSampler</code></td>
<td>Multi-objective sampler using the MOTPE algorithm.</td>
</tr>
</tbody>
</table>

**optuna.multi_objective.samplers.BaseMultiObjectiveSampler**

**class** `optuna.multi_objective.samplers.BaseMultiObjectiveSampler(*args, **kwargs)`

Base class for multi-objective samplers.

The abstract methods of this class are the same as ones defined by `BaseSampler` except for taking multi-objective versions of study and trial instances as the arguments.

**Warning**: Deprecated in v2.4.0. This feature will be removed in the future. The removal of this feature is currently scheduled for v4.0.0, but this schedule is subject to change. See [https://github.com/optuna/optuna/releases/tag/v2.4.0](https://github.com/optuna/optuna/releases/tag/v2.4.0).

#### Methods

- **`infer_relative_search_space(study, trial)`**
  - Infer the search space that will be used by relative sampling in the target trial.

- **`reseed_rng()`**
  - Reseed sampler’s random number generator.

- **`sample_independent(study, trial, param_name, ...)`**
  - Sample a parameter for a given distribution.

- **`sample_relative(study, trial, search_space)`**
  - Sample parameters in a given search space.

- **`abstract infer_relative_search_space(study, trial)`**
  - Infer the search space that will be used by relative sampling in the target trial.
This method is called right before `sample_relative()` method, and the search space returned by this method is passed to it. The parameters not contained in the search space will be sampled by using `sample_independent()` method.

**Parameters**
- **study** (optuna.multi_objective.study.MultiObjectiveStudy) – Target study object.
- **trial** (optuna.multi_objective.trial.FrozenMultiObjectiveTrial) – Target trial object.

**Returns** A dictionary containing the parameter names and parameter’s distributions.

**Return type** Dict[str, optuna.distributions.BaseDistribution]

See also:
Please refer to `intersection_search_space()` as an implementation of `infer_relative_search_space()`.

**reseed_rng()**
Reseed sampler’s random number generator.

This method is called by the `MultiObjectiveStudy` instance if trials are executed in parallel with the option `n_jobs>1`. In that case, the sampler instance will be replicated including the state of the random number generator, and they may suggest the same values. To prevent this issue, this method assigns a different seed to each random number generator.

**Return type** None

**abstract sample_independent** (study, trial, param_name, param_distribution)
Sample a parameter for a given distribution.

This method is called only for the parameters not contained in the search space returned by `sample_relative()` method. This method is suitable for sampling algorithms that do not use the relationship between parameters such as random sampling.

**Parameters**
- **study** (optuna.multi_objective.study.MultiObjectiveStudy) – Target study object.
- **trial** (optuna.multi_objective.trial.FrozenMultiObjectiveTrial) – Target trial object.
- **param_name** (str) – Name of the sampled parameter.
- **param_distribution** (optuna.distributions.BaseDistribution) – Distribution object that specifies a prior and/or scale of the sampling algorithm.

**Returns** A parameter value.

**Return type** Any

**abstract sample_relative** (study, trial, search_space)
Sample parameters in a given search space.

This method is called once at the beginning of each trial, i.e., right before the evaluation of the objective function. This method is suitable for sampling algorithms that use the relationship between parameters.

**Parameters**
- **study** (optuna.multi_objective.study.MultiObjectiveStudy) – Target study object.
• **trial** (optuna.multi_objective.trial.FrozenMultiObjectiveTrial) – Target trial object.

• **search_space** (Dict[str, optuna.distributions.BaseDistribution]) – The search space returned by `infer_relative_search_space()`.

**Returns** A dictionary containing the parameter names and the values.

**Return type** Dict[str, Any]

---

**optuna.multi_objective.samplers.NSGAIIMultiObjectiveSampler**

class optuna.multi_objective.samplers.NSGAIIMultiObjectiveSampler (population_size=50, mutation_prob=None, crossover_prob=0.9, swapping_prob=0.5, seed=None)

Multi-objective sampler using the NSGA-II algorithm.

NSGA-II stands for “Nondominated Sorting Genetic Algorithm II”, which is a well known, fast and elitist multi-objective genetic algorithm.

For further information about NSGA-II, please refer to the following paper:

- A fast and elitist multiobjective genetic algorithm: NSGA-II

**Parameters**

- **population_size** – Number of individuals (trials) in a generation.

- **mutation_prob** – Probability of mutating each parameter when creating a new individual. If `None` is specified, the value `1.0 / len(parent_trial.params)` is used where `parent_trial` is the parent trial of the target individual.

- **crossover_prob** – Probability that a crossover (parameters swapping between parents) will occur when creating a new individual.

- **swapping_prob** – Probability of swapping each parameter of the parents during crossover.

- **seed** – Seed for random number generator.

**Warning:** Deprecated in v2.4.0. This feature will be removed in the future. The removal of this feature is currently scheduled for v4.0.0, but this schedule is subject to change. See https://github.com/optuna/optuna/releases/tag/v2.4.0.
Methods

```python
infer_relative_search_space(study, trial)
Infer the search space that will be used by relative sampling in the target trial.
```

```python
reseed_rng()
Reseed sampler's random number generator.
```

```python
sample_independent(study, trial, param_name, ...)
Sample a parameter for a given distribution.
```

```python
sample_relative(study, trial, search_space)
Sample parameters in a given search space.
```

**infer_relative_search_space(study, trial)**
Infer the search space that will be used by relative sampling in the target trial.

This method is called right before `sample_relative()` method, and the search space returned by this method is passed to it. The parameters not contained in the search space will be sampled by using `sample_independent()` method.

**Parameters**

- **study** (`optuna.multi_objective.study.MultiObjectiveStudy`) – Target study object.
- **trial** (`optuna.multi_objective.trial.FrozenMultiObjectiveTrial`) – Target trial object.

**Returns** A dictionary containing the parameter names and parameter’s distributions.

**Return type** `Dict[str, optuna.distributions.BaseDistribution]`

See also:

Please refer to `intersection_search_space()` as an implementation of `infer_relative_search_space()`.

**reseed_rng()**
Reseed sampler’s random number generator.

This method is called by the `MultiObjectiveStudy` instance if trials are executed in parallel with the option `n_jobs>1`. In that case, the sampler instance will be replicated including the state of the random number generator, and they may suggest the same values. To prevent this issue, this method assigns a different seed to each random number generator.

**Return type** `None`

**sample_independent(study, trial, param_name, param_distribution)**
Sample a parameter for a given distribution.

This method is called only for the parameters not contained in the search space returned by `sample_relative()` method. This method is suitable for sampling algorithms that do not use the relationship between parameters such as random sampling.

**Parameters**

- **study** (`optuna.multi_objective.study.MultiObjectiveStudy`) – Target study object.
- **trial** (`optuna.multi_objective.trial.FrozenMultiObjectiveTrial`) – Target trial object.
- **param_name** (`str`) – Name of the sampled parameter.
- **param_distribution** (`optuna.distributions.BaseDistribution`) – Distribution object that specifies a prior and/or scale of the sampling algorithm.
Returns A parameter value.

Return type Any

`sample_relative(study, trial, search_space)`

Sample parameters in a given search space.

This method is called once at the beginning of each trial, i.e., right before the evaluation of the objective function. This method is suitable for sampling algorithms that use the relationship between parameters.

Parameters

- **study** (`optuna.multi_objective.study.MultiObjectiveStudy`) – Target study object.
- **trial** (`optuna.multi_objective.trial.FrozenMultiObjectiveTrial`) – Target trial object.
- **search_space** (`Dict[str, optuna.distributions.BaseDistribution]`) – The search space returned by `infer_relative_search_space()`.

Returns A dictionary containing the parameter names and the values.

Return type Dict[str, Any]

`optuna.multi_objective.samplers.RandomMultiObjectiveSampler`

class `optuna.multi_objective.samplers.RandomMultiObjectiveSampler`(seed=None)

Multi-objective sampler using random sampling.

This sampler is based on independent sampling. See also `BaseMultiObjectiveSampler` for more details of ‘independent sampling’.

Example

```python
import optuna
from optuna.multi_objective.samplers import RandomMultiObjectiveSampler

def objective(trial):
    x = trial.suggest_float("x", -5, 5)
    y = trial.suggest_float("y", -5, 5)
    return x ** 2, y + 10

study = optuna.multi_objective.create_study(
    ["minimize", "minimize"], sampler=RandomMultiObjectiveSampler()
)
study.optimize(objective, n_trials=10)
```

Args: seed: Seed for random number generator.

Warning: Deprecated in v2.4.0. This feature will be removed in the future. The removal of this feature is currently scheduled for v4.0.0, but this schedule is subject to change. See https://github.com/optuna/optuna/releases/tag/v2.4.0.
Methods

<table>
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<td>Infer the search space that will be used by relative sampling in the target trial.</td>
</tr>
<tr>
<td><code>reseed_rng()</code></td>
<td>Reseed sampler’s random number generator.</td>
</tr>
<tr>
<td><code>sample_independent(study, trial, param_name, ...)</code></td>
<td>Sample a parameter for a given distribution.</td>
</tr>
<tr>
<td><code>sample_relative(study, trial, search_space)</code></td>
<td>Sample parameters in a given search space.</td>
</tr>
</tbody>
</table>

`infer_relative_search_space(study, trial)`

Infer the search space that will be used by relative sampling in the target trial.

This method is called right before `sample_relative()` method, and the search space returned by this method is passed to it. The parameters not contained in the search space will be sampled by using `sample_independent()` method.

**Parameters**
- `study` (optuna.multi_objective.study.MultiObjectiveStudy) – Target study object.
- `trial` (optuna.multi_objective.trial.FrozenMultiObjectiveTrial) – Target trial object.

**Returns** A dictionary containing the parameter names and parameter’s distributions.

**Return type** Dict[str, optuna.distributions.BaseDistribution]

See also:
Please refer to `intersection_search_space()` as an implementation of `infer_relative_search_space()`.

`reseed_rng()`

Reseed sampler’s random number generator.

This method is called by the MultiObjectiveStudy instance if trials are executed in parallel with the option `n_jobs>1`. In that case, the sampler instance will be replicated including the state of the random number generator, and they may suggest the same values. To prevent this issue, this method assigns a different seed to each random number generator.

**Return type** None

`sample_independent(study, trial, param_name, param_distribution)`

Sample a parameter for a given distribution.

This method is called only for the parameters not contained in the search space returned by `sample_relative()` method. This method is suitable for sampling algorithms that do not use the relationship between parameters such as random sampling.

**Parameters**
- `study` (optuna.multi_objective.study.MultiObjectiveStudy) – Target study object.
- `trial` (optuna.multi_objective.trial.FrozenMultiObjectiveTrial) – Target trial object.
- `param_name` (str) – Name of the sampled parameter.
- `param_distribution` (optuna.distributions.BaseDistribution) – Distribution object that specifies a prior and/or scale of the sampling algorithm.
Returns A parameter value.

Return type Any

sample_relative (study, trial, search_space)
Sample parameters in a given search space.

This method is called once at the beginning of each trial, i.e., right before the evaluation of the objective function. This method is suitable for sampling algorithms that use the relationship between parameters.

Parameters

- study (optuna.multi_objective.study.MultiObjectiveStudy) – Target study object.
- trial (optuna.multi_objective.trial.FrozenMultiObjectiveTrial) – Target trial object.
- search_space (Dict[str, optuna.distributions.BaseDistribution]) – The search space returned by infer_relative_search_space().

Returns A dictionary containing the parameter names and the values.

Return type Dict[str, Any]

optuna.multi_objective.samplers.MOTPEMultiObjectiveSampler

class optuna.multi_objective.samplers.MOTPEMultiObjectiveSampler (consider_prior=True, prior_weight=1.0, consider_magic_clip=True, consider_endpoints=True, n_startup_trials=10, n_ehvi_candidates=24, gamma=<function default_gamma>, weights_above=<function default_weights_above>, seed=None)

Multi-objective sampler using the MOTPE algorithm.

This sampler is a multiobjective version of TPESampler.

For further information about MOTPE algorithm, please refer to the following paper:

- Multiobjective tree-structured parzen estimator for computationally expensive optimization problems

Parameters

- consider_prior – Enhance the stability of Parzen estimator by imposing a Gaussian prior when True. The prior is only effective if the sampling distribution is either UniformDistribution, DiscreteUniformDistribution, LogUniformDistribution, IntUniformDistribution, or IntLogUniformDistribution.
• **prior_weight** – The weight of the prior. This argument is used in *UniformDistribution*, *DiscreteUniformDistribution*, *LogUniformDistribution*, *IntUniformDistribution*, *IntLogUniformDistribution*, and *CategoricalDistribution*.

• **consider_magic_clip** – Enable a heuristic to limit the smallest variances of Gaussians used in the Parzen estimator.

• **consider_endpoints** – Take endpoints of domains into account when calculating variances of Gaussians in Parzen estimator. See the original paper for details on the heuristics to calculate the variances.

• **n_startup_trials** – The random sampling is used instead of the MOTPE algorithm until the given number of trials finish in the same study. \(11 \times \text{number of variables} - 1\) is recommended in the original paper.

• **n_ehvi_candidates** – Number of candidate samples used to calculate the expected hypervolume improvement.

• **gamma** – A function that takes the number of finished trials and returns the number of trials to form a density function for samples with low grains. See the original paper for more details.

• **weights_above** – A function that takes the number of finished trials and returns a weight for them. As default, weights are automatically calculated by the MOTPE’s default strategy.

• **seed** – Seed for random number generator.

**Note:** Initialization with Latin hypercube sampling may improve optimization performance. However, the current implementation only supports initialization with random sampling.

### Example

```python
import optuna

seed = 128
num_variables = 9
n_startup_trials = 11 * num_variables - 1

def objective(trial):
    x = []
    for i in range(1, num_variables + 1):
        x.append(trial.suggest_float(f"x{i}", 0.0, 2.0 * i))
    return x

sampler = optuna.multi_objective.samplers.MOTPEMultiObjectiveSampler(
    n_startup_trials=n_startup_trials, n_ehvi_candidates=24, seed=seed
)
study = optuna.multi_objective.create_study(
    "minimize" = num_variables, sampler=sampler
)
study.optimize(objective, n_trials=250)
```
Warning: Deprecated in v2.4.0. This feature will be removed in the future. The removal of this feature is currently scheduled for v4.0.0, but this schedule is subject to change. See https://github.com/optuna/optuna/releases/tag/v2.4.0.

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<td>Infer the search space that will be used by relative sampling in the target trial.</td>
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<td><code>reseed_rng()</code></td>
<td>Reseed sampler’s random number generator.</td>
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<tr>
<td><code>sample_independent(study, trial, param_name, ...)</code></td>
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<td>Sample parameters in a given search space.</td>
</tr>
</tbody>
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**infer_relative_search_space (study, trial)**

Infer the search space that will be used by relative sampling in the target trial.

This method is called right before `sample_relative()` method, and the search space returned by this method is passed to it. The parameters not contained in the search space will be sampled by using `sample_independent()` method.

**Parameters**

- `study` (optuna.multi_objective.study.MultiObjectiveStudy) – Target study object.
- `trial` (optuna.multi_objective.trial.FrozenMultiObjectiveTrial) – Target trial object.

**Returns** A dictionary containing the parameter names and parameter’s distributions.

**Return type** Dict[str, optuna.distributions.BaseDistribution]

See also: Please refer to `intersection_search_space()` as an implementation of `infer_relative_search_space()`.

**reseed_rng ()**

Reseed sampler’s random number generator.

This method is called by the MultiObjectiveStudy instance if trials are executed in parallel with the option n_jobs>1. In that case, the sampler instance will be replicated including the state of the random number generator, and they may suggest the same values. To prevent this issue, this method assigns a different seed to each random number generator.

**Return type** None

**sample_independent (study, trial, param_name, param_distribution)**

Sample a parameter for a given distribution.

This method is called only for the parameters not contained in the search space returned by `sample_relative()` method. This method is suitable for sampling algorithms that do not use the relationship between parameters such as random sampling.

**Parameters**

- `study` (optuna.multi_objective.study.MultiObjectiveStudy) – Target study object.
• **trial** ([`optuna.multi_objective.trial.FrozenMultiObjectiveTrial`]) – Target trial object.
• **param_name** (str) – Name of the sampled parameter.
• **param_distribution** ([`optuna.distributions.BaseDistribution`]) – Distribution object that specifies a prior and/or scale of the sampling algorithm.

**Returns** A parameter value.

**Return type** Any

`sample_relative(study, trial, search_space)`
Sample parameters in a given search space.

This method is called once at the beginning of each trial, i.e., right before the evaluation of the objective function. This method is suitable for sampling algorithms that use the relationship between parameters.

**Parameters**
• **study** ([`optuna.multi_objective.study.MultiObjectiveStudy`]) – Target study object.
• **trial** ([`optuna.multi_objective.trial.FrozenMultiObjectiveTrial`]) – Target trial object.
• **search_space** (Dict[str, `optuna.distributions.BaseDistribution`]) – The search space returned by `infer_relative_search_space()`.

**Returns** A dictionary containing the parameter names and the values.

**Return type** Dict[str, Any]

---

**optuna.multi_objective.study**

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>MultiObjectiveStudy</code></td>
<td>A study corresponds to a multi-objective optimization task, i.e., a set of trials.</td>
</tr>
<tr>
<td><code>create_study</code></td>
<td>Create a new <code>MultiObjectiveStudy</code>.</td>
</tr>
<tr>
<td><code>load_study</code></td>
<td>Load the existing <code>MultiObjectiveStudy</code> that has the specified name.</td>
</tr>
</tbody>
</table>

**class optuna.multi_objective.study.MultiObjectiveStudy(study)**

A study corresponds to a multi-objective optimization task, i.e., a set of trials.

This object provides interfaces to run a new Trial, access trials’ history, set/get user-defined attributes of the study itself.

Note that the direct use of this constructor is not recommended. To create and load a study, please refer to the documentation of `create_study()` and `load_study()` respectively.

**Warning:** Deprecated in v2.4.0. This feature will be removed in the future. The removal of this feature is currently scheduled for v4.0.0, but this schedule is subject to change. See [https://github.com/optuna/optuna/releases/tag/v2.4.0](https://github.com/optuna/optuna/releases/tag/v2.4.0).
Methods

enqueue_trial(params)  Enqueue a trial with given parameter values.
get_pareto_front_trials()  Return trials located at the pareto front in the study.
get_trials([deepcopy, states])  Return all trials in the study.
optimize(objective[, timeout, n_trials, ...])  Optimize an objective function.
set_system_attr(key, value)  Set a system attribute to the study.
set_user_attr(key, value)  Set a user attribute to the study.

Attributes

directions  Return the optimization direction list.
n_objectives  Return the number of objectives.
sampler  Return the sampler.
system_attrs  Return system attributes.
trials  Return all trials in the study.
user_attrs  Return user attributes.

property directions
    Return the optimization direction list.

Returns  A list that contains the optimization direction for each objective value.

enqueue_trial (params)
    Enqueue a trial with given parameter values.

    You can fix the next sampling parameters which will be evaluated in your objective function.

    Please refer to the documentation of optuna.study.Study.enqueue_trial() for further details.

    Parameters params (Dict[str, Any]) – Parameter values to pass your objective function.

    Return type None

get_pareto_front_trials ()
    Return trials located at the pareto front in the study.

    A trial is located at the pareto front if there are no trials that dominate the trial. It’s called that a trial $t_0$ dominates another trial $t_1$ if $\forall v_0 \leq v_1$ for $v_0, v_1$ in zip($t_0$.values, $t_1$.values) and $\exists v_0 < v_1$ for $v_0, v_1$ in zip($t_0$.values, $t_1$.values) are held.

    Returns  A list of FrozenMultiObjectiveTrial objects.

    Return type  List[optuna.multi_objective.trial.FrozenMultiObjectiveTrial]

get_trials (deepcopy=True, states=None)
    Return all trials in the study.

    The returned trials are ordered by trial number.

    Parameters

        • deepcopy (bool) – Flag to control whether to apply copy.deepcopy() to the trials.

        Note that if you set the flag to False, you shouldn’t mutate any fields of the returned trial. Otherwise the internal state of the study may corrupt and unexpected behavior may happen.
• `states` (`Optional[ Tuple[optuna.trial._state.TrialState, ..] ]`) – Trial states to filter on. If `None`, include all states.

Returns  A list of `FrozenMultiObjectiveTrial` objects.

Return type  `List[optuna.multi_objective.trial.FrozenMultiObjectiveTrial]`

**property n_objectives**

Return the number of objectives.

Returns  Number of objectives.

**optimize** (`objective`, `timeout=None`, `n_trials=None`, `n_jobs=1`, `catch=()`, `callbacks=None`, `gc_after_trial=True`, `show_progress_bar=False`)

Optimize an objective function.

This method is the same as `optuna.study.Study.optimize()` except for taking an objective function that returns multi-objective values as the argument.

Please refer to the documentation of `optuna.study.Study.optimize()` for further details.

**Example**

```python
import optuna

def objective(trial):
    # Binh and Korn Function.
    x = trial.suggest_float("x", 0, 5)
    y = trial.suggest_float("y", 0, 3)

    v0 = 4 * x ** 2 + 4 * y ** 2
    v1 = (x - 5) ** 2 + (y - 5) ** 2

    return v0, v1

study = optuna.multi_objective.create_study(["minimize", "minimize"])
study.optimize(objective, n_trials=3)
```

**Parameters**

• `objective`  (`Callable[[optuna.multi_objective.trial.MultiObjectiveTrial], Sequence[float]]`) –

• `timeout` (`Optional[int]`) –

• `n_trials` (`Optional[int]`) –

• `n_jobs` (`int`) –

• `catch` (`Tuple[Type[Exception], ..]`) –

• `callbacks`  (`Optional[List[Callable[[optuna.multi_objective.study.MultiObjectiveStudy, optuna.multi_objective.trial.FrozenMultiObjectiveTrial], None]]]`) –

• `gc_after_trial` (`bool`) –

• `show_progress_bar` (`bool`) –

Return type  `None`
property sampler
Return the sampler.

Returns A BaseMultiObjectiveSampler object.

set_system_attr(key, value)
Set a system attribute to the study.

Note that Optuna internally uses this method to save system messages. Please use set_user_attr() to set users’ attributes.

Parameters
• key (str) – A key string of the attribute.
• value (Any) – A value of the attribute. The value should be JSON serializable.

Return type None

set_user_attr(key, value)
Set a user attribute to the study.

Parameters
• key (str) – A key string of the attribute.
• value (Any) – A value of the attribute. The value should be JSON serializable.

Return type None

property system_attrs
Return system attributes.

Returns A dictionary containing all system attributes.

property trials
Return all trials in the study.

The returned trials are ordered by trial number.

This is a short form of self.get_trials(deepcopy=True, states=None).

Returns A list of FrozenMultiObjectiveTrial objects.

property user_attrs
Return user attributes.

Returns A dictionary containing all user attributes.

optuna.multi_objective.study.create_study

optuna.multi_objective.study.create_study(directions, study_name=None, storage=None, sampler=None, load_if_exists=False)

Create a new MultiObjectiveStudy.
Example

```python
import optuna

def objective(trial):
    # Binh and Korn function.
    x = trial.suggest_float("x", 0, 5)
    y = trial.suggest_float("y", 0, 3)

    v0 = 4 * x ** 2 + 4 * y ** 2
    v1 = (x - 5) ** 2 + (y - 5) ** 2

    return v0, v1

study = optuna.multi_objective.create_study(["minimize", "minimize"])
study.optimize(objective, n_trials=3)
```

Parameters

- **directions** *(List[str]*) – Optimization direction for each objective value. Set minimize for minimization and maximize for maximization.

- **study_name** *(Optional[str]*) – Study’s name. If this argument is set to None, a unique name is generated automatically.

- **storage** *(Optional[Union[str, optuna.storages._base.BaseStorage]]*) – Database URL. If this argument is set to None, in-memory storage is used, and the Study will not be persistent.

Note:

When a database URL is passed, Optuna internally uses SQLAlchemy to handle the database. Please refer to SQLAlchemy’s document for further details. If you want to specify non-default options to SQLAlchemy Engine, you can instantiate `RDBStorage` with your desired options and pass it to the `storage` argument instead of a URL.

- **sampler** *(Optional[optuna.multi_objective.samplers._base.BaseMultiObjectiveSampler]*) – A sampler object that implements background algorithm for value suggestion. If None is specified, `NSGAIMultiObjectiveSampler` is used as the default. See also `samplers`.

- **load_if_exists** *(bool)* – Flag to control the behavior to handle a conflict of study names. In the case where a study named study_name already exists in the storage, a `DuplicatedStudyError` is raised if load_if_exists is set to False. Otherwise, the creation of the study is skipped, and the existing one is returned.

Returns

A `MultiObjectiveStudy` object.

Return type

`optuna.multi_objective.study.MultiObjectiveStudy`

Warning: Deprecated in v2.4.0. This feature will be removed in the future. The removal of this feature is currently scheduled for v4.0.0, but this schedule is subject to change. See https://github.com/optuna/optuna/releases/tag/v2.4.0.
optuna.multi_objective.study.load_study

Load the existing \texttt{MultiObjectiveStudy} that has the specified name.

**Example**

```python
import optuna

def objective(trial):
    # Binh and Korn function.
    x = trial.suggest_float("x", 0, 5)
    y = trial.suggest_float("y", 0, 3)

    v0 = 4 * x ** 2 + 4 * y ** 2
    v1 = (x - 5) ** 2 + (y - 5) ** 2
    return v0, v1

study = optuna.multi_objective.create_study(
    directions=["minimize", "minimize"],
    study_name="my_study",
    storage="sqlite:///example.db",
)
study.optimize(objective, n_trials=3)

loaded_study = optuna.multi_objective.study.load_study(
    study_name="my_study", storage="sqlite:///example.db"
)
assert len(loaded_study.trials) == len(study.trials)
```

**Parameters**

- **study_name** (str) – Study’s name. Each study has a unique name as an identifier.
- **storage** (Union[str, optuna.storages._base.BaseStorage]) – Database URL such as sqlite:///example.db. Please see also the documentation of \texttt{create\_study()} for further details.
- **sampler** (Optional[optuna.multi_objective.samplers._base.BaseMultiObjectiveSampler]) – A sampler object that implements background algorithm for value suggestion. If \texttt{None} is specified, \texttt{RandomMultiObjectiveSampler} is used as the default. See also \texttt{samplers}.

**Returns** A \texttt{MultiObjectiveStudy} object.

**Return type** \texttt{optuna.multi_objective.study.MultiObjectiveStudy}

**Warning:** Deprecated in v2.4.0. This feature will be removed in the future. The removal of this feature is currently scheduled for v4.0.0, but this schedule is subject to change. See https://github.com/optuna/optuna/releases/tag/v2.4.0.
A trial is a process of evaluating an objective function.

This object is passed to an objective function and provides interfaces to get parameter suggestion, manage the trial’s state, and set/get user-defined attributes of the trial.

Note that the direct use of this constructor is not recommended. This object is seamlessly instantiated and passed to the objective function behind the `optuna.multi_objective.study.MultiObjectiveStudy.optimize()` method; hence library users do not care about instantiation of this object.

**Parameters**
- `trial` - A `Trial` object.

**Warning:** Deprecated in v2.4.0. This feature will be removed in the future. The removal of this feature is currently scheduled for v4.0.0, but this schedule is subject to change. See https://github.com/optuna/optuna/releases/tag/v2.4.0.

**Methods**

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>report(values, step)</code></td>
<td>Report intermediate objective function values for a given step.</td>
</tr>
<tr>
<td><code>set_system_attr(key, value)</code></td>
<td>Set system attributes to the trial.</td>
</tr>
<tr>
<td><code>set_user_attr(key, value)</code></td>
<td>Set user attributes to the trial.</td>
</tr>
<tr>
<td><code>suggest_categorical(name, choices)</code></td>
<td>Suggest a value for the categorical parameter.</td>
</tr>
<tr>
<td><code>suggest_discrete_uniform(name, low, high, q)</code></td>
<td>Suggest a value for the discrete parameter.</td>
</tr>
<tr>
<td><code>suggest_float(name, low, high, *[step, log])</code></td>
<td>Suggest a value for the floating point parameter.</td>
</tr>
<tr>
<td><code>suggest_int(name, low, high, *[step, log])</code></td>
<td>Suggest a value for the integer parameter.</td>
</tr>
<tr>
<td><code>suggest_loguniform(name, low, high)</code></td>
<td>Suggest a value for the continuous parameter.</td>
</tr>
<tr>
<td><code>suggest_uniform(name, low, high)</code></td>
<td>Suggest a value for the continuous parameter.</td>
</tr>
</tbody>
</table>

**Attributes**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>datetime_start</code></td>
<td>Return start datetime.</td>
</tr>
<tr>
<td><code>distributions</code></td>
<td>Return distributions of parameters to be optimized.</td>
</tr>
<tr>
<td><code>number</code></td>
<td>Return trial’s number which is consecutive and unique in a study.</td>
</tr>
<tr>
<td><code>params</code></td>
<td>Return parameters to be optimized.</td>
</tr>
<tr>
<td><code>system_attrs</code></td>
<td>Return system attributes.</td>
</tr>
</tbody>
</table>

continues on next page
property datetime_start
Return start datetime.

Returns Datetime where the Trial started.

property distributions
Return distributions of parameters to be optimized.

Returns A dictionary containing all distributions.

property number
Return trial’s number which is consecutive and unique in a study.

Returns A trial number.

property params
Return parameters to be optimized.

Returns A dictionary containing all parameters.

report (values, step)
Report intermediate objective function values for a given step.

The reported values are used by the pruners to determine whether this trial should be pruned.

See also:
Please refer to BasePruner.

Note: The reported values are converted to float type by applying float() function internally. Thus, it accepts all float-like types (e.g., numpy.float32). If the conversion fails, a TypeError is raised.

Parameters

• values (Sequence[float]) – Intermediate objective function values for a given step.

• step (int) – Step of the trial (e.g., Epoch of neural network training).

Return type None

set_system_attr (key, value)
Set system attributes to the trial.

Please refer to the documentation of optuna.trial.Trial.set_system_attr() for further details.

Parameters

• key (str) –

• value (Any) –

Return type None

set_user_attr (key, value)
Set user attributes to the trial.

Please refer to the documentation of optuna.trial.Trial.set_user_attr() for further details.
Parameters

- **key (str)**
- **value (Any)**

Return type  None

`suggest_categorical (name, choices)``

Suggest a value for the categorical parameter.

Please refer to the documentation of `optuna.trial.Trial.suggest_categorical()` for further details.

Parameters

- **name (str)**
- **choices (Sequence[Union[None, bool, int, float, str]])**

Return type  Union[None, bool, int, float, str]

`suggest_discrete_uniform (name, low, high, q)``

Suggest a value for the discrete parameter.

Please refer to the documentation of `optuna.trial.Trial.suggest_discrete_uniform()` for further details.

Parameters

- **name (str)**
- **low (float)**
- **high (float)**
- **q (float)**

Return type  float

`suggest_float (name, low, high, *, step=None, log=False)``

Suggest a value for the floating point parameter.

Please refer to the documentation of `optuna.trial.Trial.suggest_float()` for further details.

Parameters

- **name (str)**
- **low (float)**
- **high (float)**
- **step (Optional[float])**
- **log (bool)**

Return type  float

`suggest_int (name, low, high, step=1, log=False)``

Suggest a value for the integer parameter.

Please refer to the documentation of `optuna.trial.Trial.suggest_int()` for further details.

Parameters

- **name (str)**
- **low (int)**
• **high** *(int)* –
• **step** *(int)* –
• **log** *(bool)* –

**Return type** int

**suggest_loguniform** *(name, low, high)*

Suggest a value for the continuous parameter.

Please refer to the documentation of `optuna.trial.Trial.suggest_loguniform()` for further details.

**Parameters**

• **name** *(str)* –
• **low** *(float)* –
• **high** *(float)* –

**Return type** float

**suggest_uniform** *(name, low, high)*

Suggest a value for the continuous parameter.

Please refer to the documentation of `optuna.trial.Trial.suggest_uniform()` for further details.

**Parameters**

• **name** *(str)* –
• **low** *(float)* –
• **high** *(float)* –

**Return type** float

**property system_attrs**

Return system attributes.

**Returns** A dictionary containing all system attributes.

**property user_attrs**

Return user attributes.

**Returns** A dictionary containing all user attributes.

**optuna.multi_objective.trial.FrozenMultiObjectiveTrial**

class optuna.multi_objective.trial.FrozenMultiObjectiveTrial *(n_objectives, trial)*

Status and results of a `MultiObjectiveTrial`.

**number**

Unique and consecutive number of `MultiObjectiveTrial` for each `MultiObjectiveStudy`. Note that this field uses zero-based numbering.

**state**

`TrialState` of the `MultiObjectiveTrial`.

**values**

Objective values of the `MultiObjectiveTrial`.
**datetime_start**
Datetime where the `MultiObjectiveTrial` started.

**datetime_complete**
Datetime where the `MultiObjectiveTrial` finished.

**params**
Dictionary that contains suggested parameters.

**distributions**
Dictionary that contains the distributions of `params`.

**userAttrs**
Dictionary that contains the attributes of the `MultiObjectiveTrial` set with `optuna.multi_objective.trial.MultiObjectiveTrial.set_user_attr()`.

**intermediate_values**
Intermediate objective values set with `optuna.multi_objective.trial.MultiObjectiveTrial.report()`.

**Warning:** Deprecated in v2.4.0. This feature will be removed in the future. The removal of this feature is currently scheduled for v4.0.0, but this schedule is subject to change. See [https://github.com/optuna/optuna/releases/tag/v2.4.0](https://github.com/optuna/optuna/releases/tag/v2.4.0).

### Attributes

- **datetime_complete**
- **datetime_start**
- **distributions**
- **last_step**
- **number**
- **params**
- **state**
- **system_attrs**
- **user_attrs**
optuna.multi_objective.visualization

Note: optuna.multi_objective.visualization module uses plotly to create figures, but JupyterLab cannot render them by default. Please follow this installation guide to show figures in JupyterLab.

optuna.multi_objective.visualization.plot_pareto_front

Plot the pareto front of a study.

Example

The following code snippet shows how to plot the pareto front of a study.

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", 0, 5)
    y = trial.suggest_float("y", 0, 3)
    v0 = 4 * x ** 2 + 4 * y ** 2
    v1 = (x - 5) ** 2 + (y - 5) ** 2
    return v0, v1

study = optuna.multi_objective.create_study(["minimize", "minimize"])
study.optimize(objective, n_trials=50)

fig = optuna.multi_objective.visualization.plot_pareto_front(study)
fig.show()
```

Parameters

- **study** (optuna.multi_objective.study.MultiObjectiveStudy) – A MultiObjectiveStudy object whose trials are plotted for their objective values.
- **names** (Optional[List[str]]) – Objective name list used as the axis titles. If None is specified, “Objective {objective_index}” is used instead.
- **include_dominated_trials** (bool) – A flag to include all dominated trial’s objective values.
- **axis_order** (Optional[List[int]]) – A list of indices indicating the axis order. If None is specified, default order is used.

Returns

A plotly.graph_objs.Figure object.

Raises

ValueError – If the number of objectives of study isn’t 2 or 3.
### 6.3.9 optuna.pruners

The pruners module defines a `BasePruner` class characterized by an abstract `prune()` method, which, for a given trial and its associated study, returns a boolean value representing whether the trial should be pruned. This determination is made based on stored intermediate values of the objective function, as previously reported for the trial using `optuna.trial.Trial.report()`. The remaining classes in this module represent child classes, inheriting from `BasePruner`, which implement different pruning strategies.

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>optuna.pruners.BasePruner</code></td>
<td>Base class for pruners.</td>
</tr>
<tr>
<td><code>optuna.pruners.MedianPruner</code></td>
<td>Pruner using the median stopping rule.</td>
</tr>
<tr>
<td><code>optuna.pruners.NopPruner</code></td>
<td>Pruner which never prunes trials.</td>
</tr>
<tr>
<td><code>optuna.pruners.PatientPruner</code></td>
<td>Pruner which wraps another pruner with tolerance.</td>
</tr>
<tr>
<td><code>optuna.pruners.PercentilePruner</code></td>
<td>Pruner to keep the specified percentile of the trials.</td>
</tr>
<tr>
<td><code>optuna.pruners.ThresholdPruner</code></td>
<td>Pruner to detect outlying metrics of the trials.</td>
</tr>
</tbody>
</table>

#### `optuna.pruners.BasePruner`

```python
class optuna.pruners.BasePruner
    Base class for pruners.

    Methods

    prune(study, trial) Judge whether the trial should be pruned based on the reported values.
```

#### Abstract `prune(study, trial)`

Judge whether the trial should be pruned based on the reported values.

Note that this method is not supposed to be called by library users. Instead, `optuna.trial.Trial.report()` and `optuna.trial.Trial.should_prune()` provide user interfaces to implement pruning mechanism in an objective function.

**Parameters**

- `study` (*optuna.study.study.Study*) – Study object of the target study.
- `trial` (*optuna.trial._frozen.FrozenTrial*) – FrozenTrial object of the target trial. Take a copy before modifying this object.

**Returns** A boolean value representing whether the trial should be pruned.
**Return type**  
bool

**optuna.pruners.MedianPruner**

class optuna.pruners.MedianPruner(n_startup_trials=5, n_warmup_steps=0, interval_steps=1, *, n_min_trials=1)

Pruner using the median stopping rule.
Prune if the trial’s best intermediate result is worse than median of intermediate results of previous trials at the same step.

**Example**

We minimize an objective function with the median stopping rule.

```python
import numpy as np
from sklearn.datasets import load_iris
from sklearn.linear_model import SGDClassifier
from sklearn.model_selection import train_test_split
import optuna

X, y = load_iris(return_X_y=True)
X_train, X_valid, y_train, y_valid = train_test_split(X, y)
classes = np.unique(y)

def objective(trial):
    alpha = trial.suggest_float("alpha", 0.0, 1.0)
    clf = SGDClassifier(alpha=alpha)
    n_train_iter = 100
    for step in range(n_train_iter):
        clf.partial_fit(X_train, y_train, classes=classes)
        intermediate_value = clf.score(X_valid, y_valid)
        trial.report(intermediate_value, step)
        if trial.should_prune():
            raise optuna.TrialPruned()
    return clf.score(X_valid, y_valid)

study = optuna.create_study(
    direction="maximize",
    pruner=optuna.pruners.MedianPruner(
        n_startup_trials=5, n_warmup_steps=30, interval_steps=10
    ),
)
study.optimize(objective, n_trials=20)
```

**Parameters**

- **n_startup_trials** – Pruning is disabled until the given number of trials finish in the same study.
• **n_warmup_steps** – Pruning is disabled until the trial exceeds the given number of step. Note that this feature assumes that step starts at zero.

• **interval_steps** – Interval in number of steps between the pruning checks, offset by the warmup steps. If no value has been reported at the time of a pruning check, that particular check will be postponed until a value is reported.

• **n_min_trials** – Minimum number of reported trial results at a step to judge whether to prune. If the number of reported intermediate values from all trials at the current step is less than n_min_trials, the trial will not be pruned. This can be used to ensure that a minimum number of trials are run to completion without being pruned.

**Methods**

```python
prune(study, trial)
```

Judge whether the trial should be pruned based on the reported values.

Note that this method is not supposed to be called by library users. Instead, `optuna.trial.Trial.report()` and `optuna.trial.Trial.should_prune()` provide user interfaces to implement pruning mechanism in an objective function.

**Parameters**

- **study** *(optuna.study.study.Study)* – Study object of the target study.
- **trial** *(optuna.trial._frozen.FrozenTrial)* – FrozenTrial object of the target trial. Take a copy before modifying this object.

**Returns** A boolean value representing whether the trial should be pruned.

**Return type** bool

**Example**

```python
import numpy as np
from sklearn.datasets import load_iris
from sklearn.linear_model import SGDClassifier
from sklearn.model_selection import train_test_split

import optuna

X, y = load_iris(return_X_y=True)
X_train, X_valid, y_train, y_valid = train_test_split(X, y)
classes = np.unique(y)

def objective(trial):
```
alpha = trial.suggest_float("alpha", 0.0, 1.0)
clf = SGDClassifier(alpha=alpha)
n_train_iter = 100

for step in range(n_train_iter):
    clf.partial_fit(X_train, y_train, classes=classes)
    intermediate_value = clf.score(X_valid, y_valid)
    trial.report(intermediate_value, step)

    if trial.should_prune():
        assert False, "should_prune() should always return False with this pruner."
        raise optuna.TrialPruned()
    return clf.score(X_valid, y_valid)

study = optuna.create_study(direction="maximize", pruner=optuna.pruners.NopPruner())
study.optimize(objective, n_trials=20)

#### Methods

**prune**(study, trial)
Judge whether the trial should be pruned based on the reported values.

**prune**(study, trial)
Judge whether the trial should be pruned based on the reported values.

Note that this method is not supposed to be called by library users. Instead, `optuna.trial.Trial.report()` and `optuna.trial.Trial.should_prune()` provide user interfaces to implement pruning mechanism in an objective function.

**Parameters**

- **study** *(optuna.study.study.Study)* – Study object of the target study.
- **trial** *(optuna.trial._frozen.FrozenTrial)* – FrozenTrial object of the target trial. Take a copy before modifying this object.

**Returns** A boolean value representing whether the trial should be pruned.

**Return type** bool
class optuna.pruners.PatientPruner(wrapped_pruner, patience, min_delta=0.0)

Pruner which wraps another pruner with tolerance.

Example

```python
import numpy as np
from sklearn.datasets import load_iris
from sklearn.linear_model import SGDClassifier
from sklearn.model_selection import train_test_split
import optuna

X, y = load_iris(return_X_y=True)
X_train, X_valid, y_train, y_valid = train_test_split(X, y)
classes = np.unique(y)

def objective(trial):
    alpha = trial.suggest_float("alpha", 0.0, 1.0)
    clf = SGDClassifier(alpha=alpha)
    n_train_iter = 100

    for step in range(n_train_iter):
        clf.partial_fit(X_train, y_train, classes=classes)

        intermediate_value = clf.score(X_valid, y_valid)
        trial.report(intermediate_value, step)

        if trial.should_prune():
            raise optuna.TrialPruned()

    return clf.score(X_valid, y_valid)

study = optuna.create_study(
    direction="maximize",
    pruner=optuna.pruners.PatientPruner(optuna.pruners.MedianPruner(), patience=1),
)
study.optimize(objective, n_trials=20)
```

Parameters

- **wrapped_pruner** – Wrapped pruner to perform pruning when PatientPruner allows a trial to be pruned. If it is `None`, this pruner is equivalent to early-stopping taken the intermediate values in the individual trial.
- **patience** – Pruning is disabled until the objective doesn’t improve for patience consecutive steps.
- **min_delta** – Tolerance value to check whether or not the objective improves. This value should be non-negative.

**Note**: Added in v2.8.0 as an experimental feature. The interface may change in newer versions without prior
Methods

**prune**

Judge whether the trial should be pruned based on the reported values.

**prune** (*study*, *trial*)  
Judge whether the trial should be pruned based on the reported values.

Note that this method is not supposed to be called by library users. Instead, `optuna.trial.Trial.report()` and `optuna.trial.Trial.should_prune()` provide user interfaces to implement pruning mechanism in an objective function.

**Parameters**

- **study** (*optuna.study.study.Study*) – Study object of the target study.
- **trial** (*optuna.trial._frozen.FrozenTrial*) – FrozenTrial object of the target trial. Take a copy before modifying this object.

**Returns** A boolean value representing whether the trial should be pruned.

**Return type**  
`bool`

**optuna.pruners.PercentilePruner**

**class**  
*optuna.pruners.PercentilePruner* (*percentile*, *n_startup_trials*=5, *n_warmup_steps*=0,  
*interval_steps*=1, *, *n_min_trials*=1)  
Pruner to keep the specified percentile of the trials.

Prune if the best intermediate value is in the bottom percentile among trials at the same step.

**Example**

```python
import numpy as np
from sklearn.datasets import load_iris
from sklearn.linear_model import SGDClassifier
from sklearn.model_selection import train_test_split

import optuna

X, y = load_iris(return_X_y=True)
X_train, X_valid, y_train, y_valid = train_test_split(X, y)
classes = np.unique(y)

def objective(trial):
    alpha = trial.suggest_float("alpha", 0.0, 1.0)
    clf = SGDClassifier(alpha=alpha)
    n_train_iter = 100

    for step in range(n_train_iter):
        clf.partial_fit(X_train, y_train, classes=classes)
```

(continues on next page)
intermediate_value = clf.score(X_valid, y_valid)
trial.report(intermediate_value, step)

if trial.should_prune():
    raise optuna.TrialPruned()

return clf.score(X_valid, y_valid)

study = optuna.create_study(
    direction="maximize",
    pruner=optuna.pruners.PercentilePruner(
        25.0, n_startup_trials=5, n_warmup_steps=30, interval_steps=10
    ),
)
study.optimize(objective, n_trials=20)

Parameters

- **percentile** – Percentile which must be between 0 and 100 inclusive (e.g., When given 25.0, top of 25th percentile trials are kept).
- **n_startup_trials** – Pruning is disabled until the given number of trials finish in the same study.
- **n_warmup_steps** – Pruning is disabled until the trial exceeds the given number of step. Note that this feature assumes that step starts at zero.
- **interval_steps** – Interval in number of steps between the pruning checks, offset by the warmup steps. If no value has been reported at the time of a pruning check, that particular check will be postponed until a value is reported. Value must be at least 1.
- **n_min_trials** – Minimum number of reported trial results at a step to judge whether to prune. If the number of reported intermediate values from all trials at the current step is less than n_min_trials, the trial will not be pruned. This can be used to ensure that a minimum number of trials are run to completion without being pruned.

Methods

<table>
<thead>
<tr>
<th><strong>prune</strong>(study, trial)</th>
<th>Judge whether the trial should be pruned based on the reported values.</th>
</tr>
</thead>
</table>

**prune**(study, trial)

Judge whether the trial should be pruned based on the reported values.

Note that this method is not supposed to be called by library users. Instead, `optuna.trial.Trial.report()` and `optuna.trial.Trial.should_prune()` provide user interfaces to implement pruning mechanism in an objective function.

Parameters

- **study**(optuna.study.study.Study) – Study object of the target study.
- **trial**(optuna.trial._frozen.FrozenTrial) – FrozenTrial object of the target trial. Take a copy before modifying this object.
Returns  A boolean value representing whether the trial should be pruned.

Return type  bool

**optuna.pruners.SuccessiveHalvingPruner**

class optuna.pruners.SuccessiveHalvingPruner(min_resource='auto', reduction_factor=4, min_early_stopping_rate=0, bootstrap_count=0)

Pruner using Asynchronous Successive Halving Algorithm.

Successive Halving is a bandit-based algorithm to identify the best one among multiple configurations. This class implements an asynchronous version of Successive Halving. Please refer to the paper of Asynchronous Successive Halving for detailed descriptions.

Note that, this class does not take care of the parameter for the maximum resource, referred to as $R$ in the paper. The maximum resource allocated to a trial is typically limited inside the objective function (e.g., step number in simple_pruning.py, EPOCH number in chainer_integration.py).

See also:
Please refer to `report()`.

**Example**

We minimize an objective function with `SuccessiveHalvingPruner`.

```python
import numpy as np
from sklearn.datasets import load_iris
from sklearn.linear_model import SGDClassifier
from sklearn.model_selection import train_test_split
import optuna

X, y = load_iris(return_X_y=True)
X_train, X_valid, y_train, y_valid = train_test_split(X, y)
classes = np.unique(y)

def objective(trial):
    alpha = trial.suggest_float("alpha", 0.0, 1.0)
    clf = SGDClassifier(alpha=alpha)
    n_train_iter = 100

    for step in range(n_train_iter):
        clf.partial_fit(X_train, y_train, classes=classes)

        intermediate_value = clf.score(X_valid, y_valid)
        trial.report(intermediate_value, step)

    if trial.should_prune():
        raise optuna.TrialPruned()

    return clf.score(X_valid, y_valid)

study = optuna.create_study()
```

(continues on next page)
direction="maximize", pruner=optuna.pruners.SuccessiveHalvingPruner()
)
study.optimize(objective, n_trials=20)

Parameters

• **min_resource** – A parameter for specifying the minimum resource allocated to a trial (in the paper this parameter is referred to as $r$). This parameter defaults to ‘auto’ where the value is determined based on a heuristic that looks at the number of required steps for the first trial to complete.

A trial is never pruned until it executes $\text{min_resource} \times \text{reduction_factor} \times \text{min_early_stopping_rate}$ steps (i.e., the completion point of the first rung). When the trial completes the first rung, it will be promoted to the next rung only if the value of the trial is placed in the top $\frac{1}{\text{reduction_factor}}$ fraction of the all trials that already have reached the point (otherwise it will be pruned there). If the trial won the competition, it runs until the next completion point (i.e., $\text{min_resource} \times \text{reduction_factor}^{\text{min_early_stopping_rate} + \text{rung}}$ steps) and repeats the same procedure.

**Note:** If the step of the last intermediate value may change with each trial, please manually specify the minimum possible step to min_resource.

• **reduction_factor** – A parameter for specifying reduction factor of promotable trials (in the paper this parameter is referred to as $\eta$). At the completion point of each rung, about $\frac{1}{\text{reduction_factor}}$ trials will be promoted.

• **min_early_stopping_rate** – A parameter for specifying the minimum early-stopping rate (in the paper this parameter is referred to as $s$).

• **bootstrap_count** – Minimum number of trials that need to complete a rung before any trial is considered for promotion into the next rung.

Methods

<table>
<thead>
<tr>
<th><strong>prune</strong>(study, trial)</th>
<th>Judge whether the trial should be pruned based on the reported values.</th>
</tr>
</thead>
</table>

**prune**(study, trial)
Judge whether the trial should be pruned based on the reported values.

Note that this method is not supposed to be called by library users. Instead, optuna.trial.Trial.report() and optuna.trial.Trial.should_prune() provide user interfaces to implement pruning mechanism in an objective function.

**Parameters**

• **study**(optuna.study.study.Study) – Study object of the target study.

• **trial**(optuna.trial._frozen.FrozenTrial) – FrozenTrial object of the target trial. Take a copy before modifying this object.

**Returns** A boolean value representing whether the trial should be pruned.

**Return type** **bool**
**optuna.pruners.HyperbandPruner**

```python
class optuna.pruners.HyperbandPruner(min_resource=1, max_resource='auto', reduction_factor=3, bootstrap_count=0)
```

Pruner using Hyperband.

As SuccessiveHalving (SHA) requires the number of configurations \( n \) as its hyperparameter. For a given finite budget \( B \), all the configurations have the resources of \( \frac{B}{n} \) on average. As you can see, there will be a trade-off of \( B \) and \( \frac{B}{n} \). Hyperband attacks this trade-off by trying different \( n \) values for a fixed budget.

**Note:**
- In the Hyperband paper, the counterpart of `RandomSampler` is used.
- Optuna uses `TPESampler` by default.
- The benchmark result shows that `optuna.pruners.HyperbandPruner` supports both samplers.

**Note:** If you use `HyperbandPruner` with `TPESampler`, it’s recommended to consider to set larger `n_trials` or `timeout` to make full use of the characteristics of `TPESampler` because `TPESampler` uses some (by default, 10) `Trials` for its startup.

As Hyperband runs multiple `SuccessiveHalvingPruner` and collect trials based on the current `Trial`’s bracket ID, each bracket needs to observe more than 10 `Trials` for `TPESampler` to adapt its search space.

Thus, for example, if `HyperbandPruner` has 4 pruners in it, at least \( 4 \times 10 \) trials are consumed for startup.

**Note:** Hyperband has several `SuccessiveHalvingPruner`. Each `SuccessiveHalvingPruner` is referred as “bracket” in the original paper. The number of brackets is an important factor to control the early stopping behavior of Hyperband and is automatically determined by `min_resource`, `max_resource` and `reduction_factor` as \( \text{The number of brackets} = \text{floor} \left( \log_{\text{reduction_factor}}(\frac{\text{max_resource}}{\text{min_resource}}) \right) + 1 \). Please set `reduction_factor` so that the number of brackets is not too large (about 4 ~ 6 in most use cases). Please see Section 3.6 of the original paper for the detail.

**See also:**
Please refer to `report()`.

**Example**

We minimize an objective function with Hyperband pruning algorithm.

```python
import numpy as np
from sklearn.datasets import load_iris
from sklearn.linear_model import SGDClassifier
from sklearn.model_selection import train_test_split
import optuna

X, y = load_iris(return_X_y=True)
X_train, X_valid, y_train, y_valid = train_test_split(X, y)
classes = np.unique(y)
n_train_iter = 100
```
```python
def objective(trial):
    alpha = trial.suggest_float("alpha", 0.0, 1.0)
    clf = SGDClassifier(alpha=alpha)

    for step in range(n_train_iter):
        clf.partial_fit(X_train, y_train, classes=classes)
        intermediate_value = clf.score(X_valid, y_valid)
        trial.report(intermediate_value, step)

        if trial.should_prune():
            raise optuna.TrialPruned()

    return clf.score(X_valid, y_valid)

study = optuna.create_study(
    direction="maximize",
    pruner=optuna.pruners.HyperbandPruner(
        min_resource=1, max_resource=n_train_iter, reduction_factor=3
    ),
)
study.optimize(objective, n_trials=20)
```

Parameters

- **min_resource** – A parameter for specifying the minimum resource allocated to a trial noted as \( r \) in the paper. A smaller \( r \) will give a result faster, but a larger \( r \) will give a better guarantee of successful judging between configurations. See the details for `SuccessiveHalvingPruner`.

- **max_resource** – A parameter for specifying the maximum resource allocated to a trial. \( R \) in the paper corresponds to \( \text{max_resource} / \text{min_resource} \). This value represents and should match the maximum iteration steps (e.g., the number of epochs for neural networks). When this argument is “auto”, the maximum resource is estimated according to the completed trials. The default value of this argument is “auto”.

Note: With “auto”, the maximum resource will be the largest step reported by `report()` in the first, or one of the first if trained in parallel, completed trial. No trials will be pruned until the maximum resource is determined.

Note: If the step of the last intermediate value may change with each trial, please manually specify the maximum possible step to `max_resource`.

- **reduction_factor** – A parameter for specifying reduction factor of promotable trials noted as \( \eta \) in the paper. See the details for `SuccessiveHalvingPruner`.

- **bootstrap_count** – Parameter specifying the number of trials required in a rung before any trial can be promoted. Incompatible with `max_resource` is "auto". See the details for `SuccessiveHalvingPruner`.
Methods

prune(study, trial)
Judge whether the trial should be pruned based on the reported values.

prune (study, trial)
Judge whether the trial should be pruned based on the reported values.

Note that this method is not supposed to be called by library users. Instead, `optuna.trial.Trial.report()` and `optuna.trial.Trial.should_prune()` provide user interfaces to implement pruning mechanism in an objective function.

Parameters

- **study** (`optuna.study.study.Study`) – Study object of the target study.
- **trial** (`optuna.trial._frozen.FrozenTrial`) – FrozenTrial object of the target trial. Take a copy before modifying this object.

Returns  A boolean value representing whether the trial should be pruned.

Return type  `bool`

**optuna.pruners.ThresholdPruner**

**class optuna.pruners.ThresholdPruner** *(lower=None, upper=None, n_warmup_steps=0, interval_steps=1)*

Pruner to detect outlying metrics of the trials.

Prune if a metric exceeds upper threshold, falls behind lower threshold or reaches `nan`.

**Example**

```python
from optuna import create_study
from optuna.pruners import ThresholdPruner
from optuna import TrialPruned

def objective_for_upper(trial):
    for step, y in enumerate(ys_for_upper):
        trial.report(y, step)

        if trial.should_prune():
            raise TrialPruned()

    return ys_for_upper[-1]

def objective_for_lower(trial):
    for step, y in enumerate(ys_for_lower):
        trial.report(y, step)

        if trial.should_prune():
            raise TrialPruned()

    return ys_for_lower[-1]
```

(continues on next page)
ys_for_upper = [0.0, 0.1, 0.2, 0.5, 1.2]
y
ys_for_lower = [100.0, 90.0, 0.1, 0.0, -1]

study = create_study(pruner=ThresholdPruner(upper=1.0))
study.optimize(objective_for_upper, n_trials=10)

study = create_study(pruner=ThresholdPruner(lower=0.0))
study.optimize(objective_for_lower, n_trials=10)

### Parameters

- **lower** – A minimum value which determines whether pruner prunes or not. If an intermediate value is smaller than lower, it prunes.
- **upper** – A maximum value which determines whether pruner prunes or not. If an intermediate value is larger than upper, it prunes.
- **n_warmup_steps** – Pruning is disabled if the step is less than the given number of warmup steps.
- **interval_steps** – Interval in number of steps between the pruning checks, offset by the warmup steps. If no value has been reported at the time of a pruning check, that particular check will be postponed until a value is reported. Value must be at least 1.

### Methods

**prune(study, trial)**

Judge whether the trial should be pruned based on the reported values.

Judge whether the trial should be pruned based on the reported values.

Note that this method is not supposed to be called by library users. Instead, `optuna.trial.Trial.report()` and `optuna.trial.Trial.should_prune()` provide user interfaces to implement pruning mechanism in an objective function.

**Parameters**

- **study** (`optuna.study.study.Study`) – Study object of the target study.
- **trial** (`optuna.trial._frozen.FrozenTrial`) – FrozenTrial object of the target trial. Take a copy before modifying this object.

**Returns** A boolean value representing whether the trial should be pruned.

**Return type** `bool`
6.3.10 optuna.samplers

The `samplers` module defines a base class for parameter sampling as described extensively in `BaseSampler`. The remaining classes in this module represent child classes, deriving from `BaseSampler`, which implement different sampling strategies.

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>optuna.samplers.BaseSampler</code></td>
<td>Base class for samplers.</td>
</tr>
<tr>
<td><code>optuna.samplers.RandomSampler</code></td>
<td>Sampler using random sampling.</td>
</tr>
<tr>
<td><code>optuna.samplers.TPESampler</code></td>
<td>Sampler using TPE (Tree-structured Parzen Estimator) algorithm.</td>
</tr>
<tr>
<td><code>optuna.samplers.CmaEsSampler</code></td>
<td>A sampler using cmaes as the backend.</td>
</tr>
<tr>
<td><code>optuna.samplers.PartialFixedSampler</code></td>
<td>Sampler with partially fixed parameters.</td>
</tr>
<tr>
<td><code>optuna.samplers.NSGAII_sampler</code></td>
<td>Multi-objective sampler using the NSGA-II algorithm.</td>
</tr>
<tr>
<td><code>optuna.samplers.MOTPESampler</code></td>
<td>Multi-objective sampler using the MOTPE algorithm.</td>
</tr>
<tr>
<td><code>IntersectionSearchSpace</code></td>
<td>A class to calculate the intersection search space of a BaseStudy.</td>
</tr>
<tr>
<td><code>intersection_search_space</code></td>
<td>Return the intersection search space of the BaseStudy.</td>
</tr>
</tbody>
</table>

`optuna.samplers.BaseSampler`

```python
class optuna.samplers.BaseSampler
    Base class for samplers.
```

Optuna combines two types of sampling strategies, which are called *relative sampling* and *independent sampling*.

*The relative sampling* determines values of multiple parameters simultaneously so that sampling algorithms can use relationship between parameters (e.g., correlation). Target parameters of the relative sampling are described in a relative search space, which is determined by `infer_relative_search_space()`.

*The independent sampling* determines a value of a single parameter without considering any relationship between parameters. Target parameters of the independent sampling are the parameters not described in the relative search space.

More specifically, parameters are sampled by the following procedure. At the beginning of a trial, `infer_relative_search_space()` is called to determine the relative search space for the trial. Then, `sample_relative()` is invoked to sample parameters from the relative search space. During the execution of the objective function, `sample_independent()` is used to sample parameters that don’t belong to the relative search space.

The following figure depicts the lifetime of a trial and how the above three methods are called in the trial.
Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>after_trial(study, trial, state, values)</code></td>
<td>Trial post-processing. This method is called after the objective function returns and right before the trials is finished and its state is stored.</td>
</tr>
<tr>
<td><code>infer_relative_search_space(study, trial)</code></td>
<td>Infer the search space that will be used by relative sampling in the target trial.</td>
</tr>
<tr>
<td><code>reseed_rng()</code></td>
<td>Reseed sampler’s random number generator.</td>
</tr>
<tr>
<td><code>sample_independent(study, trial, param_name, ...)</code></td>
<td>Sample a parameter for a given distribution.</td>
</tr>
<tr>
<td><code>sample_relative(study, trial, search_space)</code></td>
<td>Sample parameters in a given search space.</td>
</tr>
</tbody>
</table>

**after_trial** *(study, trial, state, values)*

Trial post-processing.

This method is called after the objective function returns and right before the trials is finished and its state is stored.

**Note:** Added in v2.4.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.4.0.

**Parameters**

- `study` *(optuna.study.study.Study)* – Target study object.
- `trial` *(optuna.trial._frozen.FrozenTrial)* – Target trial object. Take a copy before modifying this object.
- `state` *(optuna.trial._state.TrialState)* – Resulting trial state.
- `values` *(Optional[Sequence[float]])* – Resulting trial values. Guaranteed to not be `None` if trial succeeded.

**Return type** `None`  

**abstract infer_relative_search_space** *(study, trial)*

Infer the search space that will be used by relative sampling in the target trial.

This method is called right before `sample_relative()` method, and the search space returned by this method is passed to it. The parameters not contained in the search space will be sampled by using `sample_independent()` method.

**Parameters**

- `study` *(optuna.study.study.Study)* – Target study object.
- `trial` *(optuna.trial._frozen.FrozenTrial)* – Target trial object. Take a copy before modifying this object.

**Returns** A dictionary containing the parameter names and parameter’s distributions.

**Return type** `Dict[str, optuna.distributions.BaseDistribution]`  

**See also:**

Please refer to `intersection_search_space()` as an implementation of `infer_relative_search_space()`.

**reseed_rng()**

Reseed sampler’s random number generator.
This method is called by the Study instance if trials are executed in parallel with the option n_jobs>1. In that case, the sampler instance will be replicated including the state of the random number generator, and they may suggest the same values. To prevent this issue, this method assigns a different seed to each random number generator.

**Return type** None

**abstract sample_independent**(study, trial, param_name, param_distribution)

Sample a parameter for a given distribution.

This method is called only for the parameters not contained in the search space returned by sample_relative() method. This method is suitable for sampling algorithms that do not use relationship between parameters such as random sampling and TPE.

**Note:** The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

**Parameters**

- **study**(optuna.study.study.Study) – Target study object.
- **trial**(optuna.trial._frozen.FrozenTrial) – Target trial object. Take a copy before modifying this object.
- **param_name**(str) – Name of the sampled parameter.
- **param_distribution**(optuna.distributions.BaseDistribution) – Distribution object that specifies a prior and/or scale of the sampling algorithm.

**Returns** A parameter value.

**Return type** Any

**abstract sample_relative**(study, trial, search_space)

Sample parameters in a given search space.

This method is called once at the beginning of each trial, i.e., right before the evaluation of the objective function. This method is suitable for sampling algorithms that use relationship between parameters such as Gaussian Process and CMA-ES.

**Note:** The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

**Parameters**

- **study**(optuna.study.study.Study) – Target study object.
- **trial**(optuna.trial._frozen.FrozenTrial) – Target trial object. Take a copy before modifying this object.
- **search_space**(Dict[str, optuna.distributions.BaseDistribution]) – The search space returned by infer_relative_search_space().

**Returns** A dictionary containing the parameter names and the values.

**Return type** Dict[str, Any]
**optuna.samplers.GridSampler**

**class optuna.samplers.GridSampler(search_space)**

Sampler using grid search.

With `GridSampler`, the trials suggest all combinations of parameters in the given search space during the study.

**Example**

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", -100, 100)
    y = trial.suggest_int("y", -100, 100)
    return x ** 2 + y ** 2

search_space = {"x": [-50, 0, 50], "y": [-99, 0, 99]}
study = optuna.create_study(sampler=optuna.samplers.GridSampler(search_space))
study.optimize(objective)
```

**Note:** `GridSampler` automatically stops the optimization if all combinations in the passed `search_space` have already been evaluated, internally invoking the `stop()` method.

**Note:** `GridSampler` does not take care of a parameter’s quantization specified by discrete suggest methods but just samples one of values specified in the search space. E.g., in the following code snippet, either of -0.5 or 0.5 is sampled as `x` instead of an integer point.

```python
import optuna

def objective(trial):
    # The following suggest method specifies integer points between -5 and 5.
    x = trial.suggest_int("x", -5, 5, step=1)
    return x ** 2

# Non-int points are specified in the grid.
search_space = {"x": [-0.5, 0.5]}
study = optuna.create_study(sampler=optuna.samplers.GridSampler(search_space))
study.optimize(objective, n_trials=2)
```

**Note:** A parameter configuration in the grid is not considered finished until its trial is finished. Therefore, during distributed optimization where trials run concurrently, different workers will occasionally suggest the same parameter configuration. The total number of actual trials may therefore exceed the size of the grid.

**Note:** The grid is randomly shuffled and the order in which parameter configurations are suggested may vary.
This is to reduce duplicate suggestions during distributed optimization.

**Parameters**

**search_space** – A dictionary whose key and value are a parameter name and the corresponding candidates of values, respectively.

**Methods**

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>after_trial</strong></td>
<td>Trial post-processing. This method is called after the objective function returns and right before the trials is finished and its state is stored.</td>
</tr>
<tr>
<td><strong>infer_relative_search_space</strong></td>
<td>Infer the search space that will be used by relative sampling in the target trial.</td>
</tr>
<tr>
<td><strong>reseed_rng</strong></td>
<td>Reseed sampler’s random number generator.</td>
</tr>
<tr>
<td><strong>sample_independent</strong></td>
<td>Sample a parameter for a given distribution.</td>
</tr>
<tr>
<td><strong>sample_relative</strong></td>
<td>Sample parameters in a given search space.</td>
</tr>
</tbody>
</table>

**after_trial** *(study, trial, state, values)*

Trial post-processing.

**Note:** Added in v2.4.0 as an experimental feature. The interface may change in newer versions without prior notice. See [https://github.com/optuna/optuna/releases/tag/v2.4.0](https://github.com/optuna/optuna/releases/tag/v2.4.0).

**Parameters**

- **study** *(optuna.study.study.Study)* – Target study object.
- **trial** *(optuna.trial._frozen.FrozenTrial)* – Target trial object. Take a copy before modifying this object.
- **state** *(optuna.trial._state.TrialState)* – Resulting trial state.
- **values** *(Optional[Sequence[float]])* – Resulting trial values. Guaranteed to not be None if trial succeeded.

**Return type** None

**infer_relative_search_space** *(study, trial)*

Infer the search space that will be used by relative sampling in the target trial.

This method is called right before **sample_relative()** method, and the search space returned by this method is passed to it. The parameters not contained in the search space will be sampled by using **sample_independent()** method.

**Parameters**

- **study** *(optuna.study.study.Study)* – Target study object.
- **trial** *(optuna.trial._frozen.FrozenTrial)* – Target trial object. Take a copy before modifying this object.

**Returns** A dictionary containing the parameter names and parameter’s distributions.

**Return type** Dict[str, optuna.distributions.BaseDistribution]
See also:

Please refer to `intersection_search_space()` as an implementation of `infer_relative_search_space()`.

**reseed_rng()**

Reseed sampler’s random number generator.

This method is called by the `Study` instance if trials are executed in parallel with the option `n_jobs>1`. In that case, the sampler instance will be replicated including the state of the random number generator, and they may suggest the same values. To prevent this issue, this method assigns a different seed to each random number generator.

**Return type** None

**sample_independent(study, trial, param_name, param_distribution)**

Sample a parameter for a given distribution.

This method is called only for the parameters not contained in the search space returned by `sample_relative()` method. This method is suitable for sampling algorithms that do not use relationship between parameters such as random sampling and TPE.

**Note:** The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

**Parameters**

- **study** (`optuna.study.Study`) – Target study object.
- **trial** (`optuna.trial.FrozenTrial`) – Target trial object. Take a copy before modifying this object.
- **param_name** (`str`) – Name of the sampled parameter.
- **param_distribution** (`optuna.distributions.BaseDistribution`) – Distribution object that specifies a prior and/or scale of the sampling algorithm.

**Returns** A parameter value.

**Return type** Any

**sample_relative(study, trial, search_space)**

Sample parameters in a given search space.

This method is called once at the beginning of each trial, i.e., right before the evaluation of the objective function. This method is suitable for sampling algorithms that use relationship between parameters such as Gaussian Process and CMA-ES.

**Note:** The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

**Parameters**

- **study** (`optuna.study.Study`) – Target study object.
- **trial** (`optuna.trial.FrozenTrial`) – Target trial object. Take a copy before modifying this object.
• **search_space** 
  \( \text{Dict[str, optuna.distributions.BaseDistribution]} \) – The search space returned by \( \text{infer_relative_search_space()} \).

  **Returns**  A dictionary containing the parameter names and the values.

  **Return type**  `Dict[str, Any]`

**optuna.samplers.RandomSampler**

**class** `optuna.samplers.RandomSampler` *(seed=None)*

Sampler using random sampling.

This sampler is based on independent sampling. See also `BaseSampler` for more details of ‘independent sampling’.

**Example**

```python
import optuna
from optuna.samplers import RandomSampler

def objective(trial):
    x = trial.suggest_float("x", -5, 5)
    return x ** 2

study = optuna.create_study(sampler=RandomSampler())
study.optimize(objective, n_trials=10)
```

**Parameters**  `seed` – Seed for random number generator.

**Methods**

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>after_trial</code> <em>(study, trial, state, values)</em></td>
<td>Trial post-processing.</td>
</tr>
<tr>
<td><code>infer_relative_search_space</code> <em>(study, trial)</em></td>
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<td><code>sample_independent</code> <em>(study, trial, param_name, ...)</em></td>
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<td><code>sample_relative</code> <em>(study, trial, search_space)</em></td>
<td>Sample parameters in a given search space.</td>
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</tbody>
</table>

**after_trial** *(study, trial, state, values)*

Trial post-processing.

This method is called after the objective function returns and right before the trials is finished and its state is stored.

**Note:**  Added in v2.4.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.4.0.
Parameters

- **study** ([optuna.study.study.Study](#study)) – Target study object.
- **trial** ([optuna.trial._frozen.FrozenTrial](#trial)) – Target trial object. Take a copy before modifying this object.
- **state** ([optuna.trial._state.TrialState](#state)) – Resulting trial state.
- **values** ([Optional[Sequence[float]]](#values)) – Resulting trial values. Guaranteed to not be None if trial succeeded.

**Return type** None

### infer_relative_search_space

```python
infer_relative_search_space(study, trial)
```

Infer the search space that will be used by relative sampling in the target trial.

This method is called right before `sample_relative()` method, and the search space returned by this method is passed to it. The parameters not contained in the search space will be sampled by using `sample_independent()` method.

**Parameters**

- **study** ([optuna.study.study.Study](#study)) – Target study object.
- **trial** ([optuna.trial._frozen.FrozenTrial](#trial)) – Target trial object. Take a copy before modifying this object.

**Returns** A dictionary containing the parameter names and parameter’s distributions.

**Return type** Dict[str, optuna.distributions.BaseDistribution]

**See also:**

Please refer to `intersection_search_space()` as an implementation of `infer_relative_search_space()`.

### reseed_rng

```python
reseed_rng()
```

Reseed sampler’s random number generator.

This method is called by the `Study` instance if trials are executed in parallel with the option `n_jobs>1`. In that case, the sampler instance will be replicated including the state of the random number generator, and they may suggest the same values. To prevent this issue, this method assigns a different seed to each random number generator.

**Return type** None

### sample_independent

```python
sample_independent(study, trial, param_name, param_distribution)
```

Sample a parameter for a given distribution.

This method is called only for the parameters not contained in the search space returned by `sample_relative()` method. This method is suitable for sampling algorithms that do not use relationship between parameters such as random sampling and TPE.

**Note:** The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

**Parameters**

- **study** ([optuna.study.study.Study](#study)) – Target study object.
• **trial** *(optuna.trial._frozen.FrozenTrial)* – Target trial object. Take a copy before modifying this object.

• **param_name** *(str)* – Name of the sampled parameter.

• **param_distribution** *(optuna.distributions.BaseDistribution)* – Distribution object that specifies a prior and/or scale of the sampling algorithm.

Returns A parameter value.

Return type Any

**sample_relative**(study, trial, search_space)

Sample parameters in a given search space.

This method is called once at the beginning of each trial, i.e., right before the evaluation of the objective function. This method is suitable for sampling algorithms that use relationship between parameters such as Gaussian Process and CMA-ES.

Note: The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

Parameters

• **study** *(optuna.study.study.Study)* – Target study object.

• **trial** *(optuna.trial._frozen.FrozenTrial)* – Target trial object. Take a copy before modifying this object.

• **search_space** *(Dict[str, optuna.distributions.BaseDistribution])* – The search space returned by `infer_relative_search_space()`.

Returns A dictionary containing the parameter names and the values.

Return type Dict[str, Any]

**optuna.samplers.TPESampler**

class **optuna.samplers.TPESampler**(consider_prior=True, prior_weight=1.0, consider_magic_clip=True, consider_endpoints=False, n_startup_trials=10, n_ei_candidates=24, gamma=<function default_gamma>, weights=<function default_weights>, seed=None, *, multivariate=False, group=False, warn_independent_sampling=True, constant_liar=False)

Sampler using TPE (Tree-structured Parzen Estimator) algorithm.

This sampler is based on independent sampling. See also BaseSampler for more details of ‘independent sampling’.

On each trial, for each parameter, TPE fits one Gaussian Mixture Model (GMM) \( l(x) \) to the set of parameter values associated with the best objective values, and another GMM \( g(x) \) to the remaining parameter values. It chooses the parameter value \( x \) that maximizes the ratio \( l(x)/g(x) \).

For further information about TPE algorithm, please refer to the following papers:

• **Algorithms for Hyper-Parameter Optimization**
• Making a Science of Model Search: Hyperparameter Optimization in Hundreds of Dimensions for Vision Architectures
• Multiobjective tree-structured parzen estimator for computationally expensive optimization problems

Example

```python
import optuna
from optuna.samplers import TPESampler

def objective(trial):
    x = trial.suggest_float("x", -10, 10)
    return x ** 2

study = optuna.create_study(sampler=TPESampler())
study.optimize(objective, n_trials=10)
```

Parameters

- **consider_prior** – Enhance the stability of Parzen estimator by imposing a Gaussian prior when True. The prior is only effective if the sampling distribution is either `UniformDistribution`, `DiscreteUniformDistribution`, `LogUniformDistribution`, `IntUniformDistribution`, or `IntLogUniformDistribution`.

- **prior_weight** – The weight of the prior. This argument is used in `UniformDistribution`, `DiscreteUniformDistribution`, `LogUniformDistribution`, `IntUniformDistribution`, `IntLogUniformDistribution`, and `CategoricalDistribution`.

- **consider_magic_clip** – Enable a heuristic to limit the smallest variances of Gaussians used in the Parzen estimator.

- **consider_endpoints** – Take endpoints of domains into account when calculating variances of Gaussians in Parzen estimator. See the original paper for details on the heuristics to calculate the variances.

- **n_startup_trials** – The random sampling is used instead of the TPE algorithm until the given number of trials finish in the same study.

- **n_ei_candidates** – Number of candidate samples used to calculate the expected improvement.

- **gamma** – A function that takes the number of finished trials and returns the number of trials to form a density function for samples with low grains. See the original paper for more details.

- **weights** – A function that takes the number of finished trials and returns a weight for them. See Making a Science of Model Search: Hyperparameter Optimization in Hundreds of Dimensions for Vision Architectures for more details.

**Note:** In the multi-objective case, this argument is only used to compute the weights of bad trials, i.e., trials to construct $g(x)$ in the paper. The weights of good trials, i.e., trials to
construct \( l(x) \), are computed by a rule based on the hypervolume contribution proposed in the paper of MOTPE.

- **seed** – Seed for random number generator.

- **multivariate** – If this is `True`, the multivariate TPE is used when suggesting parameters. The multivariate TPE is reported to outperform the independent TPE. See BOHB: Robust and Efficient Hyperparameter Optimization at Scale for more details.

  Note: Added in v2.2.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.2.0.

- **group** – If this and **multivariate** are `True`, the multivariate TPE with the group decomposed search space is used when suggesting parameters. The sampling algorithm decomposes the search space based on past trials and samples from the joint distribution in each decomposed subspace. The decomposed subspaces are a partition of the whole search space. Each subspace is a maximal subset of the whole search space, which satisfies the following: for a trial in completed trials, the intersection of the subspace and the search space of the trial becomes subspace itself or an empty set. Sampling from the joint distribution on the subspace is realized by multivariate TPE.

  Note: Added in v2.8.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.8.0.

Example:

```python
import optuna

def objective(trial):
    x = trial.suggest_categorical("x", ["A", "B"])
    if x == "A":
        return trial.suggest_float("y", -10, 10)
    else:
        return trial.suggest_int("z", -10, 10)

sampler = optuna.samplers.TPESampler(multivariate=True, group=True)
study = optuna.create_study(sampler=sampler)
study.optimize(objective, n_trials=10)
```

- **warn_independent_sampling** – If this is `True` and **multivariate** is `True`, a warning message is emitted when the value of a parameter is sampled by using an independent sampler. If **multivariate** is `False`, this flag has no effect.

- **constant_liar** – If `True`, penalize running trials to avoid suggesting parameter configurations nearby.

  Note: Abnormally terminated trials often leave behind a record with a state of `RUNNING` in the storage. Such “zombie” trial parameters will be avoided by the constant liar algorithm during subsequent sampling. When using an `RDBStorage`, it is possible to enable the `heartbeat_interval` to change the records for abnormally terminated trials to `FAIL`. 


**Note:** It is recommended to set this value to `True` during distributed optimization to avoid having multiple workers evaluating similar parameter configurations. In particular, if each objective function evaluation is costly and the durations of the running states are significant, and/or the number of workers is high.

**Note:** Added in v2.8.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.8.0.

**Raises** `ValueError` – If `multivariate` is `False` and `group` is `True`.

**Methods**

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>after_trial(study, trial, state, values)</code></td>
<td>Trial post-processing.</td>
</tr>
<tr>
<td><code>hyperopt_parameters()</code></td>
<td>Return the default parameters of hyperopt (v0.1.2).</td>
</tr>
<tr>
<td><code>infer_relative_search_space(study, trial)</code></td>
<td>Infer the search space that will be used by relative sampling in the target trial.</td>
</tr>
<tr>
<td><code>reseed_rng()</code></td>
<td>Reseed sampler’s random number generator.</td>
</tr>
<tr>
<td><code>sample_independent(study, trial, param_name, ...)</code></td>
<td>Sample a parameter for a given distribution.</td>
</tr>
<tr>
<td><code>sample_relative(study, trial, search_space)</code></td>
<td>Sample parameters in a given search space.</td>
</tr>
</tbody>
</table>

**after_trial**(study, trial, state, values)

Trial post-processing.

This method is called after the objective function returns and right before the trials is finished and its state is stored.

**Note:** Added in v2.4.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.4.0.

**Parameters**

- `study` ([`optuna.study.Study`]) – Target study object.
- `trial` ([`optuna.trial.FrozenTrial`]) – Target trial object. Take a copy before modifying this object.
- `state` ([`optuna.trial.TrialState`]) – Resulting trial state.
- `values` ([`Optional[Sequence[float]]`]) – Resulting trial values. Guaranteed to not be `None` if trial succeeded.

**Return type** `None`

**static hyperopt_parameters()**

Return the default parameters of hyperopt (v0.1.2).

`TPESampler` can be instantiated with the parameters returned by this method.
Example

Create a `TPESampler` instance with the default parameters of hyperopt.

```python
import optuna
from optuna.samplers import TPESampler

def objective(trial):
    x = trial.suggest_float("x", -10, 10)
    return x ** 2

sampler = TPESampler(**TPESampler.hyperopt_parameters())
study = optuna.create_study(sampler=sampler)
study.optimize(objective, n_trials=10)
```

**Returns** A dictionary containing the default parameters of hyperopt.

**Return type** Dict[str, Any]

`infer_relative_search_space` *(study, trial)*

Infer the search space that will be used by relative sampling in the target trial.

This method is called right before `sample_relative()` method, and the search space returned by this method is passed to it. The parameters not contained in the search space will be sampled by using `sample_independent()` method.

**Parameters**

- **study** (*optuna.study.Study*) – Target study object.
- **trial** (*optuna.trial.FrozenTrial*) – Target trial object. Take a copy before modifying this object.

**Returns** A dictionary containing the parameter names and parameter’s distributions.

**Return type** Dict[str, optuna.distributions.BaseDistribution]

See also:

Please refer to `intersection_search_space()` as an implementation of `infer_relative_search_space()`.

`reseed_rng()`

Reseed sampler’s random number generator.

This method is called by the `Study` instance if trials are executed in parallel with the option `n_jobs>1`. In that case, the sampler instance will be replicated including the state of the random number generator, and they may suggest the same values. To prevent this issue, this method assigns a different seed to each random number generator.

**Return type** None

`sample_independent` *(study, trial, param_name, param_distribution)*

Sample a parameter for a given distribution.

This method is called only for the parameters not contained in the search space returned by `sample_relative()` method. This method is suitable for sampling algorithms that do not use relationship between parameters such as random sampling and TPE.
Note: The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

Parameters

- **study** (optuna.study.study.Study) – Target study object.
- **trial** (optuna.trial._frozen.FrozenTrial) – Target trial object. Take a copy before modifying this object.
- **param_name** (str) – Name of the sampled parameter.
- **param_distribution** (optuna.distributions.BaseDistribution) – Distribution object that specifies a prior and/or scale of the sampling algorithm.

Returns A parameter value.

Return type Any

**sample_relative** (study, trial, search_space)

Sample parameters in a given search space.

This method is called once at the beginning of each trial, i.e., right before the evaluation of the objective function. This method is suitable for sampling algorithms that use relationship between parameters such as Gaussian Process and CMA-ES.

Note: The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

Parameters

- **study** (optuna.study.study.Study) – Target study object.
- **trial** (optuna.trial._frozen.FrozenTrial) – Target trial object. Take a copy before modifying this object.
- **search_space** (Dict[str, optuna.distributions.BaseDistribution]) – The search space returned by infer_relative_search_space().

Returns A dictionary containing the parameter names and the values.

Return type Dict[str, Any]

**optuna.samplers.CmaEsSampler**

class optuna.samplers.CmaEsSampler (x0=None, sigma0=None, n_startup_trials=1, independent_sampler=None, warn_independent_sampling=True, seed=None, *, consider_pruned_trials=False, restart_strategy=None, inc_popsize=2, use_separable_cma=False, source_trials=None)

A sampler using cmaes as the backend.
**Example**

Optimize a simple quadratic function by using `CmaEsSampler`.

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", -1, 1)
    y = trial.suggest_int("y", -1, 1)
    return x ** 2 + y

sampler = optuna.samplers.CmaEsSampler()
study = optuna.create_study(sampler=sampler)
study.optimize(objective, n_trials=20)
```

Please note that this sampler does not support CategoricalDistribution. However, `DiscreteUniformDistribution` (`suggest_discrete_uniform()`) and `Int(Log)Distribution` (`suggest_int()`) are supported.

If your search space contains categorical parameters, I recommend you to use `TPESampler` instead. Furthermore, there is room for performance improvements in parallel optimization settings. This sampler cannot use some trials for updating the parameters of multivariate normal distribution.

For further information about CMA-ES algorithm, please refer to the following papers:


**See also:**

You can also use `optuna.integration.PyCmaSampler` which is a sampler using cma library as the backend.

**Parameters**

- `x0` – A dictionary of an initial parameter values for CMA-ES. By default, the mean of `low` and `high` for each distribution is used. Note that `x0` is sampled uniformly within the search space domain for each restart if you specify `restart_strategy` argument.

- `sigma0` – Initial standard deviation of CMA-ES. By default, `sigma0` is set to `min_range / 6`, where `min_range` denotes the minimum range of the distributions in the search space.

- `seed` – A random seed for CMA-ES.

- `n_startup_trials` – The independent sampling is used instead of the CMA-ES algorithm until the given number of trials finish in the same study.

- `independent_sampler` – A `BaseSampler` instance that is used for independent sampling. The parameters not contained in the relative search space are sam-
If None is specified, RandomSampler is used as the default.

See also:

optuna.samplers module provides built-in independent samplers such as RandomSampler and TPESampler.

• warn_independent_sampling – If this is True, a warning message is emitted when the value of a parameter is sampled by using an independent sampler. Note that the parameters of the first trial in a study are always sampled via an independent sampler, so no warning messages are emitted in this case.

• restart_strategy – Strategy for restarting CMA-ES optimization when converges to a local minimum. If given None, CMA-ES will not restart (default). If given ‘ipop’, CMA-ES will restart with increasing population size. Please see also inc_popsize parameter.

Note: Added in v2.1.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.1.0.

• inc_popsize – Multiplier for increasing population size before each restart. This argument will be used when setting restart_strategy = 'ipop'.

• consider_pruned_trials – If this is True, the PRUNED trials are considered for sampling.

Note: Added in v2.0.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.0.0.

Note: It is suggested to set this flag False when the MedianPruner is used. On the other hand, it is suggested to set this flag True when the HyperbandPruner is used. Please see the benchmark result for the details.

• use_separable_cma – If this is True, the covariance matrix is constrained to be diagonal. Due to reduce the model complexity, the learning rate for the covariance matrix is increased. Consequently, this algorithm outperforms CMA-ES on separable functions.

Note: Added in v2.6.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.6.0.

• source_trials – This option is for Warm Starting CMA-ES, a method to transfer prior knowledge on similar HPO tasks through the initialization of CMA-ES. This method estimates a promising distribution from source_trials and generates the parameter of multivariate gaussian distribution. Please note that it is prohibited to use x0, sigma0, or use_separable_cma argument together.

Note: Added in v2.6.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.6.0.
Raises `ValueError` – If `restart_strategy` is not ‘ipop’ or `None`.

### Methods

<table>
<thead>
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<td><code>sample_relative(study, trial, search_space)</code></td>
<td>Sample parameters in a given search space.</td>
</tr>
</tbody>
</table>

#### Parameters

- `study` (`optuna.study.study.Study`) – Target study object.
- `trial` (`optuna.trial._frozen.FrozenTrial`) – Target trial object. Take a copy before modifying this object.
- `state` (`optuna.trial._state.TrialState`) – Resulting trial state.
- `values` (`Optional[Sequence[float]]`) – Resulting trial values. Guaranteed to not be `None` if trial succeeded.

#### Return type

None

#### See also:

Please refer to `intersection_search_space()` as an implementation of `infer_relative_search_space()`.
**reseed_rng()**
Reseed sampler’s random number generator.

This method is called by the *Study* instance if trials are executed in parallel with the option `n_jobs>1`. In that case, the sampler instance will be replicated including the state of the random number generator, and they may suggest the same values. To prevent this issue, this method assigns a different seed to each random number generator.

**Return type**  
None

**sample_independent(study, trial, param_name, param_distribution)**
Sample a parameter for a given distribution.

This method is called only for the parameters not contained in the search space returned by `sample_relative()` method. This method is suitable for sampling algorithms that do not use relationship between parameters such as random sampling and TPE.

**Note:**  
The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

**Parameters**

- **study** *(optuna.study.study.Study)* – Target study object.
- **trial** *(optuna.trial._frozen.FrozenTrial)* – Target trial object. Take a copy before modifying this object.
- **param_name** *(str)* – Name of the sampled parameter.
- **param_distribution** *(optuna.distributions.BaseDistribution)* – Distribution object that specifies a prior and/or scale of the sampling algorithm.

**Returns**  
A parameter value.

**Return type**  
Any

**sample_relative(study, trial, search_space)**
Sample parameters in a given search space.

This method is called once at the beginning of each trial, i.e., right before the evaluation of the objective function. This method is suitable for sampling algorithms that use relationship between parameters such as Gaussian Process and CMA-ES.

**Note:**  
The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

**Parameters**

- **study** *(optuna.study.study.Study)* – Target study object.
- **trial** *(optuna.trial._frozen.FrozenTrial)* – Target trial object. Take a copy before modifying this object.
- **search_space** *(Dict[str, optuna.distributions.BaseDistribution])* – The search space returned by `infer_relative_search_space()`.

**Returns**  
A dictionary containing the parameter names and the values.
optuna.samplers.PartialFixedSampler

class optuna.samplers.PartialFixedSampler(fixed_params, base_sampler)
Sampler with partially fixed parameters.
New in version 2.4.0.

Example

After several steps of optimization, you can fix the value of y and re-optimize it.

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", -1, 1)
    y = trial.suggest_int("y", -1, 1)
    return x ** 2 + y

study = optuna.create_study()
study.optimize(objective, n_trials=10)

best_params = study.best_params
fixed_params = {"y": best_params["y"]}
partial_sampler = optuna.samplers.PartialFixedSampler(fixed_params, study.sampler)
study.sampler = partial_sampler
study.optimize(objective, n_trials=10)
```

Parameters

- **fixed_params** – A dictionary of parameters to be fixed.
- **base_sampler** – A sampler which samples unfixed parameters.

Note: Added in v2.4.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.4.0.

Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>after_trial</code></td>
<td>Trial post-processing.</td>
</tr>
<tr>
<td><code>infer_relative_search_space</code></td>
<td>Infer the search space that will be used by relative sampling in the target trial.</td>
</tr>
<tr>
<td><code>reseed_rng</code></td>
<td>Reseed sampler’s random number generator.</td>
</tr>
<tr>
<td><code>sample_independent</code></td>
<td>Sample a parameter for a given distribution.</td>
</tr>
<tr>
<td><code>sample_relative</code></td>
<td>Sample parameters in a given search space.</td>
</tr>
</tbody>
</table>
**after_trial** *(study, trial, state, values)*

Trial post-processing.

This method is called after the objective function returns and right before the trials is finished and its state is stored.

---

**Note:** Added in v2.4.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.4.0.

---

**Parameters**

- **study** *(optuna.study.study.Study)* – Target study object.
- **trial** *(optuna.trial._frozen.FrozenTrial)* – Target trial object. Take a copy before modifying this object.
- **state** *(optuna.trial._state.TrialState)* – Resulting trial state.
- **values** *(Optional[Sequence[float]])* – Resulting trial values. Guaranteed to not be None if trial succeeded.

**Return type** None

**infer_relative_search_space** *(study, trial)*

Infer the search space that will be used by relative sampling in the target trial.

This method is called right before *sample_relative()* method, and the search space returned by this method is passed to it. The parameters not contained in the search space will be sampled by using *sample_independent()* method.

**Parameters**

- **study** *(optuna.study.study.Study)* – Target study object.
- **trial** *(optuna.trial._frozen.FrozenTrial)* – Target trial object. Take a copy before modifying this object.

**Returns** A dictionary containing the parameter names and parameter’s distributions.

**Return type** Dict[str, optuna.distributions.BaseDistribution]

**See also:**

Please refer to *intersection_search_space()* as an implementation of *infer_relative_search_space()*.

**reseed_rng** *

Reseed sampler’s random number generator.

This method is called by the *Study* instance if trials are executed in parallel with the option *n_jobs>*1. In that case, the sampler instance will be replicated including the state of the random number generator, and they may suggest the same values. To prevent this issue, this method assigns a different seed to each random number generator.

**Return type** None

**sample_independent** *(study, trial, param_name, param_distribution)*

Sample a parameter for a given distribution.

This method is called only for the parameters not contained in the search space returned by *sample_relative()* method. This method is suitable for sampling algorithms that do not use relationship between parameters such as random sampling and TPE.
Note: The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

Parameters

- **study** (*optuna.study.study.Study*) – Target study object.
- **trial** (*optuna.trial._frozen.FrozenTrial*) – Target trial object. Take a copy before modifying this object.
- **param_name** (*str*) – Name of the sampled parameter.
- **param_distribution** (*optuna.distributions.BaseDistribution*) – Distribution object that specifies a prior and/or scale of the sampling algorithm.

Returns A parameter value.

Return type Any

**sample_relative** (*study, trial, search_space*)

Sample parameters in a given search space.

This method is called once at the beginning of each trial, i.e., right before the evaluation of the objective function. This method is suitable for sampling algorithms that use relationship between parameters such as Gaussian Process and CMA-ES.

Note: The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

Parameters

- **study** (*optuna.study.study.Study*) – Target study object.
- **trial** (*optuna.trial._frozen.FrozenTrial*) – Target trial object. Take a copy before modifying this object.
- **search_space** (*Dict[str, optuna.distributions.BaseDistribution]*) – The search space returned by `infer_relative_search_space()`.

Returns A dictionary containing the parameter names and the values.

Return type Dict[str, Any]

**optuna.samplers.NSGAIISampler**

class **optuna.samplers.NSGAIISampler**(*,  
  population_size=50,  
  mutation_prob=None,  
  crossover_prob=0.9,  
  swapping_prob=0.5,  
  seed=None,  
  constraints_func=None)

Multi-objective sampler using the NSGA-II algorithm.

NSGA-II stands for “Nondominated Sorting Genetic Algorithm II”, which is a well known, fast and elitist multi-objective genetic algorithm.

For further information about NSGA-II, please refer to the following paper:

- A fast and elitist multiobjective genetic algorithm: NSGA-II
Parameters

- **population_size** – Number of individuals (trials) in a generation.
- **mutation_prob** – Probability of mutating each parameter when creating a new individual. If `None` is specified, the value `1.0 / len(parent_trial.params)` is used where `parent_trial` is the parent trial of the target individual.
- **crossover_prob** – Probability that a crossover (parameters swapping between parents) will occur when creating a new individual.
- **swapping_prob** – Probability of swapping each parameter of the parents during crossover.
- **seed** – Seed for random number generator.
- **constraints_func** – An optional function that computes the objective constraints. It must take a `FrozenTrial` and return the constraints. The return value must be a sequence of `floats`. A value strictly larger than 0 means that a constraints is violated. A value equal to or smaller than 0 is considered feasible. If `constraints_func` returns more than one value for a trial, that trial is considered feasible if and only if all values are equal to 0 or smaller.

The `constraints_func` will be evaluated after each successful trial. The function won’t be called when trials fail or they are pruned, but this behavior is subject to change in the future releases.

The constraints are handled by the constrained domination. A trial `x` is said to constrained-dominate a trial `y`, if any of the following conditions is true:

1. Trial `x` is feasible and trial `y` is not.
2. Trial `x` and `y` are both infeasible, but trial `x` has a smaller overall violation.
3. Trial `x` and `y` are feasible and trial `x` dominates trial `y`.

**Note:** Added in v2.5.0 as an experimental feature. The interface may change in newer versions without prior notice. See [https://github.com/optuna/optuna/releases/tag/v2.5.0](https://github.com/optuna/optuna/releases/tag/v2.5.0).

Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>after_trial(study, trial, state, values)</code></td>
<td>Trial post-processing.</td>
</tr>
<tr>
<td><code>infer_relative_search_space(study, trial)</code></td>
<td>Infer the search space that will be used by relative sampling in the target trial.</td>
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</tr>
<tr>
<td><code>sample_independent(study, trial, param_name, ...)</code></td>
<td>Sample a parameter for a given distribution.</td>
</tr>
<tr>
<td><code>sample_relative(study, trial, search_space)</code></td>
<td>Sample parameters in a given search space.</td>
</tr>
</tbody>
</table>

**after_trial (study, trial, state, values)**

Trial post-processing.

This method is called after the objective function returns and right before the trials is finished and its state is stored.

**Note:** Added in v2.4.0 as an experimental feature. The interface may change in newer versions without
prior notice. See https://github.com/optuna/optuna/releases/tag/v2.4.0.

Parameters

- **study** *(optuna.study.study.Study)* – Target study object.
- **trial** *(optuna.trial._frozen.FrozenTrial)* – Target trial object. Take a copy before modifying this object.
- **state** *(optuna.trial._state.TrialState)* – Resulting trial state.
- **values** *(Optional[Sequence[float]])* – Resulting trial values. Guaranteed to not be None if trial succeeded.

Return type None

**infer_relative_search_space** *(study, trial)*

Infer the search space that will be used by relative sampling in the target trial.

This method is called right before **sample_relative()** method, and the search space returned by this method is passed to it. The parameters not contained in the search space will be sampled by using **sample_independent()** method.

Parameters

- **study** *(optuna.study.study.Study)* – Target study object.
- **trial** *(optuna.trial._frozen.FrozenTrial)* – Target trial object. Take a copy before modifying this object.

Returns A dictionary containing the parameter names and parameter’s distributions.

Return type Dict[str, optuna.distributions.BaseDistribution]

See also:

Please refer to **intersection_search_space()** as an implementation of **infer_relative_search_space()**.

**reseed_rng** ()

Reseed sampler’s random number generator.

This method is called by the **Study** instance if trials are executed in parallel with the option **n_jobs>1**. In that case, the sampler instance will be replicated including the state of the random number generator, and they may suggest the same values. To prevent this issue, this method assigns a different seed to each random number generator.

Return type None

**sample_independent** *(study, trial, param_name, param_distribution)*

Sample a parameter for a given distribution.

This method is called only for the parameters not contained in the search space returned by **sample_relative()** method. This method is suitable for sampling algorithms that do not use relationship between parameters such as random sampling and TPE.

Note: The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

Parameters
• **study** (*optuna.study.study.Study*) – Target study object.

• **trial** (*optuna.trial._frozen.FrozenTrial*) – Target trial object. Take a copy before modifying this object.

• **param_name** (*str*) – Name of the sampled parameter.

• **param_distribution** (*optuna.distributions.BaseDistribution*) – Distribution object that specifies a prior and/or scale of the sampling algorithm.

**Returns**  A parameter value.

**Return type**  Any

### sample_relative(study, trial, search_space)

Sample parameters in a given search space.

This method is called once at the beginning of each trial, i.e., right before the evaluation of the objective function. This method is suitable for sampling algorithms that use relationship between parameters such as Gaussian Process and CMA-ES.

**Note:** The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

**Parameters**

• **study** (*optuna.study.study.Study*) – Target study object.

• **trial** (*optuna.trial._frozen.FrozenTrial*) – Target trial object. Take a copy before modifying this object.

• **search_space** (*Dict[str, optuna.distributions.BaseDistribution]*) – The search space returned by `infer_relative_search_space()`.

**Returns**  A dictionary containing the parameter names and the values.

**Return type**  Dict[str, Any]

### optuna.samplers.MOTPESampler

**class optuna.samplers.MOTPESampler** (*, consider_prior=True, prior_weight=1.0, consider_magic_clip=True, consider_endpoints=True, n_startup_trials=10, n_ehvi_candidates=24, gamma=<function default_gamma>, weights_above=<function _default_weights_above>, seed=None)

Multi-objective sampler using the MOTPE algorithm.

This sampler is a multiobjective version of `TPESampler`.

For further information about MOTPE algorithm, please refer to the following paper:

• Multiobjective tree-structured parzen estimator for computationally expensive optimization problems
• **`consider_prior`** – Enhance the stability of Parzen estimator by imposing a Gaussian prior when `True`. The prior is only effective if the sampling distribution is either `UniformDistribution`, `DiscreteUniformDistribution`, `LogUniformDistribution`, `IntUniformDistribution`, or `IntLogUniformDistribution`.

• **`prior_weight`** – The weight of the prior. This argument is used in `UniformDistribution`, `DiscreteUniformDistribution`, `LogUniformDistribution`, `IntUniformDistribution`, `IntLogUniformDistribution`, and `CategoricalDistribution`.

• **`consider_magic_clip`** – Enable a heuristic to limit the smallest variances of Gaussians used in the Parzen estimator.

• **`consider_endpoints`** – Take endpoints of domains into account when calculating variances of Gaussians in Parzen estimator. See the original paper for details on the heuristics to calculate the variances.

• **`n_startup_trials`** – The random sampling is used instead of the MOTPE algorithm until the given number of trials finish in the same study. $11 \times \text{number of variables} - 1$ is recommended in the original paper.

• **`n_ehvi_candidates`** – Number of candidate samples used to calculate the expected hypervolume improvement.

• **`gamma`** – A function that takes the number of finished trials and returns the number of trials to form a density function for samples with low grains. See the original paper for more details.

• **`weights_above`** – A function that takes the number of finished trials and returns a weight for them. As default, weights are automatically calculated by the MOTPE’s default strategy.

• **`seed`** – Seed for random number generator.

**Note:** Initialization with Latin hypercube sampling may improve optimization performance. However, the current implementation only supports initialization with random sampling.

### Example

```python
import optuna

seed = 128
num_variables = 2
n_startup_trials = 11 * num_variables - 1

def objective(trial):
    x = []
    for i in range(1, num_variables + 1):
        x.append(trial.suggest_float(f"x{i}", 0.0, 2.0 * i))
    return x

sampler = optuna.samplers.MOTPESampler(
    n_startup_trials=n_startup_trials, n_ehvi_candidates=24, seed=seed)
```

(continues on next page)
study = optuna.create_study(directions=["minimize"] * num_variables, ↓
   sampler=sampler)
study.optimize(objective, n_trials=n_startup_trials + 10)

**Warning:** Deprecated in v2.9.0. This feature will be removed in the future. The removal of this feature is currently scheduled for v4.0.0, but this schedule is subject to change. See https://github.com/optuna/optuna/releases/tag/v2.9.0.

### Methods

<table>
<thead>
<tr>
<th>Method Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>after_trial</strong> (study, trial, state, values)</td>
<td>Trial post-processing.</td>
</tr>
<tr>
<td><strong>hyperopt_parameters()</strong></td>
<td>Return the the default parameters of hyperopt (v0.1.2).</td>
</tr>
<tr>
<td><strong>infer_relative_search_space(study, trial)</strong></td>
<td>Infer the search space that will be used by relative sampling in the target trial.</td>
</tr>
<tr>
<td><strong>reseed_rng()</strong></td>
<td>Reseed sampler’s random number generator.</td>
</tr>
<tr>
<td><strong>sample_independent(study, trial, param_name, ...)</strong></td>
<td>Sample a parameter for a given distribution.</td>
</tr>
<tr>
<td><strong>sample_relative(study, trial, search_space)</strong></td>
<td>Sample parameters in a given search space.</td>
</tr>
</tbody>
</table>

**after_trial** *(study, trial, state, values)*

Trial post-processing.

This method is called after the objective function returns and right before the trials is finished and its state is stored.

**Note:** Added in v2.4.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.4.0.

**Parameters**

- **study** *(optuna.study.study.Study)* – Target study object.
- **trial** *(optuna.trial._frozen.FrozenTrial)* – Target trial object. Take a copy before modifying this object.
- **state** *(optuna.trial._state.TrialState)* – Resulting trial state.
- **values** *(Optional[Sequence[float]])* – Resulting trial values. Guaranteed to not be None if trial succeeded.

**Return type** None

**static hyperopt_parameters()**

Return the the default parameters of hyperopt (v0.1.2).

*TPESampler* can be instantiated with the parameters returned by this method.
Example

Create a TPESampler instance with the default parameters of hyperopt.

```python
import optuna
from optuna.samplers import TPESampler

def objective(trial):
    x = trial.suggest_float("x", -10, 10)
    return x ** 2

sampler = TPESampler(**TPESampler.hyperopt_parameters())
study = optuna.create_study(sampler=sampler)
study.optimize(objective, n_trials=10)
```

**Returns** A dictionary containing the default parameters of hyperopt.

**Return type** Dict[str, Any]

`infer_relative_search_space` *(study, trial)*

Infer the search space that will be used by relative sampling in the target trial.

This method is called right before `sample_relative()` method, and the search space returned by this method is passed to it. The parameters not contained in the search space will be sampled by using `sample_independent()` method.

**Parameters**

- **study** (optuna.study.Study) – Target study object.
- **trial** (optuna.trial._frozen.FrozenTrial) – Target trial object. Take a copy before modifying this object.

**Returns** A dictionary containing the parameter names and parameter’s distributions.

**Return type** Dict[str, optuna.distributions.BaseDistribution]

See also:

Please refer to `intersection_search_space()` as an implementation of `infer_relative_search_space()`.

`reseed_rng` ()

Reseed sampler’s random number generator.

This method is called by the Study instance if trials are executed in parallel with the option n_jobs>1. In that case, the sampler instance will be replicated including the state of the random number generator, and they may suggest the same values. To prevent this issue, this method assigns a different seed to each random number generator.

**Return type** None

`sample_independent` *(study, trial, param_name, param_distribution)*

Sample a parameter for a given distribution.

This method is called only for the parameters not contained in the search space returned by `sample_relative()` method. This method is suitable for sampling algorithms that do not use relationship between parameters such as random sampling and TPE.
Note: The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

Parameters

- **study** (*optuna.study.Study*) – Target study object.
- **trial** (*optuna.trial.FrozenTrial*) – Target trial object. Take a copy before modifying this object.
- **param_name** (*str*) – Name of the sampled parameter.
- **param_distribution** (*optuna.distributions.BaseDistribution*) – Distribution object that specifies a prior and/or scale of the sampling algorithm.

Returns: A parameter value.

Return type: Any

```
sample_relative(study, trial, search_space)
```

Sample parameters in a given search space.

This method is called once at the beginning of each trial, i.e., right before the evaluation of the objective function. This method is suitable for sampling algorithms that use relationship between parameters such as Gaussian Process and CMA-ES.

Note: The failed trials are ignored by any build-in samplers when they sample new parameters. Thus, failed trials are regarded as deleted in the samplers’ perspective.

Parameters

- **study** (*optuna.study.Study*) – Target study object.
- **trial** (*optuna.trial.FrozenTrial*) – Target trial object. Take a copy before modifying this object.
- **search_space** (*Dict[str, optuna.distributions.BaseDistribution]*) – The search space returned by `infer_relative_search_space()`.

Returns: A dictionary containing the parameter names and the values.

Return type: Dict[str, Any]

**optuna.samplers.IntersectionSearchSpace**

```
class optuna.samplers.IntersectionSearchSpace(include_pruned=False)
```

A class to calculate the intersection search space of a **BaseStudy**.

Intersection search space contains the intersection of parameter distributions that have been suggested in the completed trials of the study so far. If there are multiple parameters that have the same name but different distributions, neither is included in the resulting search space (i.e., the parameters with dynamic value ranges are excluded).

Note that an instance of this class is supposed to be used for only one study. If different studies are passed to `calculate()`, a **ValueError** is raised.
Parameters `include_pruned` – Whether pruned trials should be included in the search space.

Methods

```python
calculate(study[, ordered_dict])
```

Returns the intersection search space of the `BaseStudy`.

```python
calculate(study, ordered_dict=False)
```

Returns the intersection search space of the `BaseStudy`.

Parameters

- `study` (`optuna.study.study.BaseStudy`) – A study with completed trials.
- `ordered_dict` (`bool`) – A boolean flag determining the return type. If `False`, the returned object will be a `dict`. If `True`, the returned object will be an `collections.OrderedDict` sorted by keys, i.e. parameter names.

Returns A dictionary containing the parameter names and parameter’s distributions.

Raises `ValueError` – If different studies are passed into this method.

Return type `Dict[str, optuna.distributions.BaseDistribution]`

```python
optuna.samplers.intersection_search_space
```

```python
optuna.samplers.intersection_search_space(study, ordered_dict=False, include_pruned=False)
```

Return the intersection search space of the `BaseStudy`.

Intersection search space contains the intersection of parameter distributions that have been suggested in the completed trials of the study so far. If there are multiple parameters that have the same name but different distributions, neither is included in the resulting search space (i.e., the parameters with dynamic value ranges are excluded).

**Note:** `IntersectionSearchSpace` provides the same functionality with a much faster way. Please consider using it if you want to reduce execution time as much as possible.

Parameters

- `study` (`optuna.study.study.BaseStudy`) – A study with completed trials.
- `ordered_dict` (`bool`) – A boolean flag determining the return type. If `False`, the returned object will be a `dict`. If `True`, the returned object will be an `collections.OrderedDict` sorted by keys, i.e. parameter names.
- `include_pruned` (`bool`) – Whether pruned trials should be included in the search space.

Returns A dictionary containing the parameter names and parameter’s distributions.

Return type `Dict[str, optuna.distributions.BaseDistribution]`
6.3.11 optuna.storages

The `storages` module defines a `BaseStorage` class which abstracts a backend database and provides library-internal interfaces to the read/write histories of the studies and trials. Library users who wish to use storage solutions other than the default in-memory storage should use one of the child classes of `BaseStorage` documented below.

<table>
<thead>
<tr>
<th>Class Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>optuna.storages.RDBStorage</code></td>
<td>Storage class for RDB backend.</td>
</tr>
<tr>
<td><code>optuna.storages.RedisStorage</code></td>
<td>Storage class for Redis backend.</td>
</tr>
<tr>
<td><code>optuna.storages.RetryFailedTrialCallback</code></td>
<td>Retry a failed trial up to a maximum number of times.</td>
</tr>
<tr>
<td><code>optuna.storages.fail_stale_trials</code></td>
<td>Fail stale trials and run their failure callbacks.</td>
</tr>
</tbody>
</table>

**optuna.storages.RDBStorage**

```python
class optuna.storages.RDBStorage(url, engine_kwargs=None, skip_compatibility_check=False,
                                 *, heartbeat_interval=None, grace_period=None,
                                 failed_trial_callback=None)
```

Storage class for RDB backend.

Note that library users can instantiate this class, but the attributes provided by this class are not supposed to be directly accessed by them.

**Example**

Create an `RDBStorage` instance with customized `pool_size` and `timeout` settings.

```python
import optuna
def objective(trial):
    x = trial.suggest_float("x", -100, 100)
    return x ** 2

storage = optuna.storages.RDBStorage(
    url="sqlite:////:memory:",
    engine_kwargs={"pool_size": 20, "connect_args": {"timeout": 10}},
)

study = optuna.create_study(storage=storage)
study.optimize(objective, n_trials=10)
```

**Parameters**

- **url** – URL of the storage.
- **engine_kwargs** – A dictionary of keyword arguments that is passed to `sqlalchemy.engine.create_engine` function.
- **skip_compatibility_check** – Flag to skip schema compatibility check if set to True.
- **heartbeat_interval** – Interval to record the heartbeat. It is recorded every `interval` seconds.
- **grace_period** – Grace period before a running trial is failed from the last heartbeat. If it is `None`, the grace period will be `2 * heartbeat_interval`. 
• **failed_trial_callback** – A callback function that is invoked after failing each stale trial. The function must accept two parameters with the following types in this order: `Study` and `FrozenTrial`.

**Note:** The procedure to fail existing stale trials is called just before asking the study for a new trial.

**Note:** If you use MySQL, `pool_pre_ping` will be set to `True` by default to prevent connection timeout. You can turn it off with `engine_kwargs['pool_pre_ping']=False`, but it is recommended to keep the setting if execution time of your objective function is longer than the `wait_timeout` of your MySQL configuration.

**Raises**

• **ValueError** – If the given `heartbeat_interval` or `grace_period` is not a positive integer.

• **RuntimeError** – When a process tries to finish a trial that has already been set to `FAIL` by heartbeat.

**Methods**

| check_trial_is_updatable(trial_id, trial_state) | Check whether a trial state is updatable. |
| create_new_study((study_name)) | Create a new study from a name. |
| create_new_trial(study_id[, template_trial]) | Create and add a new trial to a study. |
| delete_study(study_id) | Delete a study. |
| fail_stale_trials(study_id) | Fail stale trials. |
| get_all_study_summaries() | Read a list of `StudySummary` objects. |
| get_all_trials(study_id[, deepcopy, states]) | Read all trials in a study. |
| get_all_versions() | Return the schema version list. |
| get_best_trial(study_id) | Return the trial with the best value in a study. |
| get_current_version() | Return the schema version currently used by this storage. |
| get_failed_trial_callback() | Get the failed trial callback function. |
| get_head_version() | Return the latest schema version. |
| get_heartbeat_interval() | Get the heartbeat interval if it is set. |
| get_n_trials(study_id[, state]) | Count the number of trials in a study. |
| get_study_directions(study_id) | Read whether a study maximizes or minimizes an objective. |
| get_study_id_from_name(study_name) | Read the ID of a study. |
| get_study_id_from_trial_id(trial_id) | Read the ID of a study to which a trial belongs. |
| get_study_name_from_id(study_id) | Read the study name of a study. |
| get_study_system_attrs(study_id) | Read the optuna-internal attributes of a study. |
| get_study_user_attrs(study_id) | Read the user-defined attributes of a study. |
| get_trial(trial_id) | Read a trial. |
| get_trial_id_from_study_id_trial_num(trial_id) | Read the trial ID of a trial. |
| get_trial_number_from_id(trial_id) | Read the trial number of a trial. |
| get_trial_param(trial_id, param_name) | Read the parameter of a trial. |
| get_trial_params(trial_id) | Read the parameter dictionary of a trial. |
### Table 88 – continued from previous page

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>get_trial_system_attrs</code> (trial_id)</td>
<td>Read the optuna-internal attributes of a trial.</td>
</tr>
<tr>
<td><code>get_trial_user_attrs</code> (trial_id)</td>
<td>Read the user-defined attributes of a trial.</td>
</tr>
<tr>
<td><code>is_heartbeat_enabled</code></td>
<td>Check whether the storage enables the heartbeat.</td>
</tr>
<tr>
<td><code>read_trials_from_remote_storage</code> (study_id)</td>
<td>Make an internal cache of trials up-to-date.</td>
</tr>
<tr>
<td><code>record_heartbeat</code> (trial_id)</td>
<td>Record the heartbeat of the trial.</td>
</tr>
<tr>
<td><code>remove_session</code></td>
<td>Removes the current session.</td>
</tr>
<tr>
<td><code>set_study_directions</code> (study_id, directions)</td>
<td>Register optimization problem directions to a study.</td>
</tr>
<tr>
<td><code>set_study_system_attr</code> (study_id, key, value)</td>
<td>Register an optuna-internal attribute to a study.</td>
</tr>
<tr>
<td><code>set_study_user_attr</code> (study_id, key, value)</td>
<td>Register a user-defined attribute to a study.</td>
</tr>
<tr>
<td><code>set_trial_intermediate_value</code> (trial_id, step, ...)</td>
<td>Report an intermediate value of an objective function.</td>
</tr>
<tr>
<td><code>set_trial_param</code> (trial_id, param_name, ...)</td>
<td>Set a parameter to a trial.</td>
</tr>
<tr>
<td><code>set_trial_state</code> (trial_id, state)</td>
<td>Update the state of a trial.</td>
</tr>
<tr>
<td><code>set_trial_system_attr</code> (trial_id, key, value)</td>
<td>Set an optuna-internal attribute to a trial.</td>
</tr>
<tr>
<td><code>set_trial_user_attr</code> (trial_id, key, value)</td>
<td>Set a user-defined attribute to a trial.</td>
</tr>
<tr>
<td><code>set_trial_values</code> (trial_id, values)</td>
<td>Set return values of an objective function.</td>
</tr>
<tr>
<td><code>upgrade</code></td>
<td>Upgrade the storage schema.</td>
</tr>
</tbody>
</table>

---

**check_trial_is_updatable** (trial_id, trial_state)

Check whether a trial state is updatable.

**Parameters**
- `trial_id` *(int)* – ID of the trial. Only used for an error message.
- `trial_state` *(optuna.trial._state.TrialState)* – Trial state to check.

**Raises** *RuntimeError* – If the trial is already finished.

**Return type** None

**create_new_study** *(study_name=\text{None})*

Create a new study from a name.

If no name is specified, the storage class generates a name. The returned study ID is unique among all current and deleted studies.

**Parameters**
- `study_name` *(Optional[str])* – Name of the new study to create.

**Returns** ID of the created study.

**Raises** *optuna.exceptions.DuplicatedStudyError* – If a study with the same `study_name` already exists.

**Return type** int

**create_new_trial** *(\text{study_id}, template_trial=\text{None})*

Create and add a new trial to a study.

The returned trial ID is unique among all current and deleted trials.

**Parameters**
- `study_id` *(int)* – ID of the study.
- `template_trial` *(Optional[optuna.trial._frozen.FrozenTrial]*) – Template FrozenTrial with default user-attributes, system-attributes, intermediate-values, and a state.

**Returns** ID of the created trial.
Raises `KeyError` – If no study with the matching `study_id` exists.

Return type `int`

```python
def delete_study(study_id)
    Delete a study.

    Parameters
    ----------
    study_id : int
        ID of the study.

    Raises
    -----
    KeyError
        If no study with the matching `study_id` exists.

    Return type
    None
```

```python
def fail_stale_trials(study_id)
    Fail stale trials.

    The running trials whose heartbeat has not been updated for a long time will be failed, that is, those states
    will be changed to `FAIL`. The grace period is `2 * heartbeat_interval`.

    Parameters
    ----------
    study_id : int
        ID of the related study.

    Returns
    List of trial IDs of the failed trials.

    Return type
    List[int]
```

```python
def get_all_study_summaries()
    Read a list of `StudySummary` objects.

    Returns
    A list of `StudySummary` objects.

    Return type
    List[optuna.study._study_summary.StudySummary]
```

```python
def get_all_trials(study_id, deepcopy=True, states=None)
    Read all trials in a study.

    Parameters
    ----------
    study_id : int
        ID of the study.
    deepcopy : bool, optional
        Whether to copy the list of trials before returning. Set to `True` if
        you intend to update the list or elements of the list.
    states : Optional[Tuple[optuna.trial._state.TrialState, ..]], optional
        Trial states to filter on. If None, include all states.

    Returns
    List of trials in the study.

    Raises
    `KeyError`
        If no study with the matching `study_id` exists.

    Return type
    List[optuna.trial._frozen.FrozenTrial]
```

```python
def get_all_versions()
    Return the schema version list.

    Return type
    List[str]
```

```python
def get_best_trial(study_id)
    Return the trial with the best value in a study.

    This method is valid only during single-objective optimization.

    Parameters
    ----------
    study_id : int
        ID of the study.

    Returns
    The trial with the best objective value among all finished trials in the study.

    Raises
    -----
    `KeyError`
        If no study with the matching `study_id` exists.
• **RuntimeError** – If the study has more than one direction.
• **ValueError** – If no trials have been completed.

**Return type** `optuna.trial._frozen.FrozenTrial`

`get_current_version()`
Return the schema version currently used by this storage.

**Return type** `str`

`get_failed_trial_callback()`
Get the failed trial callback function.

**Returns** The failed trial callback function if it is set, otherwise `None`.

**Return type** `Optional[Callable[[optuna.study.Study, optuna.trial.FrozenTrial], None]]`

`get_head_version()`
Return the latest schema version.

**Return type** `str`

`get_heartbeat_interval()`
Get the heartbeat interval if it is set.

**Returns** The heartbeat interval if it is set, otherwise `None`.

**Return type** `Optional[int]`

`get_n_trials(study_id, state=None)`
Count the number of trials in a study.

**Parameters**
• **study_id** (`int`) – ID of the study.
• **state** (`Optional[Union[Tuple[optuna.trial.TrialState, ..], optuna.trial.TrialState]]`) – Trial states to filter on. If `None`, include all states.

**Returns** Number of trials in the study.

**Raises** `KeyError` – If no study with the matching `study_id` exists.

**Return type** `int`

`get_study_directions(study_id)`
Read whether a study maximizes or minimizes an objective.

**Parameters**
• **study_id** (`int`) – ID of a study.

**Returns** Optimization directions list of the study.

**Raises** `KeyError` – If no study with the matching `study_id` exists.

**Return type** `List[optuna.study.StudyDirection]`

`get_study_id_from_name(study_name)`
Read the ID of a study.

**Parameters**
• **study_name** (`str`) – Name of the study.

**Returns** ID of the study.

**Raises** `KeyError` – If no study with the matching `study_name` exists.
get_study_id_from_trial_id(trial_id)
    Read the ID of a study to which a trial belongs.

    Parameters  
    trial_id (int) – ID of the trial.

    Returns  
    ID of the study.

    Raises  
    KeyError – If no trial with the matching trial_id exists.

    Return type  int

get_study_name_from_id(study_id)
    Read the study name of a study.

    Parameters  
    study_id (int) – ID of the study.

    Returns  
    Name of the study.

    Raises  
    KeyError – If no study with the matching study_id exists.

    Return type  str

generate_study_id()
    Generate a study ID.

    Returns  
   Generated study ID.

    Raises  
    ValueError – If generated study ID is not unique.

    Return type  int

generate_trial_id(study_id)
    Generate a trial ID.

    Parameters  
    study_id (int) – ID of the study.

    Returns  
   Generated trial ID.

    Raises  
    ValueError – If generated trial ID is not unique.

    Return type  int

get_study_system_attrs(study_id)
    Read the optuna-internal attributes of a study.

    Parameters  
    study_id (int) – ID of the study.

    Returns  
    Dictionary with the optuna-internal attributes of the study.

    Raises  
    KeyError – If no study with the matching study_id exists.

    Return type  Dict[str, Any]

generate_user_attrs(name, value)
    Generate user attributes.

    Parameters  
    name (str) – Name of the attribute.
    value (Any) – Value of the attribute.

    Returns  
   Generated user attributes.

    Raises  
    ValueError – If generated user attributes are not unique.

    Return type  Dict[str, Any]

generate_study_user_attrs(study_id)
    Generate user attributes of a study.

    Parameters  
    study_id (int) – ID of the study.

    Returns  
    Dictionary with the user attributes of the study.

    Raises  
    KeyError – If no study with the matching study_id exists.

    Return type  Dict[str, Any]

generate_study_user_attrs(study_id)
    Generate user attributes of a study.

    Parameters  
    study_id (int) – ID of the study.

    Returns  
    Dictionary with the user attributes of the study.

    Raises  
    KeyError – If no study with the matching study_id exists.

    Return type  Dict[str, Any]

generate_study_user_attrs(study_id)
    Generate user attributes of a study.

    Parameters  
    study_id (int) – ID of the study.

    Returns  
    Dictionary with the user attributes of the study.

    Raises  
    KeyError – If no study with the matching study_id exists.

    Return type  Dict[str, Any]

get_trial(trial_id)
    Read a trial.

    Parameters  
    trial_id (int) – ID of the trial.

    Returns  
    Trial with a matching trial ID.

    Raises  
    KeyError – If no trial with the matching trial_id exists.

    Return type  optuna.trial._frozen.FrozenTrial

generate_trial_id(study_id)
    Generate a trial ID.

    Parameters  
    study_id (int) – ID of the study.

    Returns  
   Generated trial ID.

    Raises  
    ValueError – If generated trial ID is not unique.

    Return type  int

generate_trial_id(study_id, trial_number)
    Generate a trial ID.

    Parameters  
    study_id (int) – ID of the study.
    trial_number (int) – Number of the trial.

    Returns  
    Generated trial ID.

    Raises  
    ValueError – If generated trial ID is not unique.

    Return type  int

generate_trial_id(study_id, trial_number)
    Generate a trial ID.

    Parameters  
    study_id (int) – ID of the study.
    trial_number (int) – Number of the trial.

    Returns  
    Generated trial ID.

    Raises  
    ValueError – If generated trial ID is not unique.

    Return type  int

generate_trial_id(study_id, trial_number)
    Generate a trial ID.

    Parameters  
    study_id (int) – ID of the study.
    trial_number (int) – Number of the trial.

    Returns  
    Generated trial ID.

    Raises  
    ValueError – If generated trial ID is not unique.

    Return type  int

get_trial_id_from_study_id_trial_number(study_id, trial_number)
    Read the trial ID of a trial.

    Parameters  
    • study_id (int) – ID of the study.
    • trial_number (int) – Number of the trial.

    Returns  
    ID of the trial.

    Raises  
    KeyError – If no trial with the matching study_id and trial_number exists.
Return type: int

get_trial_number_from_id(trial_id)
Read the trial number of a trial.

Note: The trial number is only unique within a study, and is sequential.

Parameters: trial_id (int) – ID of the trial.
Returns: Number of the trial.
Raises: KeyError – If no trial with the matching trial_id exists.

Return type: int

get_trial_param(trial_id, param_name)
Read the parameter of a trial.

Parameters:
- trial_id (int) – ID of the trial.
- param_name (str) – Name of the parameter.
Returns: Internal representation of the parameter.
Raises: KeyError – If no trial with the matching trial_id exists. If no such parameter exists.

Return type: float

get_trial_params(trial_id)
Read the parameter dictionary of a trial.

Parameters: trial_id (int) – ID of the trial.
Returns: Dictionary of parameters. Keys are parameter names and values are internal representations of the parameter values.
Raises: KeyError – If no trial with the matching trial_id exists.
Return type: Dict[str, Any]

get_trial_system_attrs(trial_id)
Read the optuna-internal attributes of a trial.

Parameters: trial_id (int) – ID of the trial.
Returns: Dictionary with the optuna-internal attributes of the trial.
Raises: KeyError – If no trial with the matching trial_id exists.
Return type: Dict[str, Any]

get_trial_user_attrs(trial_id)
Read the user-defined attributes of a trial.

Parameters: trial_id (int) – ID of the trial.
Returns: Dictionary with the user-defined attributes of the trial.
Raises: KeyError – If no trial with the matching trial_id exists.
Return type: Dict[str, Any]
is_heartbeat_enabled()
Check whether the storage enables the heartbeat.

Returns `True` if the storage supports the heartbeat and the return value of
`get_heartbeat_interval()` is an integer, otherwise `False`.

Return type `bool`

read_trials_from_remote_storage(study_id)
Make an internal cache of trials up-to-date.

Parameters `study_id` (`int`) – ID of the study.

Raises `KeyError` – If no study with the matching `study_id` exists.

Return type `None`

record_heartbeat(trial_id)
Record the heartbeat of the trial.

Parameters `trial_id` (`int`) – ID of the trial.

Return type `None`

remove_session()
Removes the current session.

A session is stored in SQLAlchemy’s ThreadLocalRegistry for each thread. This method closes and re-
moves the session which is associated to the current thread. Particularly, under multi-thread use cases, it
is important to call this method from each thread. Otherwise, all sessions and their associated DB connec-
tions are destructed by a thread that occasionally invoked the garbage collector. By default, it is not allowed
to touch a SQLite connection from threads other than the thread that created the connection. Therefore,
we need to explicitly close the connection from each thread.

Return type `None`

set_study_directions(study_id, directions)
Register optimization problem directions to a study.

Parameters

- `study_id` (`int`) – ID of the study.
- `directions` (`Sequence[optuna.study._study_direction.StudyDirection]`) – A sequence of direction whose element is either `MAXIMIZE` or `MINIMIZE`.

Raises

- `KeyError` – If no study with the matching `study_id` exists.
- `ValueError` – If the directions are already set and the each coordinate of passed `directions` is the opposite direction or `NOT_SET`.

Return type `None`

set_study_system_attr(study_id, key, value)
Register an optuna-internal attribute to a study.

This method overwrites any existing attribute.

Parameters

- `study_id` (`int`) – ID of the study.
- `key` (`str`) – Attribute key.
• **value (Any)** – Attribute value. It should be JSON serializable.

**Raises** [**KeyError**](#) – If no study with the matching `study_id` exists.

**Return type** None

### set_study_user_attr (study_id, key, value)

Register a user-defined attribute to a study.

This method overwrites any existing attribute.

**Parameters**

• **study_id (int)** – ID of the study.

• **key (str)** – Attribute key.

• **value (Any)** – Attribute value. It should be JSON serializable.

**Raises** [**KeyError**](#) – If no study with the matching `study_id` exists.

**Return type** None

### set_trial_intermediate_value (trial_id, step, intermediate_value)

Report an intermediate value of an objective function.

This method overwrites any existing intermediate value associated with the given step.

**Parameters**

• **trial_id (int)** – ID of the trial.

• **step (int)** – Step of the trial (e.g., the epoch when training a neural network).

• **intermediate_value (float)** – Intermediate value corresponding to the step.

**Raises**

• [**KeyError**](#) – If no trial with the matching `trial_id` exists.

• [**RuntimeError**](#) – If the trial is already finished.

**Return type** None

### set_trial_param (trial_id, param_name, param_value_internal, distribution)

Set a parameter to a trial.

**Parameters**

• **trial_id (int)** – ID of the trial.

• **param_name (str)** – Name of the parameter.

• **param_value_internal (float)** – Internal representation of the parameter value.

• **distribution (optuna.distributions.BaseDistribution)** – Sampled distribution of the parameter.

**Raises**

• [**KeyError**](#) – If no trial with the matching `trial_id` exists.

• [**RuntimeError**](#) – If the trial is already finished.

**Return type** None

### set_trial_state (trial_id, state)

Update the state of a trial.

**Parameters**
trial_id (int) – ID of the trial.

state (optuna.trial._state.TrialState) – New state of the trial.

Returns True if the state is successfully updated. False if the state is kept the same. The latter happens when this method tries to update the state of RUNNING trial to RUNNING.

Raises

• KeyError – If no trial with the matching trial_id exists.

• RuntimeError – If the trial is already finished.

Return type bool

set_trial_system_attr (trial_id, key, value)

Set an optuna-internal attribute to a trial.

This method overwrites any existing attribute.

Parameters

• trial_id (int) – ID of the trial.

• key (str) – Attribute key.

• value (Any) – Attribute value. It should be JSON serializable.

Raises

• KeyError – If no trial with the matching trial_id exists.

• RuntimeError – If the trial is already finished.

Return type None

set_trial_user_attr (trial_id, key, value)

Set a user-defined attribute to a trial.

This method overwrites any existing attribute.

Parameters

• trial_id (int) – ID of the trial.

• key (str) – Attribute key.

• value (Any) – Attribute value. It should be JSON serializable.

Raises

• KeyError – If no trial with the matching trial_id exists.

• RuntimeError – If the trial is already finished.

Return type None

set_trial_values (trial_id, values)

Set return values of an objective function.

This method overwrites any existing trial values.

Parameters

• trial_id (int) – ID of the trial.

• values (Sequence[float]) – Values of the objective function.

Raises
• **KeyError** – If no trial with the matching `trial_id` exists.
• **RuntimeError** – If the trial is already finished.

**Return type** None

```python
upgrade()
```
Upgrade the storage schema.

**Return type** None

### `optuna.storages.RedisStorage`

#### class `optuna.storages.RedisStorage(url, *, heartbeat_interval=None, grace_period=None, failed_trial_callback=None)`

Storage class for Redis backend.

Note that library users can instantiate this class, but the attributes provided by this class are not supposed to be directly accessed by them.

**Example**

We create an `RedisStorage` instance using the given redis database URL.

```python
import optuna

def objective(trial):
    ...

storage = optuna.storages.RedisStorage(
    url="redis://passwd@localhost:port/db",
)
study = optuna.create_study(storage=storage)
study.optimize(objective)
```

**Parameters**

- **url** – URL of the redis storage, password and db are optional. (ie: redis://localhost:6379)
- **heartbeat_interval** – Interval to record the heartbeat. It is recorded every `interval` seconds.
- **grace_period** – Grace period before a running trial is failed from the last heartbeat. If it is `None`, the grace period will be `2 * heartbeat_interval`.
- **failed_trial_callback** – A callback function that is invoked after failing each stale trial. The function must accept two parameters with the following types in this order: `Study` and `FrozenTrial`.

**Note:** The procedure to fail existing stale trials is called just before asking the study for a new trial.
Note: If you plan to use Redis as a storage mechanism for optuna, make sure Redis is installed and running. Please execute $ pip install -U redis to install the Redis Python library.

 Raises **ValueError** – If the given `heartbeat_interval` or `grace_period` is not a positive integer.

Note: Added in v1.4.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v1.4.0.

### Methods

- `check_trial_is_updatable(trial_id, trial_state)`
  - Check whether a trial state is updatable.
- `create_new_study([study_name])` Create a new study from a name.
- `create_new_trial(study_id[, template_trial])` Create and add a new trial to a study.
- `delete_study(study_id)` Delete a study.
- `fail_stale_trials(study_id)` Fail stale trials.
- `get_all_study_summaries()` Read a list of `StudySummary` objects.
- `get_all_trials(study_id[, deepcopy, states])` Read all trials in a study.
- `get_best_trial(study_id)` Return the trial with the best value in a study.
- `get_failed_trial_callback()` Get the failed trial callback function.
- `get_heartbeat_interval()` Get the heartbeat interval if it is set.
- `get_n_trials(study_id[, state])` Count the number of trials in a study.
- `get_study_directions(study_id)` Read whether a study maximizes or minimizes an objective.
- `get_study_id_from_name(study_name)` Read the ID of a study.
- `get_study_id_from_trial_id(trial_id)` Read the ID of a study to which a trial belongs.
- `get_study_name_from_id(study_id)` Read the study name of a study.
- `get_study_system_attrs(study_id)` Read the optuna-internal attributes of a study.
- `get_study_user_attrs(study_id)` Read the user-defined attributes of a study.
- `get_trial(trial_id)` Read a trial.
- `get_trial_id_from_study_id_trial_number(study_id, trial_number)` Read the trial ID of a trial.
- `get_trial_number_from_id(trial_id)` Read the trial number of a trial.
- `get_trial_param(trial_id, param_name)` Read the parameter of a trial.
- `get_trial_params(trial_id)` Read the parameter dictionary of a trial.
- `get_trial_system_attrs(trial_id)` Read the optuna-internal attributes of a trial.
- `get_trial_user_attrs(trial_id)` Read the user-defined attributes of a trial.
- `is_heartbeat_enabled()` Check whether the storage enables the heartbeat.
- `read_trials_from_remote_storage(study_id)` Make an internal cache of trials up-to-date.
- `record_heartbeat(trial_id)` Record the heartbeat of the trial.
- `remove_session()` Clean up all connections to a database.
- `set_study_directions(study_id, directions)` Register optimization problem directions to a study.
- `set_study_system_attr(study_id, key, value)` Register an optuna-internal attribute to a study.
- `set_study_user_attr(study_id, key, value)` Register a user-defined attribute to a study.
- `set_trial_intermediate_value(trial_id, step,...)` Report an intermediate value of an objective function.
Table 89 – continued from previous page

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>set_trial_param(trial_id, param_name, ...)</code></td>
<td>Set a parameter to a trial.</td>
</tr>
<tr>
<td><code>set_trial_state(trial_id, state)</code></td>
<td>Update the state of a trial.</td>
</tr>
<tr>
<td><code>set_trial_system_attr(trial_id, key, value)</code></td>
<td>Set an optuna-internal attribute to a trial.</td>
</tr>
<tr>
<td><code>set_trial_user_attr(trial_id, key, value)</code></td>
<td>Set a user-defined attribute to a trial.</td>
</tr>
<tr>
<td><code>set_trial_values(trial_id, values)</code></td>
<td>Set return values of an objective function.</td>
</tr>
</tbody>
</table>

**check_trial_is_updatable(trial_id, trial_state)**

Check whether a trial state is updatable.

**Parameters**

- **trial_id** (**int**) – ID of the trial. Only used for an error message.
- **trial_state** (**optuna.trial._state.TrialState**) – Trial state to check.

**Raises**

- **RuntimeError** – If the trial is already finished.

**Return type**

- **None**

**create_new_study(study_name=None)**

Create a new study from a name.

If no name is specified, the storage class generates a name. The returned study ID is unique among all current and deleted studies.

**Parameters**

- **study_name** (**Optional[str]**) – Name of the new study to create.

**Returns**

- **ID of the created study.**

**Raises**

- **optuna.exceptions.DuplicatedStudyError** – If a study with the same study_name already exists.

**Return type**

- **int**

**create_new_trial(study_id, template_trial=None)**

Create and add a new trial to a study.

The returned trial ID is unique among all current and deleted trials.

**Parameters**

- **study_id** (**int**) – ID of the study.
- **template_trial** (**Optional[optuna.trial._frozen.FrozenTrial]**) – Template FrozenTrial with default user-attributes, system-attributes, intermediate-values, and a state.

**Returns**

- **ID of the created trial.**

**Raises**

- **KeyError** – If no study with the matching study_id exists.

**Return type**

- **int**

**delete_study(study_id)**

Delete a study.

**Parameters**

- **study_id** (**int**) – ID of the study.

**Raises**

- **KeyError** – If no study with the matching study_id exists.

**Return type**

- **None**
**fail_stale_trials** (*study_id*)
Fail stale trials.

The running trials whose heartbeat has not been updated for a long time will be failed, that is, those states will be changed to *FAIL*. The grace period is \(2 \times heartbeat\text{-}interval\).

**Parameters**
- **study_id** (*int*) – ID of the related study.

**Returns**
List of trial IDs of the failed trials.

**Return type**
List[int]

**get_all_study_summaries**()
Read a list of *StudySummary* objects.

**Returns**
A list of *StudySummary* objects.

**Return type**
List[optuna.study._study_summary.StudySummary]

**get_all_trials** (*study_id*, *deepcopy=True*, *states=None*)
Read all trials in a study.

**Parameters**
- **study_id** (*int*) – ID of the study.
- **deepcopy** (*bool*) – Whether to copy the list of trials before returning. Set to *True* if you intend to update the list or elements of the list.
- **states** (*Optional[Tuple[optuna.trial._state.TrialState, ..]]*) – Trial states to filter on. If *None*, include all states.

**Returns**
List of trials in the study.

**Raises**
- **KeyError** – If no study with the matching *study_id* exists.

**Return type**
List[optuna.trial._frozen.FrozenTrial]

**get_best_trial** (*study_id*)
Return the trial with the best value in a study.

This method is valid only during single-objective optimization.

**Parameters**
- **study_id** (*int*) – ID of the study.

**Returns**
The trial with the best objective value among all finished trials in the study.

**Raises**
- **KeyError** – If no study with the matching *study_id* exists.
- **RuntimeError** – If the study has more than one direction.
- **ValueError** – If no trials have been completed.

**Return type**
optuna.trial._frozen.FrozenTrial

**get_failed_trial_callback**()
Get the failed trial callback function.

**Returns**
The failed trial callback function if it is set, otherwise *None*.

**Return type**
Optional[Callable[[optuna.study.Study, optuna.trial._frozen.FrozenTrial], None]]

**get_heartbeat_interval**()
Get the heartbeat interval if it is set.
Returns The heartbeat interval if it is set, otherwise None.

Return type Optional[int]

`get_n_trials(study_id, state=None)`
Count the number of trials in a study.

Parameters

- **study_id** (int) – ID of the study.
- **state** (Optional[Union[Tuple[optuna.trial._state.TrialState, ..], optuna.trial._state.TrialState]]) – Trial states to filter on. If None, include all states.

Returns Number of trials in the study.

Raises **KeyError** – If no study with the matching study_id exists.

Return type int

`get_study_directions(study_id)`
Read whether a study maximizes or minimizes an objective.

Parameters **study_id** (int) – ID of a study.

Returns Optimization directions list of the study.

Raises **KeyError** – If no study with the matching study_id exists.

Return type List[optuna.study._study_direction.StudyDirection]

`get_study_id_from_name(study_name)`
Read the ID of a study.

Parameters **study_name** (str) – Name of the study.

Returns ID of the study.

Raises **KeyError** – If no study with the matching study_name exists.

Return type int

`get_study_id_from_trial_id(trial_id)`
Read the ID of a study to which a trial belongs.

Parameters **trial_id** (int) – ID of the trial.

Returns ID of the study.

 Raises **KeyError** – If no trial with the matching trial_id exists.

Return type int

`get_study_name_from_id(study_id)`
Read the study name of a study.

Parameters **study_id** (int) – ID of the study.

Returns Name of the study.

 Raises **KeyError** – If no study with the matching study_id exists.

Return type str

`get_study_system_attrs(study_id)`
Read the optuna-internal attributes of a study.

Parameters **study_id** (int) – ID of the study.
Returns Dictionary with the optuna-internal attributes of the study.
 Raises **KeyError** – If no study with the matching `study_id` exists.
 Return type Dict[str, Any]

**get_study_user_attrs** *(study_id)*
Read the user-defined attributes of a study.

Parameters `study_id` *(int)* – ID of the study.
 Returns Dictionary with the user attributes of the study.
 Raises **KeyError** – If no study with the matching `study_id` exists.
 Return type Dict[str, Any]

**get_trial** *(trial_id)*
Read a trial.

Parameters `trial_id` *(int)* – ID of the trial.
 Returns Trial with a matching trial ID.
 Raises **KeyError** – If no trial with the matching `trial_id` exists.
 Return type optuna.trial._frozen.FrozenTrial

**get_trial_id_from_study_id_trial_number** *(study_id, trial_number)*
Read the trial ID of a trial.

Parameters
- `study_id` *(int)* – ID of the study.
- `trial_number` *(int)* – Number of the trial.
 Returns ID of the trial.
 Raises **KeyError** – If no trial with the matching `study_id` and `trial_number` exists.
 Return type int

**get_trial_number_from_id** *(trial_id)*
Read the trial number of a trial.

Note: The trial number is only unique within a study, and is sequential.

Parameters `trial_id` *(int)* – ID of the trial.
 Returns Number of the trial.
 Raises **KeyError** – If no trial with the matching `trial_id` exists.
 Return type int

**get_trial_param** *(trial_id, param_name)*
Read the parameter of a trial.

Parameters
- `trial_id` *(int)* – ID of the trial.
- `param_name` *(str)* – Name of the parameter.
 Returns Internal representation of the parameter.
Raises **KeyError** – If no trial with the matching `trial_id` exists. If no such parameter exists.

**Return type** float

### get_trial_params(trial_id)
Read the parameter dictionary of a trial.

**Parameters**
- `trial_id` (**int**) – ID of the trial.

**Returns**
Dictionary of a parameters. Keys are parameter names and values are internal representations of the parameter values.

**Raises** **KeyError** – If no trial with the matching `trial_id` exists.

**Return type** Dict[str, Any]

### get_trial_system_attrs(trial_id)
Read the optuna-internal attributes of a trial.

**Parameters**
- `trial_id` (**int**) – ID of the trial.

**Returns**
Dictionary with the optuna-internal attributes of the trial.

**Raises** **KeyError** – If no trial with the matching `trial_id` exists.

**Return type** Dict[str, Any]

### get_trial_user_attrs(trial_id)
Read the user-defined attributes of a trial.

**Parameters**
- `trial_id` (**int**) – ID of the trial.

**Returns**
Dictionary with the user-defined attributes of the trial.

**Raises** **KeyError** – If no trial with the matching `trial_id` exists.

**Return type** Dict[str, Any]

### is_heartbeat_enabled()
Check whether the storage enables the heartbeat.

**Returns**
`True` if the storage supports the heartbeat and the return value of `get_heartbeat_interval()` is an integer, otherwise `False`.

**Return type** bool

### read_trials_from_remote_storage(study_id)
Make an internal cache of trials up-to-date.

**Parameters**
- `study_id` (**int**) – ID of the study.

**Raises** **KeyError** – If no study with the matching `study_id` exists.

**Return type** None

### record_heartbeat(trial_id)
Record the heartbeat of the trial.

**Parameters**
- `trial_id` (**int**) – ID of the trial.

**Return type** None

### remove_session()
Clean up all connections to a database.

**Return type** None
**set_study_directions** (*study_id, directions*)
Register optimization problem directions to a study.

**Parameters**

- **study_id** (*int*) – ID of the study.
- **directions** (*Sequence[optuna.study._study_direction.StudyDirection]*) – A sequence of direction whose element is either **MAXIMIZE** or **MINIMIZE**.

**Raises**

- **KeyError** – If no study with the matching study_id exists.
- **ValueError** – If the directions are already set and the each coordinate of passed directions is the opposite direction or **NOT_SET**.

**Return type** None

**set_study_system_attr** (*study_id, key, value*)
Register an optuna-internal attribute to a study.
This method overwrites any existing attribute.

**Parameters**

- **study_id** (*int*) – ID of the study.
- **key** (*str*) – Attribute key.
- **value** (*Any*) – Attribute value. It should be JSON serializable.

**Raises** **KeyError** – If no study with the matching study_id exists.

**Return type** None

**set_study_user_attr** (*study_id, key, value*)
Register a user-defined attribute to a study.
This method overwrites any existing attribute.

**Parameters**

- **study_id** (*int*) – ID of the study.
- **key** (*str*) – Attribute key.
- **value** (*Any*) – Attribute value. It should be JSON serializable.

**Raises** **KeyError** – If no study with the matching study_id exists.

**Return type** None

**set_trial_intermediate_value** (*trial_id, step, intermediate_value*)
Report an intermediate value of an objective function.
This method overwrites any existing intermediate value associated with the given step.

**Parameters**

- **trial_id** (*int*) – ID of the trial.
- **step** (*int*) – Step of the trial (e.g., the epoch when training a neural network).
- **intermediate_value** (*float*) – Intermediate value corresponding to the step.

**Raises**
• **KeyError** – If no trial with the matching `trial_id` exists.
• **RuntimeError** – If the trial is already finished.

**Return type** None

`set_trial_param(trial_id, param_name, param_value_internal, distribution)`
Set a parameter to a trial.

**Parameters**
- `trial_id (int)` – ID of the trial.
- `param_name (str)` – Name of the parameter.
- `param_value_internal (float)` – Internal representation of the parameter value.
- `distribution (optuna.distributions.BaseDistribution)` – Sampled distribution of the parameter.

**Raises**
- **KeyError** – If no trial with the matching `trial_id` exists.
- **RuntimeError** – If the trial is already finished.

**Return type** None

`set_trial_state(trial_id, state)`
Update the state of a trial.

**Parameters**
- `trial_id (int)` – ID of the trial.
- `state (optuna.trial._state.TrialState)` – New state of the trial.

**Returns** `True` if the state is successfully updated. `False` if the state is kept the same. The latter happens when this method tries to update the state of `RUNNING` trial to `RUNNING`.

**Raises**
- **KeyError** – If no trial with the matching `trial_id` exists.
- **RuntimeError** – If the trial is already finished.

**Return type** `bool`

`set_trial_system_attr(trial_id, key, value)`
Set an optuna-internal attribute to a trial.

This method overwrites any existing attribute.

**Parameters**
- `trial_id (int)` – ID of the trial.
- `key (str)` – Attribute key.
- `value (Any)` – Attribute value. It should be JSON serializable.

**Raises**
- **KeyError** – If no trial with the matching `trial_id` exists.
- **RuntimeError** – If the trial is already finished.

**Return type** None
set_trial_user_attr \((trial_id, key, value)\)
Set a user-defined attribute to a trial.

This method overwrites any existing attribute.

**Parameters**
- **trial_id**\((int)\) – ID of the trial.
- **key**\((str)\) – Attribute key.
- **value**\(\text{Any}\) – Attribute value. It should be JSON serializable.

**Raises**
- **KeyError** – If no trial with the matching trial_id exists.
- **RuntimeError** – If the trial is already finished.

**Return type** None

set_trial_values \((trial_id, values)\)
Set return values of an objective function.

This method overwrites any existing trial values.

**Parameters**
- **trial_id**\((int)\) – ID of the trial.
- **values**\(\text{Sequence[float]}\) – Values of the objective function.

**Raises**
- **KeyError** – If no trial with the matching trial_id exists.
- **RuntimeError** – If the trial is already finished.

**Return type** None

optuna.storages.RetryFailedTrialCallback

class optuna.storages.RetryFailedTrialCallback\((max_retry=None)\)
Retry a failed trial up to a maximum number of times.

When a trial fails, this callback can be used with the optuna.storage class to recreate the trial in TrialState.WAITING to queue up the trial to be run again.

This is helpful in environments where trials may fail due to external conditions, such as being preempted by other processes.

**Usage:**

```python
import optuna
from optuna.storages import RetryFailedTrialCallback

storage = optuna.storages.RDBStorage(
    url="sqlite:///:memory:",
    heartbeat_interval=60,
    grace_period=120,
    failed_trial_callback=RetryFailedTrialCallback(max_retry=3),
)

study = optuna.create_study(
```
Parameters `max_retry` – The max number of times a trial can be retried. Must be set to `None` or an integer. If set to the default value of `None` will retry indefinitely. If set to an integer, will only retry that many times.

Note: Added in v2.8.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.8.0.

**Methods**

```python
(retried_trial_number(trial))
```

Return the number of the trial being retried.

```python
static retried_trial_number(trial)
```

Return the number of the trial being retried.

Parameters `trial` ([`optuna.trial._frozen.FrozenTrial`]) – The trial object.

Returns The number of the first failed trial. If not retry of a previous trial, returns `None`.

Return type `Optional[int]`

Note: Added in v2.8.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.8.0.

```python
(optuna.storages.fail_stale_trials(study))
```

Fail stale trials and run their failure callbacks.

The running trials whose heartbeat has not been updated for a long time will be failed, that is, those states will be changed to `FAIL`.

See also:

See `RDBStorage`.

Parameters `study` ([`optuna.study.study.Study`]) – Study holding the trials to check.

Return type `None`
6.3.12 optuna.structs

This module is deprecated, with former functionality moved to `optuna.trial` and `optuna.study`.

```python
class optuna.structs.TrialState(value)
State of a Trial.

RUNNING
The Trial is running.

WAITING
The Trial is waiting and unfinished.

COMPLETE
The Trial has been finished without any error.

PRUNED
The Trial has been pruned with TrialPruned.

FAIL
The Trial has failed due to an uncaught error.
```

Deprecated since version 1.4.0: This class is deprecated. Please use `TrialState` instead.

```python
class optuna.structs.StudyDirection(value)
Direction of a Study.

NOT_SET
Direction has not been set.

MINIMIZE
Study minimizes the objective function.

MAXIMIZE
Study maximizes the objective function.
```

Deprecated since version 1.4.0: This class is deprecated. Please use `StudyDirection` instead.

```python
class optuna.structs.FrozenTrial(number, state, value, datetime_start, datetime_complete, params, distributions, user_attrs, system_attrs, intermediate_values, trial_id, *, values=None)
```

Warning: Deprecated in v1.4.0. This feature will be removed in the future. The removal of this feature is currently scheduled for v3.0.0, but this schedule is subject to change. See https://github.com/optuna/optuna/releases/tag/v1.4.0.

This class was moved to `trial`. Please use `FrozenTrial` instead.

```python
property distributions
Dictionary that contains the distributions of params.

property duration
Return the elapsed time taken to complete the trial.

Returns The duration.

property last_step
Return the maximum step of intermediate_values in the trial.

Returns The maximum step of intermediates.
```
**report** *(value, step)*

Interface of report function.

Since *FrozenTrial* is not pruned, this report function does nothing.

See also:

Please refer to *should_prune()*.

**Parameters**

- **value** *(float)* – A value returned from the objective function.
- **step** *(int)* – Step of the trial (e.g., Epoch of neural network training). Note that pruners assume that step starts at zero. For example, *MedianPruner* simply checks if step is less than *n_warmup_steps* as the warmup mechanism.

**Return type** None

**should_prune()**

Suggest whether the trial should be pruned or not.

The suggestion is always *False* regardless of a pruning algorithm.

**Note:** *FrozenTrial* only samples one combination of parameters.

**Returns** *False*.

**Return type** bool

**class** `optuna.structs.StudySummary`

(study_name, direction, best_trial, user_attrs, system_attrs, n_trials, datetime_start, study_id, *, directions=None)

**Warning:** Deprecated in v1.4.0. This feature will be removed in the future. The removal of this feature is currently scheduled for v3.0.0, but this schedule is subject to change. See https://github.com/optuna/optuna/releases/tag/v1.4.0.

This class was moved to *study*. Please use *StudySummary* instead.

### 6.3.13 optuna.study

The *study* module implements the *Study* object and related functions. A public constructor is available for the *Study* class, but direct use of this constructor is not recommended. Instead, library users should create and load a *Study* using *create_study()* and *load_study()* respectively.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>optuna.study.Study</em></td>
<td>A study corresponds to an optimization task, i.e., a set of trials.</td>
</tr>
<tr>
<td><em>optuna.study.create_study</em></td>
<td>Create a new <em>Study</em>.</td>
</tr>
<tr>
<td><em>optuna.study.load_study</em></td>
<td>Load the existing <em>Study</em> that has the specified name.</td>
</tr>
<tr>
<td><em>optuna.study.delete_study</em></td>
<td>Delete a <em>Study</em> object.</td>
</tr>
<tr>
<td><em>optuna.study.copy_study</em></td>
<td>Copy study from one storage to another.</td>
</tr>
<tr>
<td><em>optuna.study.get_all_study_summaries</em></td>
<td>Get all history of studies stored in a specified storage.</td>
</tr>
</tbody>
</table>

continues on next page
Table 91 – continued from previous page

<table>
<thead>
<tr>
<th>Class Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>optuna.study.MaxTrialsCallback</code></td>
<td>Set a maximum number of trials before ending the study.</td>
</tr>
<tr>
<td><code>optuna.study.StudyDirection</code></td>
<td>Direction of a <code>Study</code>.</td>
</tr>
<tr>
<td><code>optuna.study.StudySummary</code></td>
<td>Basic attributes and aggregated results of a <code>Study</code>.</td>
</tr>
</tbody>
</table>

**optuna.study.Study**

```python
class optuna.study.Study(study_name, storage, sampler=None, pruner=None)
```

A study corresponds to an optimization task, i.e., a set of trials.

This object provides interfaces to run a new `Trial`, access trials’ history, set/get user-defined attributes of the study itself.

Note that the direct use of this constructor is not recommended. To create and load a study, please refer to the documentation of `create_study()` and `load_study()` respectively.

**Methods**

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>add_trial(trial)</code></td>
<td>Add trial to study.</td>
</tr>
<tr>
<td><code>add_trials(trials)</code></td>
<td>Add trials to study.</td>
</tr>
<tr>
<td><code>ask([fixed_distributions])</code></td>
<td>Create a new trial from which hyperparameters can be suggested.</td>
</tr>
<tr>
<td><code>enqueue_trial(params)</code></td>
<td>Enqueue a trial with given parameter values.</td>
</tr>
<tr>
<td><code>get_trials([deepcopy, states])</code></td>
<td>Return all trials in the study.</td>
</tr>
<tr>
<td><code>optimize(func[, n_trials, timeout, n_jobs, ...])</code></td>
<td>Optimize an objective function.</td>
</tr>
<tr>
<td><code>set_system_attr(key, value)</code></td>
<td>Set a system attribute to the study.</td>
</tr>
<tr>
<td><code>set_user_attr(key, value)</code></td>
<td>Set a user attribute to the study.</td>
</tr>
<tr>
<td><code>stop()</code></td>
<td>Exit from the current optimization loop after the running trials finish.</td>
</tr>
<tr>
<td><code>tell(trial[, values, state])</code></td>
<td>Finish a trial created with <code>ask()</code>.</td>
</tr>
<tr>
<td><code>trials_dataframe([attrs, multi_index])</code></td>
<td>Export trials as a pandas DataFrame.</td>
</tr>
</tbody>
</table>

**Attributes**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>best_params</code></td>
<td>Return parameters of the best trial in the study.</td>
</tr>
<tr>
<td><code>best_trial</code></td>
<td>Return the best trial in the study.</td>
</tr>
<tr>
<td><code>best_trials</code></td>
<td>Return trials located at the Pareto front in the study.</td>
</tr>
<tr>
<td><code>best_value</code></td>
<td>Return the best objective value in the study.</td>
</tr>
<tr>
<td><code>direction</code></td>
<td>Return the direction of the study.</td>
</tr>
<tr>
<td><code>directions</code></td>
<td>Return the directions of the study.</td>
</tr>
<tr>
<td><code>system_attrs</code></td>
<td>Return system attributes.</td>
</tr>
<tr>
<td><code>trials</code></td>
<td>Return all trials in the study.</td>
</tr>
<tr>
<td><code>user_attrs</code></td>
<td>Return user attributes.</td>
</tr>
</tbody>
</table>

**add_trial(trial)**

Add trial to study.

The trial is validated before being added.
Example

```python
import optuna
from optuna.distributions import UniformDistribution

def objective(trial):
    x = trial.suggest_float("x", 0, 10)
    return x ** 2

study = optuna.create_study()
assert len(study.trials) == 0

trial = optuna.trial.create_trial(
    params={"x": 2.0},
    distributions={"x": UniformDistribution(0, 10)},
    value=4.0,
)
study.add_trial(trial)
assert len(study.trials) == 1

study.optimize(objective, n_trials=3)
assert len(study.trials) == 4

other_study = optuna.create_study()
for trial in study.trials:
    other_study.add_trial(trial)
assert len(other_study.trials) == len(study.trials)

other_study.optimize(objective, n_trials=2)
assert len(other_study.trials) == len(study.trials) + 2

See also:

This method should in general be used to add already evaluated trials (trial.state.is_finished() == True). To queue trials for evaluation, please refer to enqueue_trial().

See also:

See create_trial() for how to create trials.

Parameters

- **trial** (optuna.trial._frozen.FrozenTrial) – Trial to add.

Raises

- **ValueError** – If trial is an invalid state.

Return type

None

Note: Added in v2.0.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.0.0.

add_trials(trials)

Add trials to study.

The trials are validated before being added.
Example

```python
import optuna
from optuna.distributions import UniformDistribution

def objective(trial):
    x = trial.suggest_float("x", 0, 10)
    return x ** 2

study = optuna.create_study()
study.optimize(objective, n_trials=3)
assert len(study.trials) == 3

other_study = optuna.create_study()
other_study.add_trials(study.trials)
assert len(other_study.trials) == len(study.trials)

other_study.optimize(objective, n_trials=2)
assert len(other_study.trials) == len(study.trials) + 2
```

See also:

See `add_trial()` for addition of each trial.

**Parameters**

- `trials` *(Iterable[optuna.trial._frozen.FrozenTrial])* – Trials to add.

- **Raises** `ValueError` – If `trials` include invalid trial.

- **Return type** `None`

**Note:** Added in v2.5.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.5.0.

**ask** *(fixed_distributions=None)*

Create a new trial from which hyperparameters can be suggested.

This method is part of an alternative to `optimize()` that allows controlling the lifetime of a trial outside the scope of `func`. Each call to this method should be followed by a call to `tell()` to finish the created trial.

See also:

The Ask-and-Tell Interface tutorial provides use-cases with examples.
Example

Getting the trial object with the `ask()` method.

```python
import optuna

study = optuna.create_study()
trial = study.ask()
x = trial.suggest_float("x", -1, 1)
study.tell(trial, x ** 2)
```

Example

Passing previously defined distributions to the `ask()` method.

```python
import optuna

study = optuna.create_study()
distributions = {
    "optimizer": optuna.distributions.CategoricalDistribution(["adam", "sgd"租车]),
    "lr": optuna.distributions.LogUniformDistribution(0.0001, 0.1),
}

# You can pass the distributions previously defined.
trial = study.ask(fixed_distributions=distributions)

# `optimizer` and `lr` are already suggested and accessible with `trial.params`.
assert "optimizer" in trial.params
assert "lr" in trial.params
```

Parameters `fixed_distributions` *(Optional[Dict[str, optuna.distributions.BaseDistribution]*)* – A dictionary containing the parameter names and parameter’s distributions. Each parameter in this dictionary is automatically suggested for the returned trial, even when the suggest method is not explicitly invoked by the user. If this argument is set to `None`, no parameter is automatically suggested.

Returns A `Trial`.

Return type `optuna.trial._trial.Trial`

property `best_params`

Return parameters of the best trial in the study.

Returns A dictionary containing parameters of the best trial.

Raises `RuntimeError` – If the study has more than one direction.

property `best_trial`

Return the best trial in the study.
Returns A `FrozenTrial` object of the best trial.

Raises `RuntimeError` – If the study has more than one direction.

**property best_trials**
Return trials located at the Pareto front in the study.

A trial is located at the Pareto front if there are no trials that dominate the trial. It’s called that a trial t0 dominates another trial t1 if all (v0 <= v1) for v0, v1 in zip(t0.values, t1.values) and any (v0 < v1) for v0, v1 in zip(t0.values, t1.values) are held.

Returns A list of `FrozenTrial` objects.

**property best_value**
Return the best objective value in the study.

Returns A float representing the best objective value.

Raises `RuntimeError` – If the study has more than one direction.

**property direction**
Return the direction of the study.

Returns A `StudyDirection` object.

Raises `RuntimeError` – If the study has more than one direction.

**property directions**
Return the directions of the study.

Returns A list of `StudyDirection` objects.

enqueue_trial(params)
Enqueue a trial with given parameter values.

You can fix the next sampling parameters which will be evaluated in your objective function.

**Example**

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", 0, 10)
    return x ** 2

study = optuna.create_study()
study.enqueue_trial({'x': 5})
study.enqueue_trial({'x': 0})
study.optimize(objective, n_trials=2)

assert study.trials[0].params == {'x': 5}
assert study.trials[1].params == {'x': 0}
```

Parameters `params` (`Dict[str, Any]`) – Parameter values to pass your objective function.

Return type `None`
get_trials (deepcopy=True, states=None)

Return all trials in the study.

The returned trials are ordered by trial number.

Example

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", -1, 1)
    return x ** 2

study = optuna.create_study()
study.optimize(objective, n_trials=3)

trials = study.get_trials()
assert len(trials) == 3
```

Parameters

- **deepcopy** *(bool)* — Flag to control whether to apply copy.deepcopy() to the trials. Note that if you set the flag to False, you shouldn’t mutate any fields of the returned trial. Otherwise the internal state of the study may corrupt and unexpected behavior may happen.

- **states** *(Optional[Tuple[optuna.trial._state.TrialState, ..]*])— Trial states to filter on. If None, include all states.

Returns A list of FrozenTrial objects.

Return type List[optuna.trial._frozen.FrozenTrial]

optimize *(func, n_trials=None, timeout=None, n_jobs=1, catch=(), callbacks=None, gc_after_trial=False, show_progress_bar=False)*

Optimize an objective function.

Optimization is done by choosing a suitable set of hyperparameter values from a given range. Uses a sampler which implements the task of value suggestion based on a specified distribution. The sampler is specified in create_study() and the default choice for the sampler is TPE. See also TPESampler for more details on ‘TPE’.
Example

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", -1, 1)
    return x ** 2

study = optuna.create_study()
study.optimize(objective, n_trials=3)
```

Parameters

- **func** (Callable[[optuna.trial._trial.Trial], Union[float, Sequence[float]]]) – A callable that implements objective function.

- **n_trials** (Optional[int]) – The number of trials. If this argument is set to None, there is no limitation on the number of trials. If timeout is also set to None, the study continues to create trials until it receives a termination signal such as Ctrl+C or SIGTERM.

- **timeout** (Optional[float]) – Stop study after the given number of second(s). If this argument is set to None, the study is executed without time limitation. If n_trials is also set to None, the study continues to create trials until it receives a termination signal such as Ctrl+C or SIGTERM.

- **n_jobs** (int) – The number of parallel jobs. If this argument is set to -1, the number is set to CPU count.

**Note:** n_jobs allows parallelization using threading and may suffer from Python’s GIL. It is recommended to use process-based parallelization if func is CPU bound.

**Warning:** Deprecated in v2.7.0. This feature will be removed in the future. It is recommended to use process-based parallelization. The removal of this feature is currently scheduled for v4.0.0, but this schedule is subject to change. See https://github.com/optuna/optuna/releases/tag/v2.7.0.

- **catch** (Tuple[Type[Exception], ...]) – A study continues to run even when a trial raises one of the exceptions specified in this argument. Default is an empty tuple, i.e. the study will stop for any exception except for TrialPruned.

- **callbacks** (Optional[List[Callable[[optuna.study.study.Study, optuna.trial._frozen.FrozenTrial], None]]]) – List of callback functions that are invoked at the end of each trial. Each function must accept two parameters with the following types in this order: Study and FrozenTrial.

- **gc_after_trial** (bool) – Flag to determine whether to automatically run garbage collection after each trial. Set to True to run the garbage collection, False otherwise. When it runs, it runs a full collection by internally calling gc.collect(). If you see an increase in memory consumption over several trials, try setting this flag to True.

**See also:**

*How do I avoid running out of memory (OOM) when optimizing studies?*
• **show_progress_bar** *(bool)* – Flag to show progress bars or not. To disable progress bar, set this `False`. Currently, progress bar is experimental feature and disabled when `n_jobs ≠ 1`.

**Raises** `RuntimeError` – If nested invocation of this method occurs.

**Return type** None

### set_system_attr(key, value)

Set a system attribute to the study.

Note that Optuna internally uses this method to save system messages. Please use `set_user_attr()` to set users’ attributes.

**Parameters**

- **key** *(str)* – A key string of the attribute.

- **value** *(Any)* – A value of the attribute. The value should be JSON serializable.

**Return type** None

### set_user_attr(key, value)

Set a user attribute to the study.

**See also:**

See `user_attrs` for related attribute.

**Example**

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", 0, 1)
    y = trial.suggest_float("y", 0, 1)
    return x ** 2 + y ** 2

study = optuna.create_study()
study.set_user_attr("objective function", "quadratic function")
study.set_user_attr("dimensions", 2)
study.set_user_attr("contributors", ["Akiba", "Sano"])
assert study.user_attrs == {
    "objective function": "quadratic function",
    "dimensions": 2,
    "contributors": ["Akiba", "Sano"],
}
```

**Parameters**

- **key** *(str)* – A key string of the attribute.

- **value** *(Any)* – A value of the attribute. The value should be JSON serializable.

**Return type** None
**stop()**
Exit from the current optimization loop after the running trials finish.

This method lets the running `optimize()` method return immediately after all trials which the `optimize()` method spawned finishes. This method does not affect any behaviors of parallel or successive study processes.

**Example**

```python
import optuna

def objective(trial):
    if trial.number == 4:
        trial.study.stop()
    x = trial.suggest_float("x", 0, 10)
    return x ** 2

study = optuna.create_study()
study.optimize(objective, n_trials=10)
assert len(study.trials) == 5
```

**Raises** `RuntimeError` — If this method is called outside an objective function or callback.

**Return type** None

**property system_attrs**
Return system attributes.

**Returns** A dictionary containing all system attributes.

**tell**(trial, values=None, state=``TrialState.COMPLETED``)
Finish a trial created with `ask()`.

**See also:**
The `Ask-and-Tell Interface` tutorial provides use-cases with examples.

**Example**

```python
import optuna
from optuna.trial import TrialState

def f(x):
    return (x - 2) ** 2

def df(x):
    return 2 * x - 4

study = optuna.create_study()
n_trials = 30
```
for _ in range(n_trials):
    trial = study.ask()

    lr = trial.suggest_float("lr", 1e-5, 1e-1, log=True)

    # Iterative gradient descent objective function.
    x = 3  # Initial value.
    for step in range(128):
        y = f(x)

        trial.report(y, step=step)

        if trial.should_prune():
            # Finish the trial with the pruned state.
            study.tell(trial, state= TrialState.PRUNED)
            break

        gy = df(x)
        x -= gy * lr
    else:
        # Finish the trial with the final value after all iterations.
        study.tell(trial, y)

Parameters

- **trial** (Union[optuna.trial._trial.Trial, int]) – A Trial object or a trial number.

- **values** (Optional[Union[float, Sequence[float]]]) – Optional objective value or a sequence of such values in case the study is used for multi-objective optimization. Argument must be provided if state is COMPLETE and should be None if state is FAIL or PRUNED.

- **state** (optuna.trial._state.TrialState) – State to be reported. Must be COMPLETE, FAIL or PRUNED.

Raises

- **TypeError** – If trial is not a Trial or an int.

- **ValueError** – If any of the following. values is a sequence but its length does not match the number of objectives for its associated study. state is COMPLETE but values is None. state is FAIL or PRUNED but values is not None. state is not COMPLETE, FAIL or PRUNED. trial is a trial number but no trial exists with that number.

Return type None

**property trials**

Return all trials in the study.

The returned trials are ordered by trial number.

This is a short form of self.get_trials(deepcopy=True, states=None).

**Returns** A list of FrozenTrial objects.
trials_dataframe(attrs=('number', 'value', 'datetime_start', 'datetime_complete', 'duration', 'params', 'user_attrs', 'system_attrs', 'state'), multi_index=False)

Export trials as a pandas DataFrame.

The DataFrame provides various features to analyze studies. It is also useful to draw a histogram of objective values and to export trials as a CSV file. If there are no trials, an empty DataFrame is returned.

Example

```python
import optuna
import pandas

def objective(trial):
    x = trial.suggest_float("x", -1, 1)
    return x ** 2

study = optuna.create_study()
study.optimize(objective, n_trials=3)

# Create a dataframe from the study.
df = study.trials_dataframe()
assert isinstance(df, pandas.DataFrame)
assert df.shape[0] == 3  # n_trials.
```

Parameters

- **attrs** *(Tuple[str, ..]*) – Specifies field names of `FrozenTrial` to include them to a DataFrame of trials.

- **multi_index** *(bool)* – Specifies whether the returned DataFrame employs MultiIndex or not. Columns that are hierarchical by nature such as `(params, x)` will be flattened to `params_x` when set to `False`.

Returns

A pandas DataFrame of trials in the `Study`.

Return type

pandas.core.frame.DataFrame

Note: If `value` is in `attrs` during multi-objective optimization, it is implicitly replaced with `values`.

property user_attrs

Return user attributes.

See also:

See `set_user_attr()` for related method.
Example

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", 0, 1)
    y = trial.suggest_float("y", 0, 1)
    return x ** 2 + y ** 2

study = optuna.create_study()
study.set_user_attr("objective function", "quadratic function")
study.set_user_attr("dimensions", 2)
study.set_user_attr("contributors", ["Akiba", "Sano"])

assert study.user_attrs == {
    "objective function": "quadratic function",
    "dimensions": 2,
    "contributors": ["Akiba", "Sano"],
}

Returns A dictionary containing all user attributes.

optuna.study.create_study

optuna.study.create_study(storage=None, sampler=None, pruner=None, study_name=None, direction=None, load_if_exists=False, *, directions=None)

Create a new Study.

Example

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", 0, 10)
    return x ** 2

study = optuna.create_study()
study.optimize(objective, n_trials=3)
```

Parameters

- **storage** (Optional[Union[str, optuna.storages._base.BaseStorage]]) – Database URL. If this argument is set to None, in-memory storage is used, and the Study will not be persistent.

Note:

When a database URL is passed, Optuna internally uses SQLAlchemy to handle the database. Please refer to SQLAlchemy’s document for further details. If you
want to specify non-default options to SQLAlchemy Engine, you can instantiate `RDBStorage` with your desired options and pass it to the `storage` argument instead of a URL.

- **sampler** *(Optional[optuna.samplers._base.BaseSampler]*) – A sampler object that implements background algorithm for value suggestion. If `None` is specified, `TPESampler` is used during single-objective optimization and `NSGAIISampler` during multi-objective optimization. See also `samplers`.

- **pruner** *(Optional[optuna.pruners._base.BasePruner]*) – A pruner object that decides early stopping of unpromising trials. If `None` is specified, `MedianPruner` is used as the default. See also `pruners`.

- **study_name** *(Optional[str]*) – Study’s name. If this argument is set to `None`, a unique name is generated automatically.

- **direction** *(Optional[Union[str, optuna.study._study_direction.StudyDirection]*) – Direction of optimization. Set `minimize` for minimization and `maximize` for maximization. You can also pass the corresponding `StudyDirection` object.

  **Note:** If none of `direction` and `directions` are specified, the direction of the study is set to “minimize”.

- **load_if_exists** *(bool)* – Flag to control the behavior to handle a conflict of study names. In the case where a study named `study_name` already exists in the `storage`, a `DuplicatedStudyError` is raised if `load_if_exists` is set to `False`. Otherwise, the creation of the study is skipped, and the existing one is returned.

- **directions** *(Optional[Sequence[Union[str, optuna.study._study_direction.StudyDirection]]]*) – A sequence of directions during multi-objective optimization.

  **Returns** A `Study` object.

  **Raises** `ValueError` – If the length of `directions` is zero. Or, if `direction` is neither ‘minimize’ nor ‘maximize’ when it is a string. Or, if the element of `directions` is neither `minimize` nor `maximize`. Or, if both `direction` and `directions` are specified.

  **Return type** `optuna.study.study.Study`

  See also:
  
  `optuna.create_study()` is an alias of `optuna.study.create_study()`.

**optuna.study.load_study**

`optuna.study.load_study(study_name, storage, sampler=None, pruner=None)`

Load the existing `Study` that has the specified name.
Example

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", 0, 10)
    return x ** 2

study = optuna.create_study(storage="sqlite:///example.db", study_name="my_study")
study.optimize(objective, n_trials=3)

loaded_study = optuna.load_study(study_name="my_study", storage="sqlite:///example.db")
assert len(loaded_study.trials) == len(study.trials)
```

Parameters

- **study_name** (Optional[str]) – Study’s name. Each study has a unique name as an identifier. If None, checks whether the storage contains a single study, and if so loads that study.
- **storage** (Union[str, optuna.storages._base.BaseStorage]) – Database URL such as sqlite:///example.db. Please see also the documentation of create_study() for further details.
- **sampler** (Optional[optuna.samplers._base.BaseSampler]) – A sampler object that implements background algorithm for value suggestion. If None is specified, TPESampler is used as the default. See also samplers.
- **pruner** (Optional[optuna.pruners._base.BasePruner]) – A pruner object that decides early stopping of unpromising trials. If None is specified, MedianPruner is used as the default. See also pruners.

Raises **ValueError** – If study_name is None and the storage contains more than 1 study.

Return type **optuna.study.study.Study**

See also:

- optuna.load_study() is an alias of optuna.study.load_study().

optuna.study.delete_study

Delete a Study object.
Example

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", -10, 10)
    return (x - 2)**2

study = optuna.create_study(study_name="example-study", storage="sqlite:///example.db")
study.optimize(objective, n_trials=3)

optuna.delete_study(study_name="example-study", storage="sqlite:///example.db")
```

Parameters

- **study_name** *(str)* – Study’s name.
- **storage** *(Union[str, optuna.storages._base.BaseStorage]*) – Database URL such as sqlite:///example.db. Please see also the documentation of `create_study()` for further details.

Return type

None

See also:

`optuna.delete_study()` is an alias of `optuna.study.delete_study()`.

`optuna.study.copy_study`

`optuna.study.copy_study` *(from_study_name, from_storage, to_storage, to_study_name=None)*

Copy study from one storage to another.

The direction(s) of the objective(s) in the study, trials, user attributes and system attributes are copied.

Example

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", -10, 10)
    return (x - 2)**2

study = optuna.create_study(
    study_name="example-study",
    storage="sqlite:///example.db",
)
study.optimize(objective, n_trials=3)

optuna.copy_study(
    from_study_name="example-study",
    from_storage="sqlite:///example.db",
```

(continues on next page)
to_storage="sqlite:///example_copy.db",
)
study = optuna.load_study(
    study_name=None,
    storage="sqlite:///example_copy.db",
)

Parameters

- **from_study_name** (*str*) – Name of study.
- **from_storage** (*Union[str, optuna.storages._base.BaseStorage]*) – Source database URL such as sqlite:///example.db. Please see also the documentation of *create_study()* for further details.
- **to_storage** (*Union[str, optuna.storages._base.BaseStorage]*) – Destination database URL.
- **to_study_name** (*Optional[str]*) – Name of the created study. If omitted, from_study_name is used.

Raises **DuplicatedStudyError** – If a study with a conflicting name already exists in the destination storage.

Return type **None**

Note: Added in v2.8.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.8.0.

---

**optuna.study.get_all_study_summaries**

**optuna.study.get_all_study_summaries** (*storage*)
Get all history of studies stored in a specified storage.

Example

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", -10, 10)
    return (x - 2) ** 2

study = optuna.create_study(study_name="example-study", storage="sqlite:///example.db")
study.optimize(objective, n_trials=3)

study_summaries = optuna.study.get_all_study_summaries(storage="sqlite:///example.db")
assert len(study_summaries) == 1
```
study_summary = study_summaries[0]
assert study_summary.study_name == "example-study"

Parameters
storage (Union[str, optuna.storages._base.BaseStorage]) – Database URL such as sqlite:///example.db. Please see also the documentation of `create_study()` for further details.

Returns
List of study history summarized as `StudySummary` objects.

Return type
List[optuna.study._study_summary.StudySummary]

See also:
optuna.get_all_study_summaries() is an alias of optuna.study.get_all_study_summaries().

optuna.study.MaxTrialsCallback
class optuna.study.MaxTrialsCallback (n_trials, states=(TrialState.COMPLETE))
Set a maximum number of trials before ending the study.

While the n_trials argument of optuna.optimize sets the number of trials that will be run, you may want to continue running until you have a certain number of successful trials or stop the study when you have a certain number of trials that fail. This MaxTrialsCallback class allows you to set a maximum number of trials for a particular TrialState before stopping the study.

Example

```python
import optuna
from optuna.study import MaxTrialsCallback
from optuna.trial import TrialState

def objective(trial):
    x = trial.suggest_float("x", -1, 1)
    return x ** 2

study = optuna.create_study()
study.optimize(
    objective,
    callbacks=[MaxTrialsCallback(10, states=(TrialState.COMPLETE,))],
)
```

Parameters
- n_trials – The max number of trials. Must be set to an integer.
- states – Tuple of the TrialState to be counted towards the max trials limit. Default value is (TrialState.COMPLETE,).

Note: Added in v2.8.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.8.0.
**optuna.study.StudyDirection**

```python
class optuna.study.StudyDirection(value)
```

Direction of a `Study`.

- **NOT_SET**
  - Direction has not been set.

- **MINIMIZE**
  - `Study` minimizes the objective function.

- **MAXIMIZE**
  - `Study` maximizes the objective function.

**Attributes**

```python
MAXIMIZE

MINIMIZE

NOT_SET
```

**optuna.study.StudySummary**

```python
class optuna.study.StudySummary(study_name, direction, best_trial, user_attrs, system_attrs, n_trials, datetime_start, study_id, *, directions=None)
```

Basic attributes and aggregated results of a `Study`.

See also `optuna.study.get_all_study_summaries()`.

- **study_name**
  - Name of the `Study`.

- **direction**
  - `StudyDirection` of the `Study`.

  **Note:** This attribute is only available during single-objective optimization.

- **directions**
  - A sequence of `StudyDirection` objects.

- **best_trial**
  - FrozenTrial with best objective value in the `Study`.

- **user_attrs**
  - Dictionary that contains the attributes of the `Study` set with `optuna.study.Study.set_user_attr()`.

- **system_attrs**
  - Dictionary that contains the attributes of the `Study` internally set by Optuna.

- **n_trials**
  - The number of trials ran in the `Study`. 
**datetime_start**
Datetime where the Study started.

**Attributes**

**direction**

**directions**

### 6.3.14 optuna.trial

The `trial` module contains `Trial` related classes and functions.

A `Trial` instance represents a process of evaluating an objective function. This instance is passed to an objective function and provides interfaces to get parameter suggestion, manage the trial’s state, and set/get user-defined attributes of the trial, so that Optuna users can define a custom objective function through the interfaces. Basically, Optuna users only use it in their custom objective functions.

<table>
<thead>
<tr>
<th>optuna.trial.Trial</th>
<th>A trial is a process of evaluating an objective function.</th>
</tr>
</thead>
<tbody>
<tr>
<td>optuna.trial.FixedTrial</td>
<td>A trial class which suggests a fixed value for each parameter.</td>
</tr>
<tr>
<td>optuna.trial.FrozenTrial</td>
<td>Status and results of a Trial.</td>
</tr>
<tr>
<td>optuna.trial.TrialState</td>
<td>State of a Trial.</td>
</tr>
<tr>
<td>optuna.trial.create_trial</td>
<td>Create a new FrozenTrial.</td>
</tr>
</tbody>
</table>

**optuna.trial.Trial**

class optuna.trial.Trial (study, trial_id)

A trial is a process of evaluating an objective function.

This object is passed to an objective function and provides interfaces to get parameter suggestion, manage the trial’s state, and set/get user-defined attributes of the trial.

Note that the direct use of this constructor is not recommended. This object is seamlessly instantiated and passed to the objective function behind the `optuna.study.Study.optimize()` method; hence library users do not care about instantiation of this object.

**Parameters**

- **study** – A `Study` object.
- **trial_id** – A trial ID that is automatically generated.
Methods

```
report(value, step)               Report an objective function value for a given step.
set_system_attr(key, value)      Set system attributes to the trial.
set_user_attr(key, value)        Set user attributes to the trial.
should_prune()                   Suggest whether the trial should be pruned or not.
suggest_categorical(name, choices) Suggest a value for the categorical parameter.
suggest_discrete_uniform(name, low, high, q) Suggest a value for the discrete parameter.
suggest_float(name, low, high, *[step, log]) Suggest a value for the floating point parameter.
suggest_int(name, low, high[, step, log]) Suggest a value for the integer parameter.
suggest_loguniform(name, low, high) Suggest a value for the continuous parameter.
suggest_uniform(name, low, high) Suggest a value for the continuous parameter.
```

Attributes

```
datetime_start                  Return start datetime.
distributions                  Return distributions of parameters to be optimized.
number                         Return trial’s number which is consecutive and unique in a study.
params                         Return parameters to be optimized.
system_attrs                   Return system attributes.
user_attrs                     Return user attributes.

property datetime_start         Return start datetime.
    Returns Datetime where the Trial started.

property distributions          Return distributions of parameters to be optimized.
    Returns A dictionary containing all distributions.

property number                 Return trial’s number which is consecutive and unique in a study.
    Returns A trial number.

property params                 Return parameters to be optimized.
    Returns A dictionary containing all parameters.

report (value, step)            Report an objective function value for a given step.
    The reported values are used by the pruners to determine whether this trial should be pruned.
    See also: Please refer to BasePruner.

Note: The reported value is converted to float type by applying float() function internally. Thus, it accepts all float-like types (e.g., numpy.float32). If the conversion fails, a TypeError is raised.
Example

Report intermediate scores of SGDClassifier training.

```python
import numpy as np
from sklearn.datasets import load_iris
from sklearn.linear_model import SGDClassifier
from sklearn.model_selection import train_test_split
import optuna

X, y = load_iris(return_X_y=True)
X_train, X_valid, y_train, y_valid = train_test_split(X, y)

def objective(trial):
    clf = SGDClassifier(random_state=0)
    for step in range(100):
        clf.partial_fit(X_train, y_train, np.unique(y))
        intermediate_value = clf.score(X_valid, y_valid)
        trial.report(intermediate_value, step=step)
        if trial.should_prune():
            raise optuna.TrialPruned()
    return clf.score(X_valid, y_valid)

study = optuna.create_study(direction="maximize")
study.optimize(objective, n_trials=3)
```

Parameters

- **value** *(float)* — A value returned from the objective function.
- **step** *(int)* — Step of the trial (e.g., Epoch of neural network training). Note that pruners assume that step starts at zero. For example, MedianPruner simply checks if step is less than n_warmup_steps as the warmup mechanism.

Raises **NotImplementedError** — If trial is being used for multi-objective optimization.

Return type None

**set_system_attr** *(key, value)*

Set system attributes to the trial.

Note that Optuna internally uses this method to save system messages such as failure reason of trials. Please use **set_user_attr()** to set users’ attributes.

Parameters

- **key** *(str)* — A key string of the attribute.
- **value** *(Any)* — A value of the attribute. The value should be JSON serializable.

Return type None

**set_user_attr** *(key, value)*

Set user attributes to the trial.

The user attributes in the trial can be access via `optuna.trial.Trial.user_attrs()`.
Example

Save fixed hyperparameters of neural network training.

```python
import numpy as np
from sklearn.datasets import load_iris
from sklearn.model_selection import train_test_split
from sklearn.neural_network import MLPClassifier

import optuna

X, y = load_iris(return_X_y=True)
X_train, X_valid, y_train, y_valid = train_test_split(X, y, random_state=0)

def objective(trial):
    trial.set_user_attr("BATCHSIZE", 128)
    momentum = trial.suggest_uniform("momentum", 0, 1.0)
    clf = MLPClassifier(
        hidden_layer_sizes=(100, 50),
        batch_size=trial.user_attrs["BATCHSIZE"],
        momentum=momentum,
        solver="sgd",
        random_state=0,
    )
    clf.fit(X_train, y_train)

    return clf.score(X_valid, y_valid)

study = optuna.create_study(direction="maximize")
study.optimize(objective, n_trials=3)
assert "BATCHSIZE" in study.best_trial.user_attrs.keys()
assert study.best_trial.user_attrs["BATCHSIZE"] == 128
```

Parameters

- **key** *(str)* – A key string of the attribute.
- **value** *(Any)* – A value of the attribute. The value should be JSON serializable.

Return type **None**

**should_prune()**

Suggest whether the trial should be pruned or not.

The suggestion is made by a pruning algorithm associated with the trial and is based on previously reported values. The algorithm can be specified when constructing a *Study*.

**Note:** If no values have been reported, the algorithm cannot make meaningful suggestions. Similarly, if this method is called multiple times with the exact same set of reported values, the suggestions will be the same.

**See also:**

Please refer to the example code in `optuna.trial.Trial.report()`.
Returns A boolean value. If True, the trial should be pruned according to the configured pruning algorithm. Otherwise, the trial should continue.

Raises NotImplemented Error – If trial is being used for multi-objective optimization.

Return type bool

**suggest_categorical**\( (name, choices) \)

Suggest a value for the categorical parameter.

The value is sampled from choices.

**Example**

Suggest a kernel function of SVC.

```python
import numpy as np
from sklearn.datasets import load_iris
from sklearn.model_selection import train_test_split
from sklearn.svm import SVC
import optuna

X, y = load_iris(return_X_y=True)
X_train, X_valid, y_train, y_valid = train_test_split(X, y)

def objective(trial):
    kernel = trial.suggest_categorical("kernel", ["linear", "poly", "rbf"])
    clf = SVC(kernel=kernel, gamma="scale", random_state=0)
    clf.fit(X_train, y_train)
    return clf.score(X_valid, y_valid)

study = optuna.create_study(direction="maximize")
study.optimize(objective, n_trials=3)
```

**Parameters**

- `name`\( \text{(str)} \) – A parameter name.

- `choices`\( \text{(Sequence[Union[None, bool, int, float, str]])} \) – Parameter value candidates.

**Return type** Union[None, bool, int, float, str]

See also:

*CategoricalDistribution*.

**Returns** A suggested value.

**Parameters**

- `name`\( \text{(str)} \) –

- `choices`\( \text{(Sequence[Union[None, bool, int, float, str]])} \) –

**Return type** Union[None, bool, int, float, str]
suggest_discrete_uniform(name, low, high, q)

Suggest a value for the discrete parameter.

The value is sampled from the range \([\text{low}, \text{high}]\), and the step of discretization is \(q\). More specifically, this method returns one of the values in the sequence \(\text{low}, \text{low} + q, \text{low} + 2q, \ldots, \text{low} + kq \leq \text{high}\), where \(k\) denotes an integer. Note that \(\text{high}\) may be changed due to round-off errors if \(q\) is not an integer. Please check warning messages to find the changed values.

Example

Suggest a fraction of samples used for fitting the individual learners of GradientBoostingClassifier.

```python
import numpy as np
from sklearn.datasets import load_iris
from sklearn.ensemble import GradientBoostingClassifier
from sklearn.model_selection import train_test_split
import optuna

X, y = load_iris(return_X_y=True)
X_train, X_valid, y_train, y_valid = train_test_split(X, y)

def objective(trial):
    subsample = trial.suggest_discrete_uniform("subsample", 0.1, 1.0, 0.1)
    clf = GradientBoostingClassifier(subsample=subsample, random_state=0)
    clf.fit(X_train, y_train)
    return clf.score(X_valid, y_valid)

study = optuna.create_study(direction="maximize")
study.optimize(objective, n_trials=3)
```

Parameters

- **name** (str) – A parameter name.
- **low** (float) – Lower endpoint of the range of suggested values. \(\text{low}\) is included in the range.
- **high** (float) – Upper endpoint of the range of suggested values. \(\text{high}\) is included in the range.
- **q** (float) – A step of discretization.

Returns

A suggested float value.

Return type

float

suggest_float(name, low, high, *, step=None, log=False)

Suggest a value for the floating point parameter.

Note that this is a wrapper method for suggest_uniform(), suggest_loguniform() and suggest_discrete_uniform().

New in version 1.3.0.
See also:
Please see also `suggest_uniform()`, `suggest_loguniform()` and `suggest_discrete_uniform()`.

Example

Suggest a momentum, learning rate and scaling factor of learning rate for neural network training.

```python
import numpy as np
from sklearn.datasets import load_iris
from sklearn.model_selection import train_test_split
from sklearn.neural_network import MLPClassifier
import optuna

X, y = load_iris(return_X_y=True)
X_train, X_valid, y_train, y_valid = train_test_split(X, y, random_state=0)

def objective(trial):
    momentum = trial.suggest_float("momentum", 0.0, 1.0)
    learning_rate_init = trial.suggest_float(
        "learning_rate_init", 1e-5, 1e-3, log=True
    )
    power_t = trial.suggest_float("power_t", 0.2, 0.8, step=0.1)
    clf = MLPClassifier(
        hidden_layer_sizes=(100, 50),
        momentum=momentum,
        learning_rate_init=learning_rate_init,
        solver="sgd",
        random_state=0,
        power_t=power_t,
    )
    clf.fit(X_train, y_train)
    return clf.score(X_valid, y_valid)

study = optuna.create_study(direction="maximize")
study.optimize(objective, n_trials=3)
```

Parameters

- **name** *(str)* – A parameter name.
- **low** *(float)* – Lower endpoint of the range of suggested values. *low* is included in the range.
- **high** *(float)* – Upper endpoint of the range of suggested values. *high* is excluded from the range.

**Note:** If *step* is specified, *high* is included as well as *low* because this method falls back to `suggest_discrete_uniform()`.

- **step** *(Optional[float])* – A step of discretization.
Note: The step and log arguments cannot be used at the same time. To set the step argument to a float number, set the log argument to False.

- **log** *(bool)* – A flag to sample the value from the log domain or not. If log is true, the value is sampled from the range in the log domain. Otherwise, the value is sampled from the range in the linear domain. See also `suggest_uniform()` and `suggest_loguniform()`.

Note: The step and log arguments cannot be used at the same time. To set the log argument to True, set the step argument to None.

Raises **ValueError** – If step is not None and log = True are specified.

Returns A suggested float value.

Return type float

**suggest_int**(name, low, high, step=1, log=False)

Suggest a value for the integer parameter. The value is sampled from the integers in [low, high].

Example

Suggest the number of trees in RandomForestClassifier.

```python
import numpy as np
from sklearn.datasets import load_iris
from sklearn.ensemble import RandomForestClassifier
from sklearn.model_selection import train_test_split
import optuna

X, y = load_iris(return_X_y=True)
X_train, X_valid, y_train, y_valid = train_test_split(X, y)

def objective(trial):
    n_estimators = trial.suggest_int("n_estimators", 50, 400)
    clf = RandomForestClassifier(n_estimators=n_estimators, random_state=0)
    clf.fit(X_train, y_train)
    return clf.score(X_valid, y_valid)

study = optuna.create_study(direction="maximize")
study.optimize(objective, n_trials=3)
```

Parameters

- **name**(str) – A parameter name.
- **low**(int) – Lower endpoint of the range of suggested values. low is included in the range.
• high (int) – Upper endpoint of the range of suggested values. high is included in the range.

• step (int) – A step of discretization.

Note: Note that high is modified if the range is not divisible by step. Please check the warning messages to find the changed values.

Note: The method returns one of the values in the sequence \( \text{low}, \text{low} + \text{step}, \text{low} + 2 \times \text{step}, \ldots, \text{low} + k \times \text{step} \leq \text{high} \), where \( k \) denotes an integer.

Note: The step \( \neq 1 \) and log arguments cannot be used at the same time. To set the step argument \( \text{step} \geq 2 \), set the log argument to False.

• log (bool) – A flag to sample the value from the log domain or not.

Note: If log is true, at first, the range of suggested values is divided into grid points of width 1. The range of suggested values is then converted to a log domain, from which a value is sampled. The uniformly sampled value is re-converted to the original domain and rounded to the nearest grid point that we just split, and the suggested value is determined. For example, if \( \text{low} = 2 \) and \( \text{high} = 8 \), then the range of suggested values is \( \{2, 3, 4, 5, 6, 7, 8\} \) and lower values tend to be more sampled than higher values.

Note: The step \( \neq 1 \) and log arguments cannot be used at the same time. To set the log argument to True, set the step argument to 1.

Raises ValueError – If step \( \neq 1 \) and log = True are specified.

Return type int

suggest_loguniform (name, low, high)

Suggest a value for the continuous parameter.

The value is sampled from the range \([\text{low}, \text{high})\) in the log domain. When \( \text{low} = \text{high} \), the value of \( \text{low} \) will be returned.

Example

Suggest penalty parameter \( C \) of SVC.

```python
import numpy as np
from sklearn.datasets import load_iris
from sklearn.model_selection import train_test_split
from sklearn.svm import SVC
import optuna

X, y = load_iris(return_X_y=True)
```
X_train, X_valid, y_train, y_valid = train_test_split(X, y)

def objective(trial):
    c = trial.suggest_loguniform("c", 1e-5, 1e2)
    clf = SVC(C=c, gamma="scale", random_state=0)
    clf.fit(X_train, y_train)
    return clf.score(X_valid, y_valid)

study = optuna.create_study(direction="maximize")
study.optimize(objective, n_trials=3)

Parameters

- **name** (str) – A parameter name.
- **low** (float) – Lower endpoint of the range of suggested values. low is included in the range.
- **high** (float) – Upper endpoint of the range of suggested values. high is excluded from the range.

Returns A suggested float value.

Return type float

suggest_uniform(name, low, high)

Suggest a value for the continuous parameter.

The value is sampled from the range [low, high) in the linear domain. When low = high, the value of low will be returned.

Example

Suggest a momentum for neural network training.

```python
import numpy as np
from sklearn.datasets import load_iris
from sklearn.model_selection import train_test_split
from sklearn.neural_network import MLPClassifier

import optuna

X, y = load_iris(return_X_y=True)
X_train, X_valid, y_train, y_valid = train_test_split(X, y)

def objective(trial):
    momentum = trial.suggest_uniform("momentum", 0.0, 1.0)
    clf = MLPClassifier(
        hidden_layer_sizes=(100, 50),
        momentum=momentum,
        solver="sgd",
        random_state=0,
    )
    return clf.score(X_valid, y_valid)

study = optuna.create_study(direction="maximize")
study.optimize(objective, n_trials=3)
```
clf.fit(X_train, y_train)

    return clf.score(X_valid, y_valid)

study = optuna.create_study(direction="maximize")
study.optimize(objective, n_trials=3)

**Parameters**

- **name** *(str)* – A parameter name.
- **low** *(float)* – Lower endpoint of the range of suggested values. low is included in the range.
- **high** *(float)* – Upper endpoint of the range of suggested values. high is excluded from the range.

**Returns** A suggested float value.

**Return type** *float*

**property** *system_attrs*

Return system attributes.

**Returns** A dictionary containing all system attributes.

**property** *user_attrs*

Return user attributes.

**Returns** A dictionary containing all user attributes.

**optuna.trial.FixedTrial**

**class** *optuna.trial.FixedTrial*(params, number=0)

A trial class which suggests a fixed value for each parameter.

This object has the same methods as *Trial*, and it suggests pre-defined parameter values. The parameter values can be determined at the construction of the *FixedTrial* object. In contrast to *Trial*, *FixedTrial* does not depend on *Study*, and it is useful for deploying optimization results.

**Example**

Evaluate an objective function with parameter values given by a user.

```python
import optuna

def objective(trial):
    x = trial.suggest_uniform("x", -100, 100)
    y = trial.suggest_categorical("y", [-1, 0, 1])
    return x ** 2 + y

assert objective(optuna.trial.FixedTrial({"x": 1, "y": 0})) == 1
```
Note: Please refer to Trial for details of methods and properties.

Parameters

- **params** – A dictionary containing all parameters.
- **number** – A trial number. Defaults to 0.

Methods

- `report(value, step)`
- `set_system_attr(key, value)`
- `set_user_attr(key, value)`
- `should_prune()`
- `suggest_categorical(name, choices)`
- `suggest_discrete_uniform(name, low, high, q)`
- `suggest_float(name, low, high, *[step, log])`
- `suggest_int(name, low, high[, step, log])`
- `suggest_loguniform(name, low, high)`
- `suggest_uniform(name, low, high)`

Attributes

- `datetime_start`
- `distributions`
- `number`
- `params`
- `system_attrs`
- `user_attrs`
**optuna.trial.FrozenTrial**

*class optuna.trial.FrozenTrial*(number, state, value, datetime_start, datetime_complete, params, distributions, user_attrs, system_attrs, intermediate_values, trial_id, *, values=None)*

Status and results of a Trial.

This object has the same methods as Trial, and it suggests best parameter values among performed trials. In contrast to Trial, FrozenTrial does not depend on Study, and it is useful for deploying optimization results.

**Example**

Re-evaluate an objective function with parameter values optimized study.

```python
import optuna
def objective(trial):
    x = trial.suggest_uniform("x", -1, 1)
    return x ** 2

study = optuna.create_study()
study.optimize(objective, n_trials=3)
assert objective(study.best_trial) == study.best_value
```

**Note:** Instances are mutable, despite the name. For instance, *set_user_attr()* will update user attributes of objects in-place.

**Example:**

Overwritten attributes.

```python
import copy
import datetime
import optuna
def objective(trial):
    x = trial.suggest_uniform("x", -1, 1)

    # this user attribute always differs
    trial.set_user_attr("evaluation time", datetime.datetime.now())

    return x ** 2

study = optuna.create_study()
study.optimize(objective, n_trials=3)
best_trial = study.best_trial
best_trial_copy = copy.deepcopy(best_trial)
```

(continues on next page)
```python
# re-evaluate
objective(best_trial)

# the user attribute is overwritten by re-evaluation
assert best_trial.user_attrs != best_trial_copy.user_attrs
```

Note: Please refer to `Trial` for details of methods and properties.

**number**
Unique and consecutive number of `Trial` for each `Study`. Note that this field uses zero-based numbering.

**state**
`TrialState` of the `Trial`.

**value**
Objective value of the `Trial`.

**values**
Sequence of objective values of the `Trial`. The length is greater than 1 if the problem is multi-objective optimization.

**datetime_start**
Datetime where the `Trial` started.

**datetime_complete**
Datetime where the `Trial` finished.

**params**
Dictionary that contains suggested parameters.

**user_attrs**
Dictionary that contains the attributes of the `Trial` set with `optuna.trial.Trial.set_user_attr()`.

**intermediate_values**
Intermediate objective values set with `optuna.trial.Trial.report()`.

Raises `ValueError` – If both `value` and `values` are specified.

**Methods**

- `report(value, step)` Interface of report function.
- `set_system_attr(key, value)`
- `set_user_attr(key, value)`
- `should_prune()` Suggest whether the trial should be pruned or not.
- `suggest_categorical(name, choices)`
- `suggest_discrete_uniform(name, low, high, q)`
suggest_float(name, low, high, *[step, log])

suggest_int(name, low, high, *[step, log])

suggest_loguniform(name, low, high)

suggest_uniform(name, low, high)

### Attributes

**datetime_start**

**distributions** Dictionary that contains the distributions of `params`.

**duration** Return the elapsed time taken to complete the trial.

**last_step** Return the maximum step of `intermediate_values` in the trial.

**number**

**params**

**system_attrs**

**user_attrs**

**value**

**values**

**property distributions** Dictionary that contains the distributions of `params`.

**property duration** Return the elapsed time taken to complete the trial.

  Returns The duration.

**property last_step** Return the maximum step of `intermediate_values` in the trial.

  Returns The maximum step of intermediates.

**report** *(value, step)* Interface of report function.

Since `FrozenTrial` is not pruned, this report function does nothing.

See also:

Please refer to `should_prune()`.

Parameters
• **value** *(float)* – A value returned from the objective function.

• **step** *(int)* – Step of the trial (e.g., Epoch of neural network training). Note that pruners assume that step starts at zero. For example, *MedianPruner* simply checks if step is less than *n_warmup_steps* as the warmup mechanism.

**Return type** None

**should_prune()**

Suggest whether the trial should be pruned or not.

The suggestion is always *False* regardless of a pruning algorithm.

**Returns** *False*.

**Return type** *bool*

---

**optuna.trial.TrialState**

**class optuna.trial.TrialState(value)**

State of a *Trial*.

**RUNNING**

The *Trial* is running.

**WAITING**

The *Trial* is waiting and unfinished.

**COMPLETE**

The *Trial* has been finished without any error.

**PRUNED**

The *Trial* has been pruned with *TrialPruned*.

**FAIL**

The *Trial* has failed due to an uncaught error.

**Attributes**

**COMPLETE**

**FAIL**

**PRUNED**

**RUNNING**

**WAITING**
**optuna.trial.create_trial**

```python
optuna.trial.create_trial(*, state= TrialState.COMPLETE, value=None, values=None, params=None, distributions=None, user_attrs=None, system_attrs=None, intermediate_values=None)
```

Create a new *FrozenTrial*.

**Example**

```python
import optuna
from optuna.distributions import CategoricalDistribution
from optuna.distributions import UniformDistribution

trial = optuna.trial.create_trial(
    params={"x": 1.0, "y": 0},
    distributions={
        "x": UniformDistribution(0, 10),
        "y": CategoricalDistribution([-1, 0, 1]),
    },
    value=5.0,
)

assert isinstance(trial, optuna.trial.FrozenTrial)
assert trial.value == 5.0
assert trial.params =={"x": 1.0, "y": 0}
```

See also:

See *add_trial()* for how this function can be used to create a study from existing trials.

**Note:** Please note that this is a low-level API. In general, trials that are passed to objective functions are created inside *optimize()*.

**Note:** When *state* is *TrialState.COMPLETE*, the following parameters are required:

- *params*
- *distributions*
- *value* or *values*

**Parameters**

- **state**(optuna.trial._state.TrialState) – Trial state.
- **value**(Optional[float]) – Trial objective value. Must be specified if *state* is *TrialState.COMPLETE*.
- **values**(Optional[Sequence[float]]) – Sequence of the trial objective values. The length is greater than 1 if the problem is multi-objective optimization. Must be specified if *state* is *TrialState.COMPLETE*.
- **params**(Optional[Dict[str, Any]]) – Dictionary with suggested parameters of the trial.
• **distributions** (Optional[Dict[str, optuna.distributions.BaseDistribution]]) – Dictionary with parameter distributions of the trial.

• **user_attrs** (Optional[Dict[str, Any]]) – Dictionary with user attributes.

• **system_attrs** (Optional[Dict[str, Any]]) – Dictionary with system attributes. Should not have to be used for most users.

• **intermediate_values** (Optional[Dict[int, float]]) – Dictionary with intermediate objective values of the trial.

**Returns** Created trial.

**Raises** ValueError – If both value and values are specified.

**Return type** optuna.trial._frozen.FrozenTrial

---

**Note:** Added in v2.0.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.0.0.

---

### 6.3.15 optuna.visualization

The `visualization` module provides utility functions for plotting the optimization process using `plotly` and `matplotlib`. Plotting functions generally take a `Study` object and optional parameters are passed as a list to the `params` argument.

**Note:** In the `optuna.visualization` module, the following functions use `plotly` to create figures, but JupyterLab cannot render them by default. Please follow this installation guide to show figures in JupyterLab.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>optuna.visualization.plot_contour</code></td>
<td>Plot the parameter relationship as contour plot in a study.</td>
</tr>
<tr>
<td><code>optuna.visualization.plot_edf</code></td>
<td>Plot the objective value EDF (empirical distribution function) of a study.</td>
</tr>
<tr>
<td><code>optuna.visualization.plot_intermediate_values</code></td>
<td>Plot intermediate values of all trials in a study.</td>
</tr>
<tr>
<td><code>optuna.visualization.plot_optimization_history</code></td>
<td>Plot optimization history of all trials in a study.</td>
</tr>
<tr>
<td><code>optuna.visualization.plot_parallel_coordinate</code></td>
<td>Plot the high-dimensional parameter relationships in a study.</td>
</tr>
<tr>
<td><code>optuna.visualization.plot_param_importances</code></td>
<td>Plot hyperparameter importances.</td>
</tr>
<tr>
<td><code>optuna.visualization.plot_pareto_front</code></td>
<td>Plot the Pareto front of a study.</td>
</tr>
<tr>
<td><code>optuna.visualization.plot_slice</code></td>
<td>Plot the parameter relationship as slice plot in a study.</td>
</tr>
<tr>
<td><code>optuna.visualization.is_available</code></td>
<td>Returns whether visualization with <code>plotly</code> is available or not.</td>
</tr>
</tbody>
</table>
optuna.visualization.plot_contour

```python
optuna.visualization.plot_contour(study, params=None, *, target=None, target_name='Objective Value')
```

Plot the parameter relationship as contour plot in a study.

Note that, if a parameter contains missing values, a trial with missing values is not plotted.

**Example**

The following code snippet shows how to plot the parameter relationship as contour plot.

```python
import optuna
def objective(trial):
    x = trial.suggest_float("x", -100, 100)
    y = trial.suggest_categorical("y", [-1, 0, 1])
    return x ** 2 + y

sampler = optuna.samplers.TPESampler(seed=10)
study = optuna.create_study(sampler=sampler)
study.optimize(objective, n_trials=30)
fig = optuna.visualization.plot_contour(study, params=['x', 'y'])
fig.show()
```

**Parameters**

- `study (optuna.study.Study)`: A `Study` object whose trials are plotted for their target values.
- `params (Optional[List[str]])`: Parameter list to visualize. The default is all parameters.
- `target (Optional[Callable[[optuna.trial._frozen.FrozenTrial], float]])`: A function to specify the value to display. If it is `None` and `study` is being used for single-objective optimization, the objective values are plotted.

**Note**: Specify this argument if `study` is being used for multi-objective optimization.

- `target_name (str)`: Target’s name to display on the color bar.

**Returns**

A `plotly.graph_objs.Figure` object.

**Raises** `ValueError` – If `target` is `None` and `study` is being used for multi-objective optimization.

**Return type** `plotly.graph_objs.Figure`
**optuna.visualization.plot_edf**

`optuna.visualization.plot_edf(study, *, target=None, target_name='Objective Value')`  
Plot the objective value EDF (empirical distribution function) of a study.

Note that only the complete trials are considered when plotting the EDF.

**Note:** EDF is useful to analyze and improve search spaces. For instance, you can see a practical use case of EDF in the paper *Designing Network Design Spaces*.

**Note:** The plotted EDF assumes that the value of the objective function is in accordance with the uniform distribution over the objective space.

**Example**

The following code snippet shows how to plot EDF.

```python
import math
import optuna

def ackley(x, y):
    a = 20 * math.exp(-0.2 * math.sqrt(0.5 * (x ** 2 + y ** 2)))
    b = math.exp(0.5 * (math.cos(2 * math.pi * x) + math.cos(2 * math.pi * y)))
    return -a - b + math.e + 20

def objective(trial, low, high):
    x = trial.suggest_float("x", low, high)
    y = trial.suggest_float("y", low, high)
    return ackley(x, y)

sampler = optuna.samplers.RandomSampler(seed=10)

# Widest search space.
study0 = optuna.create_study(study_name="x=[0,5), y=[0,5)", sampler=sampler)
study0.optimize(lambda t: objective(t, 0, 5), n_trials=500)

# Narrower search space.
study1 = optuna.create_study(study_name="x=[0,4), y=[0,4)", sampler=sampler)
study1.optimize(lambda t: objective(t, 0, 4), n_trials=500)

# Narrowest search space but it doesn't include the global optimum point.
study2 = optuna.create_study(study_name="x=[1,3), y=[1,3)", sampler=sampler)
study2.optimize(lambda t: objective(t, 1, 3), n_trials=500)

fig = optuna.visualization.plot_edf([study0, study1, study2])
fig.show()
```

**Parameters**
• **study** (Union[optuna.study.study.Study, Sequence[optuna.study.study.Study]]) – A target **Study** object. You can pass multiple studies if you want to compare those EDFs.

• **target** (Optional[Callable[[optuna.trial._frozen.FrozenTrial], float]]) – A function to specify the value to display. If it is `None` and study is being used for single-objective optimization, the objective values are plotted.

**Note**: Specify this argument if study is being used for multi-objective optimization.

• **target_name** (str) – Target’s name to display on the axis label.

**Returns** A `plotly.graph_objs.Figure` object.

**Raises** `ValueError` – If target is `None` and study is being used for multi-objective optimization.

**Return type** `plotly.graph_objs._figure.Figure`

**optuna.visualization.plot_intermediate_values**

**optuna.visualization.plot_intermediate_values(study)**

Plot intermediate values of all trials in a study.

**Example**

The following code snippet shows how to plot intermediate values.

```python
import optuna

def f(x):
    return (x - 2) ** 2

def df(x):
    return 2 * x - 4

def objective(trial):
    lr = trial.suggest_float("lr", 1e-5, 1e-1, log=True)

    x = 3
    for step in range(128):
        y = f(x)

        trial.report(y, step=step)
        if trial.should_prune():
            raise optuna.TrialPruned()

        gy = df(x)
        x -= gy * lr

    return y
```

(continues on next page)
sampler = optuna.samplers.TPESampler(seed=10)
study = optuna.create_study(sampler=sampler)
study.optimize(objective, n_trials=16)

fig = optuna.visualization.plot_intermediate_values(study)
fig.show()

Parameters

**study** *(optuna.study.Study)* — A *Study* object whose trials are plotted for their intermediate values.

Returns

A *plotly.graph_objs.Figure* object.

Return type

*plotly.graph_objs._figure.Figure*

### optuna.visualization.plot_optimization_history

**optuna.visualization.plot_optimization_history** *(study, *, target=None, target_name='Objective Value')*

Plot optimization history of all trials in a study.

**Example**

The following code snippet shows how to plot optimization history.

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", -100, 100)
    y = trial.suggest_categorical("y", [-1, 0, 1])
    return x ** 2 + y

sampler = optuna.samplers.TPESampler(seed=10)
study = optuna.create_study(sampler=sampler)
study.optimize(objective, n_trials=10)

fig = optuna.visualization.plot_optimization_history(study)
fig.show()
```

Parameters

- **study** *(optuna.study.Study)* — A *Study* object whose trials are plotted for their target values.

- **target** *(Optional[Callable[[optuna.trial.FrozenTrial], float]])* — A function to specify the value to display. If it is *None* and *study* is being used for single-objective optimization, the objective values are plotted.

  **Note:** Specify this argument if *study* is being used for multi-objective optimization.

- **target_name** *(str)* — Target’s name to display on the axis label and the legend.
Returns A `plotly.graph_objs.Figure` object.

Raises `ValueError`—If `target` is `None` and `study` is being used for multi-objective optimization.

Return type `plotly.graph_objs.Figure`
**optuna.visualization.plot_param_importances**

`optuna.visualization.plot_param_importances(study, evaluator=None, params=None, *, target=None, target_name='Objective Value')`

Plot hyperparameter importances.

**Example**

The following code snippet shows how to plot hyperparameter importances.

```python
import optuna

def objective(trial):
    x = trial.suggest_int("x", 0, 2)
    y = trial.suggest_float("y", -1.0, 1.0)
    z = trial.suggest_float("z", 0.0, 1.5)
    return x ** 2 + y ** 3 - z ** 4

sampler = optuna.samplers.RandomSampler(seed=10)
study = optuna.create_study(sampler=sampler)
study.optimize(objective, n_trials=100)

fig = optuna.visualization.plot_param_importances(study)
fig.show()
```

See also:

This function visualizes the results of `optuna.importance.get_param_importances()`.

**Parameters**

- **study** (`optuna.study.Study`) – An optimized study.
- **evaluator** (`Optional[optuna.importance._base.BaseImportanceEvaluator]`) – An importance evaluator object that specifies which algorithm to base the importance assessment on. Defaults to `FanovaImportanceEvaluator`.
- **params** (`Optional[List[str]]`) – A list of names of parameters to assess. If `None`, all parameters that are present in all of the completed trials are assessed.
- **target** (`Optional[Callable[[optuna.trial._frozen.FrozenTrial], float]]`) – A function to specify the value to display. If it is `None` and `study` is being used for single-objective optimization, the objective values are plotted.

**Note**: Specify this argument if `study` is being used for multi-objective optimization. For example, to get the hyperparameter importance of the first objective, use `target=lambda t: t.values[0]` for the target parameter.

- **target_name** (`str`) – Target’s name to display on the axis label.

**Returns** `plotly.graph_objs.Figure` object.

**Raises** `ValueError` – If `target` is `None` and `study` is being used for multi-objective optimization.
Return type  plotly.graph_objs._figure.Figure

optuna.visualization.plot_pareto_front

optuna.visualization.plot_pareto_front(study, *, target_names=None, include_dominated_trials=True, axis_order=None)

Plot the Pareto front of a study.

Example

The following code snippet shows how to plot the Pareto front of a study.

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", 0, 5)
    y = trial.suggest_float("y", 0, 3)

    v0 = 4 * x ** 2 + 4 * y ** 2
    v1 = (x - 5) ** 2 + (y - 5) ** 2
    return v0, v1

study = optuna.create_study(directions=["minimize", "minimize"])
study.optimize(objective, n_trials=50)

fig = optuna.visualization.plot_pareto_front(study)
fig.show()
```

Parameters

- **study** (optuna.study.study.Study) – A Study object whose trials are plotted for their objective values.
- **target_names** (Optional[List[str]]) – Objective name list used as the axis titles. If None is specified, “Objective [objective_index]” is used instead.
- **include_dominated_trials** (bool) – A flag to include all dominated trial’s objective values.
- **axis_order** (Optional[List[int]]) – A list of indices indicating the axis order. If None is specified, default order is used.

Returns  A plotly.graph_objs.Figure object.

Raises Value Error – If the number of objectives of study isn’t 2 or 3.

Return type  plotly.graph_objs._figure.Figure

Note:  Added in v2.4.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.4.0.
optuna.visualization.plot_slice

optuna.visualization.plot_slice(study, params=None, *, target=None, target_name='Objective Value')

Plot the parameter relationship as slice plot in a study.

Note that, if a parameter contains missing values, a trial with missing values is not plotted.

Example

The following code snippet shows how to plot the parameter relationship as slice plot.

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", -100, 100)
    y = trial.suggest_categorical("y", [-1, 0, 1])
    return x ** 2 + y

sampler = optuna.samplers.TPESampler(seed=10)
study = optuna.create_study(sampler=sampler)
study.optimize(objective, n_trials=10)

fig = optuna.visualization.plot_slice(study, params=['x', 'y'])
fig.show()
```

Parameters

- **study** (optuna.study.study.Study) – A Study object whose trials are plotted for their target values.

- **params** (Optional[List[str]]) – Parameter list to visualize. The default is all parameters.

- **target** (Optional[Callable[[optuna.trial._frozen.FrozenTrial], float]]) – A function to specify the value to display. If it is None and study is being used for single-objective optimization, the objective values are plotted.

  **Note**: Specify this argument if study is being used for multi-objective optimization.

- **target_name** (str) – Target’s name to display on the axis label.

Returns A plotly.graph_objs.Figure object.

Raises ValueError – If target is None and study is being used for multi-objective optimization.

Return type plotly.graph_objs._figure.Figure
**optuna.visualization.is_available**

`optuna.visualization.is_available()`

Returns whether visualization with plotly is available or not.

**Note:** `visualization` module depends on plotly version 4.0.0 or higher. If a supported version of plotly isn’t installed in your environment, this function will return `False`. In such case, please execute `pip install -U plotly>=4.0.0` to install plotly.

**Returns** `True` if visualization with plotly is available, `False` otherwise.

**Return type** `bool`

**Note:** The following `optuna.visualization.matplotlib` module uses Matplotlib as a backend.

**optuna.visualization.matplotlib**

**Note:** The following functions use Matplotlib as a backend.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>plot_contour</code></td>
<td>Plot the parameter relationship as contour plot in a study with Matplotlib.</td>
</tr>
<tr>
<td><code>plot_edf</code></td>
<td>Plot the objective value EDF (empirical distribution function) of a study with Matplotlib.</td>
</tr>
<tr>
<td><code>plot_intermediate_values</code></td>
<td>Plot intermediate values of all trials in a study with Matplotlib.</td>
</tr>
<tr>
<td><code>plot_optimization_history</code></td>
<td>Plot optimization history of all trials in a study with Matplotlib.</td>
</tr>
<tr>
<td><code>plot_parallel_coordinate</code></td>
<td>Plot the high-dimensional parameter relationships in a study with Matplotlib.</td>
</tr>
<tr>
<td><code>plot_param_importances</code></td>
<td>Plot hyperparameter importances with Matplotlib.</td>
</tr>
<tr>
<td><code>plot_pareto_front</code></td>
<td>Plot the Pareto front of a study.</td>
</tr>
<tr>
<td><code>plot_slice</code></td>
<td>Plot the parameter relationship as slice plot in a study with Matplotlib.</td>
</tr>
<tr>
<td><code>is_available</code></td>
<td>Returns whether visualization with Matplotlib is available or not.</td>
</tr>
</tbody>
</table>
optuna.visualization.matplotlib.plot_contour

optuna.visualization.matplotlib.plot_contour(study, params=None, *, target=None, target_name='Objective Value')

Plot the parameter relationship as contour plot in a study with Matplotlib.

Note that, if a parameter contains missing values, a trial with missing values is not plotted.

See also:
Please refer to optuna.visualization.plot_contour() for an example.

Warning: Output figures of this Matplotlib-based plot_contour() function would be different from those of the Plotly-based plot_contour().

Example

The following code snippet shows how to plot the parameter relationship as contour plot.

```python
import optuna
def objective(trial):
    x = trial.suggest_float("x", -100, 100)
    y = trial.suggest_categorical("y", [-1, 0, 1])
    return x ** 2 + y

sampler = optuna.samplers.TPESampler(seed=10)
study = optuna.create_study(sampler=sampler)
study.optimize(objective, n_trials=30)

optuna.visualization.matplotlib.plot_contour(study, params=["x", "y"])
```

Parameters

- **study** (optuna.study.study.Study) – A Study object whose trials are plotted for their target values.
- **params** (Optional[List[str]]) – Parameter list to visualize. The default is all parameters.
- **target** (Optional[Callable[[optuna.trial._frozen.FrozenTrial], float]]) – A function to specify the value to display. If it is None and study is being used for multi-objective optimization, the objective values are plotted.

Note: Specify this argument if study is being used for multi-objective optimization.

- **target_name** (str) – Target’s name to display on the color bar.

Returns
A matplotlib.axes.Axes object.

Raises
ValueError – If target is None and study is being used for multi-objective optimization.

Return type
matplotlib.axes._axes.Axes
Note: Added in v2.2.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.2.0.

**optuna.visualization.matplotlib.plot_edf**

`optuna.visualization.matplotlib.plot_edf(study, *, target=None, target_name='Objective Value')`

Plot the objective value EDF (empirical distribution function) of a study with Matplotlib.

See also:

Please refer to `optuna.visualization.plot_edf()` for an example, where this function can be replaced with it.

Note: Please refer to matplotlib.pyplot.legend to adjust the style of the generated legend.

**Example**

The following code snippet shows how to plot EDF:

```python
import math
import optuna

def ackley(x, y):
    a = 20 * math.exp(-0.2 * math.sqrt(0.5 * (x ** 2 + y ** 2)))
    b = math.exp(0.5 * (math.cos(2 * math.pi * x) + math.cos(2 * math.pi * y)))
    return -a - b + math.e + 20

def objective(trial, low, high):
    x = trial.suggest_float("x", low, high)
    y = trial.suggest_float("y", low, high)
    return ackley(x, y)

sampler = optuna.samplers.RandomSampler(seed=10)

# Widest search space.
study0 = optuna.create_study(study_name="x=[0,5), y=[0,5)", sampler=sampler)
study0.optimize(lambda t: objective(t, 0, 5), n_trials=500)

# Narrower search space.
study1 = optuna.create_study(study_name="x=[0,4), y=[0,4)", sampler=sampler)
study1.optimize(lambda t: objective(t, 0, 4), n_trials=500)

# Narrowest search space but it doesn't include the global optimum point.
study2 = optuna.create_study(study_name="x=[1,3), y=[1,3)", sampler=sampler)
study2.optimize(lambda t: objective(t, 1, 3), n_trials=500)

optuna.visualization.matplotlib.plot_edf([study0, study1, study2])
```
Parameters

- **study** *(Union[optuna.study.study.Study, Sequence[optuna.study.study.Study]])* – A target Study object. You can pass multiple studies if you want to compare those EDFs.

- **target** *(Optional[Callable[[optuna.trial._frozen.FrozenTrial], float]])* – A function to specify the value to display. If it is None and study is being used for single-objective optimization, the objective values are plotted.

  **Note:** Specify this argument if study is being used for multi-objective optimization.

- **target_name** *(str)* – Target’s name to display on the axis label.

**Returns** A matplotlib.axes.Axes object.

**Raises** `ValueError` – If target is None and study is being used for multi-objective optimization.

**Return type** matplotlib.axes._axes.Axes

**Note:** Added in v2.2.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.2.0.

**Example**

The following code snippet shows how to plot intermediate values.

```python
import optuna

def f(x):
    return (x - 2) ** 2

def df(x):
    return 2 * x - 4

def objective(trial):
    lr = trial.suggest_float("lr", 1e-5, 1e-1, log=True)

    x = 3
    for step in range(128):
```

(continues on next page)
See also:

Please refer to `optuna.visualization.plot_intermediate_values()` for an example.

**Parameters**

- `study (optuna.study.Study)` — A `Study` object whose trials are plotted for their intermediate values.
Returns A matplotlib.axes.Axes object.

Return type matplotlib.axes.Axes

Note: Added in v2.2.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.2.0.

optuna.visualization.matplotlib.plot_optimization_history

optuna.visualization.matplotlib.plot_optimization_history(study, *, target=None, target_name='Objective Value')

Plot optimization history of all trials in a study with Matplotlib.

See also:
Please refer to optuna.visualization.plot_optimization_history() for an example.

Example

The following code snippet shows how to plot optimization history.

```python
import optuna
def objective(trial):
    x = trial.suggest_float("x", -100, 100)
    y = trial.suggest_categorical("y", [-1, 0, 1])
    return x ** 2 + y
sampler = optuna.samplers.TPESampler(seed=10)
study = optuna.create_study(sampler=sampler)
study.optimize(objective, n_trials=10)
optuna.visualization.matplotlib.plot_optimization_history(study)
```

Parameters

- **study** (optuna.study.study.Study) – A Study object whose trials are plotted for their target values.

- **target** (Optional[Callable[[optuna.trial._frozen.FrozenTrial], float]]) – A function to specify the value to display. If it is None and study is being used for single-objective optimization, the objective values are plotted.

  Note: Specify this argument if study is being used for multi-objective optimization.

- **target_name** (str) – Target’s name to display on the axis label and the legend.

Returns A matplotlib.axes.Axes object.

Raises ValueError – If target is None and study is being used for multi-objective optimization.
Return type  matplotlib.axes.Axes

Note:  Added in v2.2.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.2.0.

```
optuna.visualization.matplotlib.plot_parallel_coordinate

optuna.visualization.matplotlib.plot_parallel_coordinate(study, params=None, *, target=None, target_name='Objective Value')
```

Plot the high-dimensional parameter relationships in a study with Matplotlib.

See also:
Please refer to `optuna.visualization.plot_parallel_coordinate()` for an example.

Example

The following code snippet shows how to plot the high-dimensional parameter relationships.

```python
import optuna
def objective(trial):
x = trial.suggest_float("x", -100, 100)
y = trial.suggest_categorical("y", [-1, 0, 1])
return x ** 2 + y

sampler = optuna.samplers.TPESampler(seed=10)
study = optuna.create_study(sampler=sampler)
study.optimize(objective, n_trials=10)
optuna.visualization.matplotlib.plot_parallel_coordinate(study, params=['x', 'y'])
```

Parameters

- `study` (optuna.study.Study) – A Study object whose trials are plotted for their target values.
- `params` (Optional[List[str]]) – Parameter list to visualize. The default is all parameters.
- `target` (Optional[Callable[[optuna.trial.FrozenTrial], float]]) – A function to specify the value to display. If it is None and study is being used for single-objective optimization, the objective values are plotted.

Note:  Specify this argument if study is being used for multi-objective optimization.

- `target_name` (str) – Target’s name to display on the axis label and the legend.

Returns  A matplotlib.axes.Axes object.
Raises **ValueError** – If `target` is `None` and `study` is being used for multi-objective optimization.

**Return type** `matplotlib.axes.Axes`

**Note:** Added in v2.2.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.2.0.

```python
import optuna

def objective(trial):
    x = trial.suggest_int("x", 0, 2)
    y = trial.suggest_float("y", -1.0, 1.0)
    z = trial.suggest_float("z", 0.0, 1.5)
    return x ** 2 + y ** 3 - z ** 4

sampler = optuna.samplers.RandomSampler(seed=10)
study = optuna.create_study(sampler=sampler)
study.optimize(objective, n_trials=100)
optuna.visualization.matplotlib.plot_param_importances(study)
```

**Parameters**

- **study** (`optuna.study.Study`) – An optimized study.
- **evaluator** (`Optional[optuna.importance._base.BaseImportanceEvaluator]`) – An importance evaluator object that specifies which algorithm to base the importance assessment on. Defaults to `FanovaImportanceEvaluator`.
- **params** (`Optional[List[str]]`) – A list of names of parameters to assess. If `None`, all parameters that are present in all of the completed trials are assessed.
Hyperparameter Importances

Importance for Objective Value

x

y

z

Hyperparameter
**target** *(Optional)[Callable[[optuna.trial._frozen.FrozenTrial], float]]* – A function to specify the value to display. If it is `None` and `study` is being used for single-objective optimization, the objective values are plotted.

**Note:** Specify this argument if `study` is being used for multi-objective optimization. For example, to get the hyperparameter importance of the first objective, use `target=lambda t: t.values[0]` for the target parameter.

**target_name** *(str)* – Target’s name to display on the axis label.


Raises: `ValueError` – If `target` is `None` and `study` is being used for multi-objective optimization.

Return type: `matplotlib.axes.Axes`

**Note:** Added in v2.2.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.2.0.

### optuna.visualization.matplotlib.plot_pareto_front

```
import optuna

def objective(trial):
    x = trial.suggest_float("x", 0, 5)
    y = trial.suggest_float("y", 0, 3)
    v0 = 4 * x ** 2 + 4 * y ** 2
    v1 = (x - 5) ** 2 + (y - 5) ** 2
    return v0, v1

study = optuna.create_study(directions=["minimize", "minimize"])
study.optimize(objective, n_trials=50)

optuna.visualization.matplotlib.plot_pareto_front(study)
```

**Parameters**
- **study** (*optuna.study.study.Study*) – A *Study* object whose trials are plotted for their objective values.
- **target_names** (*Optional[List[str]]*) – Objective name list used as the axis titles. If *None* is specified, “Objective [objective_index]” is used instead.
- **include_dominated_trials** (*bool*) – A flag to include all dominated trial’s objective values.
- **axis_order** (*Optional[List[int]]*) – A list of indices indicating the axis order. If *None* is specified, default order is used.

Returns

Raises **ValueError** – If the number of objectives of *study* isn’t 2 or 3.

**Return type**
*matplotlib.axes._axes.Axes*

---

**Note:** Added in v2.8.0 as an experimental feature. The interface may change in newer versions without prior notice. See https://github.com/optuna/optuna/releases/tag/v2.8.0.

**optuna.visualization.matplotlib.plot_slice**

*optuna.visualization.matplotlib.plot_slice*(study, params=None, *, target=None, target_name='Objective Value')

Plot the parameter relationship as slice plot in a study with Matplotlib.

See also:
Please refer to *optuna.visualization.plot_slice()* for an example.

**Example**

The following code snippet shows how to plot the parameter relationship as slice plot.

```python
import optuna

def objective(trial):
    x = trial.suggest_float("x", -100, 100)
    y = trial.suggest_categorical("y", [-1, 0, 1])
    return x ** 2 + y

sampler = optuna.samplers.TPESampler(seed=10)
study = optuna.create_study(sampler=sampler)
study.optimize(objective, n_trials=10)

optuna.visualization.matplotlib.plot_slice(study, params=["x", "y"])
```

**Parameters**

- **study** (*optuna.study.study.Study*) – A *Study* object whose trials are plotted for their target values.
• **params** *(Optional[List[str]])* – Parameter list to visualize. The default is all parameters.

• **target** *(Optional[Callable[[optuna.trial._frozen.FrozenTrial], float]])* – A function to specify the value to display. If it is `None` and `study` is being used for single-objective optimization, the objective values are plotted.

**Note:** Specify this argument if `study` is being used for multi-objective optimization.

• **target_name** *(str)* – Target’s name to display on the axis label.

**Returns** `matplotlib.axes.Axes` object.

**Raises** `ValueError` – If `target` is `None` and `study` is being used for multi-objective optimization.

**Return type** `matplotlib.axes._axes.Axes`

---

**optuna.visualization.matplotlib.is_available**

**optuna.visualization.matplotlib.is_available()**

Returns whether visualization with Matplotlib is available or not.

**Note:** `matplotlib` module depends on Matplotlib version 3.0.0 or higher. If a supported version of Matplotlib isn’t installed in your environment, this function will return `False`. In such a case, please execute `$ pip install -U matplotlib>=3.0.0` to install Matplotlib.

**Returns** `True` if visualization with Matplotlib is available, `False` otherwise.

**Return type** `bool`

---

**6.4 FAQ**

• *Can I use Optuna with X? (where X is your favorite ML library)*

• *How to define objective functions that have own arguments?*

• *Can I use Optuna without remote RDB servers?*

• *How can I save and resume studies?*

• *How to suppress log messages of Optuna?*
• How to save machine learning models trained in objective functions?
• How can I obtain reproducible optimization results?
• How are exceptions from trials handled?
• How are NaNs returned by trials handled?
• What happens when I dynamically alter a search space?
• How can I use two GPUs for evaluating two trials simultaneously?
• How can I test my objective functions?
• How do I avoid running out of memory (OOM) when optimizing studies?
• How can I output a log only when the best value is updated?
• How do I suggest variables which represent the proportion, that is, are in accordance with Dirichlet distribution?

6.4.1 Can I use Optuna with X? (where X is your favorite ML library)

Optuna is compatible with most ML libraries, and it’s easy to use Optuna with those. Please refer to examples.

6.4.2 How to define objective functions that have own arguments?

There are two ways to realize it.

First, callable classes can be used for that purpose as follows:

```python
import optuna

class Objective(object):
    def __init__(self, min_x, max_x):
        # Hold this implementation specific arguments as the fields of the class.
        self.min_x = min_x
        self.max_x = max_x

    def __call__(self, trial):
        # Calculate an objective value by using the extra arguments.
        x = trial.suggest_float("x", self.min_x, self.max_x)
        return (x - 2) ** 2

# Execute an optimization by using an `Objective` instance.
study = optuna.create_study()
study.optimize(Objective(-100, 100), n_trials=100)
```

Second, you can use `lambda` or `functools.partial` for creating functions (closures) that hold extra arguments. Below is an example that uses `lambda`:

```python
import optuna

# Objective function that takes three arguments.
def objective(trial, min_x, max_x):
    x = trial.suggest_float("x", min_x, max_x)
```
return (x - 2) ** 2

# Extra arguments.
min_x = -100
max_x = 100

# Execute an optimization by using the above objective function wrapped by 'lambda'.
study = optuna.create_study()
study.optimize(lambda trial: objective(trial, min_x, max_x), n_trials=100)

Please also refer to sklearn_addtitional_args.py example, which reuses the dataset instead of loading it in each trial execution.

6.4.3 Can I use Optuna without remote RDB servers?

Yes, it’s possible.

In the simplest form, Optuna works with in-memory storage:

```python
study = optuna.create_study()
study.optimize(objective)
```

If you want to save and resume studies, it’s handy to use SQLite as the local storage:

```python
study = optuna.create_study(study_name="foo_study", storage="sqlite:///example.db")
study.optimize(objective)  # The state of `study` will be persisted to the local SQLite file.
```

Please see Saving/Resuming Study with RDB Backend for more details.

6.4.4 How can I save and resume studies?

There are two ways of persisting studies, which depends if you are using in-memory storage (default) or remote databases (RDB). In-memory studies can be saved and loaded like usual Python objects using pickle or joblib. For example, using joblib:

```python
study = optuna.create_study()
joblib.dump(study, "study.pkl")
```

And to resume the study:

```python
study = joblib.load("study.pkl")
print("Best trial until now:")
print(" Value: ", study.best_trial.value)
print(" Params: ")
for key, value in study.best_trial.params.items():
    print(f" {key}: {value}")
```

If you are using RDBs, see Saving/Resuming Study with RDB Backend for more details.
6.4.5 How to suppress log messages of Optuna?

By default, Optuna shows log messages at the `optuna.logging.INFO` level. You can change logging levels by using `optuna.logging.set_verbosity()`.

For instance, you can stop showing each trial result as follows:

```python
optuna.logging.set_verbosity(optuna.logging.WARNING)
study = optuna.create_study()
study.optimize(objective)
# Logs like '[I 2020-07-21 13:41:45,627] Trial 0 finished with value:' are disabled.
```

Please refer to `optuna.logging` for further details.

6.4.6 How to save machine learning models trained in objective functions?

Optuna saves hyperparameter values with its corresponding objective value to storage, but it discards intermediate objects such as machine learning models and neural network weights. To save models or weights, please use features of the machine learning library you used.

We recommend saving `optuna.trial.Trial.number` with a model in order to identify its corresponding trial. For example, you can save SVM models trained in the objective function as follows:

```python
def objective(trial):
    svc_c = trial.suggest_float("svc_c", 1e-10, 1e10, log=True)
    clf = sklearn.svm.SVC(C=svc_c)
    clf.fit(X_train, y_train)

    # Save a trained model to a file.
    with open("{}.pickle".format(trial.number), "wb") as fout:
        pickle.dump(clf, fout)
    return 1.0 - accuracy_score(y_valid, clf.predict(X_valid))

study = optuna.create_study()
study.optimize(objective, n_trials=100)

# Load the best model.
with open("{}.pickle".format(study.best_trial.number), "rb") as fin:
    best_clf = pickle.load(fin)
print(accuracy_score(y_valid, best_clf.predict(X_valid)))
```

6.4.7 How can I obtain reproducible optimization results?

To make the parameters suggested by Optuna reproducible, you can specify a fixed random seed via `seed` argument of `RandomSampler` or `TPESampler` as follows:

```python
sampler = TPESampler(seed=10)  # Make the sampler behave in a deterministic way.
study = optuna.create_study(sampler=sampler)
study.optimize(objective)

However, there are two caveats.
```
First, when optimizing a study in distributed or parallel mode, there is inherent non-determinism. Thus it is very difficult to reproduce the same results in such condition. We recommend executing optimization of a study sequentially if you would like to reproduce the result.

Second, if your objective function behaves in a non-deterministic way (i.e., it does not return the same value even if the same parameters were suggested), you cannot reproduce an optimization. To deal with this problem, please set an option (e.g., random seed) to make the behavior deterministic if your optimization target (e.g., an ML library) provides it.

### 6.4.8 How are exceptions from trials handled?

Trials that raise exceptions without catching them will be treated as failures, i.e. with the `FAIL` status.

By default, all exceptions except `TrialPruned` raised in objective functions are propagated to the caller of `optimize()`. In other words, studies are aborted when such exceptions are raised. It might be desirable to continue a study with the remaining trials. To do so, you can specify in `optimize()` which exception types to catch using the `catch` argument. Exceptions of these types are caught inside the study and will not propagate further.

You can find the failed trials in log messages.

```
[W 2018-12-07 16:38:36,889] Setting status of trial#0 as TrialState.FAIL because of the following error: ValueError('A sample error in objective.')
```

You can also find the failed trials by checking the trial states as follows:

```
study.trials_dataframe()
```

<table>
<thead>
<tr>
<th>number</th>
<th>state</th>
<th>value</th>
<th>...</th>
<th>params</th>
<th>system_attrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>TrialState.FAIL</td>
<td>... 0</td>
<td></td>
<td>Setting status of trial#0 as TrialState.FAIL because of the following error: ValueError('A test error in objective.')</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>TrialState.COMPLETE</td>
<td>1269</td>
<td>...</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

See also: The `catch` argument in `optimize()`.

### 6.4.9 How are NaNs returned by trials handled?

Trials that return `NaN` (float('nan')) are treated as failures, but they will not abort studies.

Trials which return NaN are shown as follows:

```
[W 2018-12-07 16:41:59,000] Setting status of trial#2 as TrialState.FAIL because the objective function returned nan.
```
6.4.10 What happens when I dynamically alter a search space?

Since parameters search spaces are specified in each call to the suggestion API, e.g. `suggest_float()` and `suggest_int()`, it is possible to, in a single study, alter the range by sampling parameters from different search spaces in different trials. The behavior when altered is defined by each sampler individually.

Note: Discussion about the TPE sampler. [https://github.com/optuna/optuna/issues/822](https://github.com/optuna/optuna/issues/822)

6.4.11 How can I use two GPUs for evaluating two trials simultaneously?

If your optimization target supports GPU (CUDA) acceleration and you want to specify which GPU is used, the easiest way is to set `CUDA_VISIBLE_DEVICES` environment variable:

```bash
# On a terminal.
# Specify to use the first GPU, and run an optimization.
$ export CUDA_VISIBLE_DEVICES=0
$ optuna study optimize foo.py objective --study-name foo --storage sqlite:///example.db

# On another terminal.
# Specify to use the second GPU, and run another optimization.
$ export CUDA_VISIBLE_DEVICES=1
$ optuna study optimize bar.py objective --study-name bar --storage sqlite:///example.db
```

Please refer to CUDA C Programming Guide for further details.

6.4.12 How can I test my objective functions?

When you test objective functions, you may prefer fixed parameter values to sampled ones. In that case, you can use `FixedTrial`, which suggests fixed parameter values based on a given dictionary of parameters. For instance, you can input arbitrary values of $x$ and $y$ to the objective function $x + y$ as follows:

```python
def objective(trial):
    x = trial.suggest_float("x", -1.0, 1.0)
    y = trial.suggest_int("y", -5, 5)
    return x + y

objective(FixedTrial({"x": 1.0, "y": 0}))  # 0.0
objective(FixedTrial({"x": -1.0, "y": -4}))  # -5.0
```

Using `FixedTrial`, you can write unit tests as follows:

```python
# A test function of pytest
def test_objective():
    assert 1.0 == objective(FixedTrial({"x": 1.0, "y": 0}))
    assert -1.0 == objective(FixedTrial({"x": 0.0, "y": -1}))
    assert 0.0 == objective(FixedTrial({"x": -1.0, "y": 1}))
```
6.4.13 How do I avoid running out of memory (OOM) when optimizing studies?

If the memory footprint increases as you run more trials, try to periodically run the garbage collector. Specify `gc_after_trial` to `True` when calling `optimize()` or call `gc.collect()` inside a callback.

```python
def objective(trial):
    x = trial.suggest_float("x", -1.0, 1.0)
    y = trial.suggest_int("y", -5, 5)
    return x + y

study = optuna.create_study()
study.optimize(objective, n_trials=10, gc_after_trial=True)

# 'gc_after_trial=True' is more or less identical to the following.
study.optimize(objective, n_trials=10, callbacks=[lambda study, trial: gc.collect()])
```

There is a performance trade-off for running the garbage collector, which could be non-negligible depending on how fast your objective function otherwise is. Therefore, `gc_after_trial` is `False` by default. Note that the above examples are similar to running the garbage collector inside the objective function, except for the fact that `gc.collect()` is called even when errors, including `TrialPruned` are raised.

**Note:** `ChainerMNStudy` does currently not provide `gc_after_trial` nor callbacks for `optimize()`. When using this class, you will have to call the garbage collector inside the objective function.

6.4.14 How can I output a log only when the best value is updated?

Here’s how to replace the logging feature of optuna and with your own logging callback function. The implemented callback can be passed to `optimize()`. Here’s an example:

```python
import optuna

# Turn off optuna log notes.
optuna.logging.set_verbosity(optuna.logging.WARN)

def objective(trial):
    x = trial.suggest_float("x", 0, 1)
    return x ** 2

def logging_callback(study, frozen_trial):
    previous_best_value = study.user_attrs.get("previous_best_value", None)
    if previous_best_value != study.best_value:
        study.set_user_attr("previous_best_value", study.best_value)
        print("Trial {} finished with best value: {} and parameters: {}.").format(frozen_trial.number, frozen_trial.value, frozen_trial.params,
                                                                                   )
```

(continues on next page)
6.4.15 How do I suggest variables which represent the proportion, that is, are in accordance with Dirichlet distribution?

When you want to suggest $n$ variables which represent the proportion, that is, $p[0], p[1], ..., p[n-1]$ which satisfy $0 \leq p[k] \leq 1$ for any $k$ and $p[0] + p[1] + ... + p[n-1] = 1$, try the below. For example, these variables can be used as weights when interpolating the loss functions. These variables are in accordance with the flat Dirichlet distribution.

```python
import numpy as np
import matplotlib.pyplot as plt
import optuna

def objective(trial):
    n = 5
    x = []
    for i in range(n):
        x.append(- np.log(trial.suggest_float(f"x_{i}"", 0, 1)))

    p = []
    for i in range(n):
        p.append(x[i] / sum(x))

    for i in range(n):
        trial.set_user_attr(f"p_{i}"", p[i])

    return 0

study = optuna.create_study(sampler=optuna.samplers.RandomSampler())
study.optimize(objective, n_trials=1000)

n = 5
p = []
for i in range(n):
    p.append([trial.user_attrs[f"p_{i}""] for trial in study.trials])

axes = plt.subplots(n, n, figsize=(20, 20))[1]

for i in range(n):
    for j in range(n):
        axes[j][i].scatter(p[i], p[j], marker=".")
        axes[j][i].set_xlim(0, 1)
        axes[j][i].set_ylim(0, 1)
        axes[j][i].set_xlabel(f"p_{i}""
        axes[j][i].set_ylabel(f"p_{j}""

plt.savefig("sampled_ps.png")
```

This method is justified in the following way: First, if we apply the transformation $x = -\log(u)$ to the variable $u$ sampled from the uniform distribution $Uni(0, 1)$ in the interval $[0, 1]$, the variable $x$ will follow the exponential distribution $Exp(1)$ with scale parameter 1. Furthermore, for $n$ variables $x[0], ..., x[n-1]$ that follow the exponential distribution of scale parameter 1 independently, normalizing them with $p[i] = x[i] / \sum x[i]$, the vector $p$ follows the Dirichlet distribution $Dir(\alpha)$ of scale parameter $\alpha = (1, ..., 1)$. You can verify the transformation by calculating the parameters.
elements of the Jacobian.
INDICES AND TABLES

• genindex
• modindex
• search
OPTUNA MODULE INDEX

O

optuna, 53
optuna.cli, 59
optuna.distributions, 65
optuna.exceptions, 72
optuna.importance, 74
optuna.integration, 78
optuna.logging, 119
optuna.multi_objective, 123
optuna.multi_objective.samplers, 123
optuna.multi_objective.study, 132
optuna.multi_objective.trial, 137
optuna.multi_objective.visualization, 142
optuna.pruners, 144
optuna.samplers, 156
optuna.storages, 186
optuna.structs, 207
optuna.study, 209
optuna.trial, 228
optuna.visualization, 245
optuna.visualization.matplotlib, 254
Symbols

--allow-websocket-origin
   <BOKEH_ALLOW_WEBSOCKET_ORIGINS>
   optuna-dashboard command line
   option, 62
--debug
   optuna command line option, 59
--direction <DIRECTION>
   optuna-ask command line option, 60
   optuna-create-study command line
   option, 61
--directions <DIRECTIONS>
   optuna-ask command line option, 60
   optuna-create-study command line
   option, 61
--flatten
   optuna-ask command line option, 60
   optuna-best-trial command line
   option, 61
   optuna-best-trials command line
   option, 61
   optuna-studies command line option, 63
   optuna-trials command line option, 65
--format <FORMAT>
   optuna-ask command line option, 60
   optuna-best-trial command line
   option, 60
   optuna-best-trials command line
   option, 61
   optuna-studies command line option, 63
   optuna-trials command line option, 65
--key <KEY>
   optuna-study-set-user-attr command
   line option, 64
--log-file <LOG_FILE>
   optuna command line option, 59
--n-jobs <N_JOBS>
   optuna-study-optimize command line
   option, 63
--n-trials <N_TRIALS>
   optuna-study-optimize command line
   option, 63
--out <OUT>
   optuna-dashboard command line
   option, 62
--quiet
   optuna command line option, 59
--sampler <SAMPLER>
   optuna-ask command line option, 60
   --sampler-kwarg <SAMPLER_KWARGS>
   optuna-ask command line option, 60
   --search-space <SEARCH_SPACE>
   optuna-ask command line option, 60
   --skip-if-exists
   optuna-create-study command line
   option, 61
--state <STATE>
   optuna-tell command line option, 64
--storage <STORAGE>
   optuna command line option, 60
--study <STUDY>
   optuna-dashboard command line
   option, 62
   optuna-study-optimize command line
   option, 63
   optuna-study-set-user-attr command
   line option, 64
--study-name <STUDY_NAME>
   optuna-ask command line option, 60
   optuna-best-trial command line
   option, 60
   optuna-best-trials command line
   option, 61
   optuna-create-study command line
   option, 61
   optuna-dashboard command line
   option, 62
   optuna-delete-study command line
   option, 62
   optuna-study-optimize command line
add_trial() (optuna.study.Study method), 210
add_trials() (optuna.study.Study method), 211
after_trial() (optuna.integration.BoTorchSampler method), 83
after_trial() (optuna.integration.CmaEsSampler method), 105
after_trial() (optuna.integration.PyCmaSampler method), 102
after_trial() (optuna.integration.SkoptSampler method), 115
after_trial() (optuna.samplers.BaseSampler method), 159
after_trial() (optuna.samplers.CmaEsSampler method), 174
after_trial() (optuna.samplers.GridSampler method), 162
after_trial() (optuna.samplers.MOTPESampler method), 183
after_trial() (optuna.samplers.NSGAIISampler method), 179
after_trial() (optuna.samplers.PartialFixedSampler method), 176
after_trial() (optuna.samplers.RandomSampler method), 164
after_trial() (optuna.samplers.TPESampler method), 169
AllenNLPExecutor (class in optuna.integration), 79
AllenNLPPruningCallback (class in optuna.integration), 80
ask() (optuna.study.Study method), 212

B
BaseMultiObjectiveSampler (class in optuna.multi_objective.samplers), 123
BasePruner (class in optuna.pruners), 144
BaseSampler (class in optuna.samplers), 157

A
add_trial() (optuna.study.Study method), 210
add_trials() (optuna.study.Study method), 211
after_trial() (optuna.integration.BoTorchSampler method), 83
after_trial() (optuna.integration.CmaEsSampler method), 105
after_trial() (optuna.integration.PyCmaSampler method), 102
duration() (optuna.structs.FrozenTrial property), 208
duration() (optuna.trial.FrozenTrial property), 242
enable_default_handler() (in module optuna.logging), 121
enable_propagation() (in module optuna.logging), 122
enqueue_trial() (optuna.multi_objective.study.MultiObjectiveStudy method), 133
enqueue_trial() (optuna.study.Study method), 214
evaluate() (optuna.importance.FanovaImportanceEvaluator method), 76
evaluate() (optuna.importance.MeanDecreaseImpurityImportanceEvaluator method), 77
FAIL (optuna.structs.TrialState attribute), 208
FAIL (optuna.trial.TrialState attribute), 243
fail_stale_trials() (in module optuna.storages), 207
fail_stale_trials() (optuna.storages.RDBStorage method), 190
fail_stale_trials() (optuna.storages.RedisStorage method), 199
FanovaImportanceEvaluator (class in optuna.importance), 76
FastAIPruningCallback (in module optuna.integration), 90
FastAV1PruningCallback (class in optuna.integration), 88
FastAV2PruningCallback (class in optuna.integration), 89
file
    optuna-study-optimize command line option, 63
fit() (optuna.integration.OptunaSearchCV method), 112
FixedTrial (class in optuna.trial), 238
FrozenMultiObjectiveTrial (class in optuna.multi_objective.trial), 141
FrozenTrial (class in optuna.structs), 208
FrozenTrial (class in optuna.trial), 240
get_all_study_summaries() (in module optuna), 58
get_all_study_summaries() (in module optuna.study), 225
get_all_study_summaries() (optuna.storages.RDBStorage method), 190
get_all_study_summaries() (optuna.storages.RedisStorage method), 200
get_all_trials() (optuna.storages.RDBStorage method), 190
get_all_trials() (optuna.storages.RedisStorage method), 200
get_all_versions() (optuna.storages.RDBStorage method), 190
get_best_booster() (optuna.integration.lightgbm.LightGBMTuner method), 94
get_best_booster() (optuna.integration.lightgbm.LightGBMTunerCV method), 97
get_best_trial() (optuna.storages.RDBStorage method), 190
get_best_trial() (optuna.storages.RedisStorage method), 200
get_current_version() (optuna.storages.RDBStorage method), 191
get_failed_trial_callback() (optuna.storages.RDBStorage method), 191
get_failed_trial_callback() (optuna.storages.RedisStorage method), 200
get_head_version() (optuna.storages.RDBStorage method), 191
get_heartbeat_interval() (optuna.storages.RDBStorage method), 191
get_heartbeat_interval() (optuna.storages.RedisStorage method), 201
get_n_trials() (optuna.storages.RDBStorage method), 200
get_n_trials() (optuna.storages.RedisStorage method), 201
get_param_importances() (in module optuna.importance), 75
get_params() (optuna.integration.OptunaSearchCV method), 112
get_pareto_front_trials() (optuna.multi_objective.study.MultiObjectiveStudy method), 133
get_study_directions() (optuna.storages.RDBStorage method), 191
get_study_directions() (optuna.storages.RedisStorage method), 201
get_study_id_from_name() (optuna.storages.RDBStorage method), 191
get_study_id_from_name() (optuna.storages.RedisStorage method), 201
get_study_id_from_trial_id() (optuna.storages.RDBStorage method), 192
get_study_id_from_trial_id() (optuna.storages.RedisStorage method), 201
get_study_name_from_id() (optuna.storages.RDBStorage method), 191
get_study_name_from_id() (optuna.storages.RedisStorage method), 201
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X
Y
Z
tuna.storages.RDBStorage method), 192
get_study_name_from_id() (optuna.storages.RedisStorage method), 201
get_study_system_attrs() (optuna.storages.RDBStorage method), 192
get_study_system_attrs() (optuna.storages.RedisStorage method), 201
get_study_user_attrs() (optuna.storages.RDBStorage method), 192
get_study_user_attrs() (optuna.storages.RedisStorage method), 201
get_trial() (optuna.storages.RDBStorage method), 192
get_trial() (optuna.storages.RedisStorage method), 202
get_trial_id_from_study_id_trial_number() (optuna.storages.RDBStorage method), 192
get_trial_id_from_study_id_trial_number() (optuna.storages.RedisStorage method), 202
get_trial_number_from_id() (optuna.storages.RDBStorage method), 193
get_trial_number_from_id() (optuna.storages.RedisStorage method), 202
get_trial_param() (optuna.storages.RDBStorage method), 193
get_trial_param() (optuna.storages.RedisStorage method), 202
get_trial_params() (optuna.storages.RDBStorage method), 193
get_trial_params() (optuna.storages.RedisStorage method), 202
get_trials() (optuna.multi_objective.study.MultiObjectiveStudy method), 133
get_trials() (optuna.study.Study method), 215
get_verbosity() (in module optuna.logging), 120
GridSampler (class in optuna.samplers), 120

high (optuna.distributions.DiscreteUniformDistribution attribute), 68
HyperbandPruner (class in optuna.pruners), 153
hyperopt_parameters() (optuna.samplers.MOTPEMultiObjectiveSampler static method), 183
hyperopt_parameters() (optuna.samplers.TPESampler static method), 169

H
high (optuna.distributions.UniformDistribution attribute), 66

H
high (optuna.distributions.IntLogUniformDistribution attribute), 70
high (optuna.distributions.IntUniformDistribution attribute), 69
high (optuna.distributions.LogUniformDistribution attribute), 67

I
infer_relative_search_space() (optuna.integration.BoTorchSampler method), 83
infer_relative_search_space() (optuna.integration.CmaEsSampler method), 105
infer_relative_search_space() (optuna.integration.PyCmaSampler method), 103
infer_relative_search_space() (optuna.integration.SkoptSampler method), 116
infer_relative_search_space() (optuna.multi_objective.samplers.BaseMultiObjectiveSampler method), 123
infer_relative_search_space() (optuna.multi_objective.samplers.MOTPEMultiObjectiveSampler method), 131
infer_relative_search_space() (optuna.multi_objective.samplers.NSGAIMultiObjectiveSampler method), 126
infer_relative_search_space() (optuna.multi_objective.samplers.RandomMultiObjectiveSampler method), 128
infer_relative_search_space() (optuna.samplers.CmaEsSampler method), 159
infer_relative_search_space() (optuna.samplers.CmaEsSampler method), 177
infer_relative_search_space() (optuna.samplers.GridSampler method), 162
infer_relative_search_space() (optuna.samplers.MOTPESampler method), 184
infer_relative_search_space() (optuna.samplers.NSGAIIISampler method), 180
infer_relative_search_space() (optuna.samplers.PartialFixedSampler method), 177
infer_relative_search_space() (optuna.samplers.RandomSampler method), 165
infer_relative_search_space() (optuna.samplers.TPESampler method), 170
intermediate_values (optuna.multi_objective.trial.FrozenMultiObjectiveTrial attribute), 142
intermediate_values (optuna.FrozenTrial attribute), 241
intersection_search_space() (in module optuna.samplers), 186
IntersectionSearchSpace (class in optuna.samplers), 185
IntLogUniformDistribution (class in optuna.distributions), 70
IntUniformDistribution (class in optuna.distributions), 69
inverse_transform() (optuna.integration.OptunaSearchCV property), 113
is_available() (in module optuna.visualization), 254
is_available() (in module optuna.visualization.matplotlib), 271
is_heartbeat_enabled() (optuna.storages.RDBStorage method), 193
is_heartbeat_enabled() (optuna.storages.RedisStorage method), 203
json_to_distribution() (in module optuna.distributions), 72
KerasPruningCallback (class in optuna.integration), 90
LightGBMPRUNINGCallback (class in optuna.integration), 91
LightGBMTuner (class in optuna.integration.lightgbm), 92
LightGBMTunerCV (class in optuna.integration.lightgbm), 95
load_study() (in module optuna), 55
load_study() (in module optuna.multi_objective.study), 137
load_study() (in module optuna.study), 222
LogUniformDistribution (class in optuna.distributions), 67
low (optuna.distributions.DiscreteUniformDistribution attribute), 68
low (optuna.distributions.IntLogUniformDistribution attribute), 70
low (optuna.distributions.IntUniformDistribution attribute), 69
low (optuna.distributions.LogUniformDistribution attribute), 67
low (optuna.distributions.UniformDistribution attribute), 66
MAXIMIZE (optuna.structs.StudyDirection attribute), 208
MAXIMIZE (optuna.study.StudyDirection attribute), 227
MaxTrialsCallback (class in optuna.study), 226
MeanDecreaseImpurityImportanceEvaluator (class in optuna.importance), 77
MedianPruner (class in optuna.pruners), 145
MeanDecreaseImpurityImportanceEvaluator (class in optuna.importance), 77
MINIMIZE (optuna.structs.StudyDirection attribute), 208
MINIMIZE (optuna.study.StudyDirection attribute), 227
MLflowCallback (class in optuna.integration), 97
module
optuna, 53
optuna.cli, 59
optuna.distributions, 65
optuna.exceptions, 72
optuna.importance, 74
optuna.integration, 78
optuna.logging, 119
optuna.multi_objective, 123
optuna.multi_objective.samplers, 123
optuna.multi_objective.study, 132
optuna.multi_objective.trial, 137
optuna.multi_objective.visualization, 142
optuna.pruners, 144
optuna.samplers, 156
optuna.storages, 186
optuna.structs, 207
optuna.study, 209
optuna.trial, 228
optuna.visualization, 245
optuna.visualization.matplotlib, 254
MOTPEMultiObjectiveSampler (class in optuna.multi_objective.samplers), 129
MOTPESampler (class in optuna.samplers), 181
MultiObjectiveStudy (class in optuna.multi_objective.study), 132
MultiObjectiveTrial (class in optuna.multi_objective.trial), 138
MXNetPruningCallback (class in optuna.integration), 101

N
n_objectives() (optuna.multi_objective.study.MultiObjectiveStudy property), 134
n_splits_ (optuna.integration.OptunaSearchCV attribute), 110
n_trials (optuna.study.StudySummary attribute), 227
n_trials_ (optuna.integration.OptunaSearchCV property), 113
NopPruner (class in optuna.pruners), 146
NOT_SET (optuna.structs.StudyDirection attribute), 208
NOT_SET (optuna.study.StudyDirection attribute), 227
NSGAIIMultiObjectiveSampler (class in optuna.multi_objective.samplers), 125
NSGAIISSampler (class in optuna.samplers), 178
number (optuna.multi_objective.trial.FrozenMultiObjectiveTrial attribute), 141
number (optuna.trial.FrozenTrial attribute), 241
number() (optuna.multi_objective.trial.MultiObjectiveTrial property), 139
number() (optuna.trial.Trial property), 229

O
on_epoch() (optuna.integration.AllenNLPPruningCallback method), 81
optimize() (optuna.integration.ChainerMNStudy method), 88
optimize() (optuna.multi_objective.study.MultiObjectiveStudy method), 134
optimize() (optuna.study.Study method), 215
optuna module, 53
optuna command line option
--debug, 59
--log-file <LOG_FILE>, 59
--quiet, 59
--storage <STORAGE>, 60
--verbose, 59
--version, 59
-q, 59
-v, 59
optuna.cli module, 59
optuna.distributions module, 65
optuna.exceptions module, 72
optuna.importance module, 74
optuna.integration module, 78
optuna.logging module, 119
optuna.multi_objective module, 123
optuna.multi_objective.samplers module, 123
optuna.multi_objective.study module, 132
optuna.multi_objective.trial module, 137
optuna.multi_objective.visualization module, 142
optuna.pruners module, 144
optuna.samplers module, 156
optuna.storages module, 186
optuna.study module, 207
optuna.trial module, 228
optuna.visualization module, 245
optuna.visualization.matplotlib module, 254
optuna-ask command line option
--direction <DIRECTION>, 60
--directions <DIRECTIONS>, 60
--flatten, 60
--format <FORMAT>, 60
--sampler <SAMPLER>, 60
--sampler-kwarg <SAMPLER_KWARGS>, 60
--search-space <SEARCH_SPACE>, 60
--study-name <STUDY_NAME>, 60
-f <FORMAT>, 60
optuna-best-trial command line option
--flatten, 61
--format <FORMAT>, 60
--study-name <STUDY_NAME>, 60
-f <FORMAT>, 60
optuna-best-trials command line option
--flatten, 61
--format <FORMAT>, 61
--study-name <STUDY_NAME>, 61
-f <FORMAT>, 61
optuna-create-study command line option
--direction <DIRECTION>, 61
--directions <DIRECTIONS>, 61
--skip-if-exists, 61

Index 291
--study-name <STUDY_NAME>, 61
optuna-dashboard command line option
--allow-websocket-origin
  <BOKEH_ALLOW_WEBSOCKET_ORIGINS>, 62
--out <OUT>, 62
--study <STUDY>, 62
--study-name <STUDY_NAME>, 62
-o <OUT>, 62
optuna-delete-study command line option
--study-name <STUDY_NAME>, 62
optuna-studies command line option
--flatten, 63
--format <FORMAT>, 63
-f <FORMAT>, 63
optuna-study-optimize command line option
--n-jobs <N_JOBS>, 63
--n-trials <N_TRIALS>, 63
--study <STUDY>, 63
--timeout <TIMEOUT>, 63
file, 63
method, 63
optuna-study-set-user-attr command line option
--key <KEY>, 64
--study <STUDY>, 64
--study-name <STUDY_NAME>, 64
--value <VALUE>, 64
-k <KEY>, 64
-v <VALUE>, 64
optuna-tell command line option
--state <STATE>, 64
--study <STUDY>, 64
--study-name <STUDY_NAME>, 64
--values <VALUES>, 64
optuna-trials command line option
--flatten, 65
--format <FORMAT>, 65
--study-name <STUDY_NAME>, 65
-f <FORMAT>, 65
OptunaError, 73
OptunaSearchCV (class in optuna.integration), 109

P
params (optuna.multi_objective.trial.FrozenMultiObjectiveTrial attribute), 142
params (optuna.trial.FrozenTrial attribute), 241
params () (optuna.multi_objective.trial.MultiObjectiveTrial property), 139
params () (optuna.trial.Trial property), 229
PartialFixedSampler (class in optuna.samplers), 176
PatientPruner (class in optuna.pruners), 148
PercentilePruner (class in optuna.pruners), 149
plot_contour () (in module optuna.visualization), 246
plot_contour () (in module optuna.visualization.matplotlib), 255
plot_edf () (in module optuna.visualization), 247
plot_edf () (in module optuna.visualization.matplotlib), 257
plot_intermediate_values () (in module optuna.visualization), 248
plot_intermediate_values () (in module optuna.visualization.matplotlib), 259
plot_optimization_history () (in module optuna.visualization), 249
plot_optimization_history () (in module optuna.visualization.matplotlib), 261
plot_parallel_coordinate () (in module optuna.visualization), 250
plot_parallel_coordinate () (in module optuna.visualization.matplotlib), 263
plot_param_importances () (in module optuna.visualization), 251
plot_param_importances () (in module optuna.visualization.matplotlib), 265
plot_pareto_front () (in module optuna.multi_objective.visualization), 143
plot_pareto_front () (in module optuna.visualization), 252
plot_pareto_front () (in module optuna.visualization.matplotlib), 267
plot_slice () (in module optuna.visualization), 253
plot_slice () (in module optuna.visualization.matplotlib), 269
predict () (optuna.integration.OptunaSearchCV property), 113
predict_log_proba () (optuna.integration.OptunaSearchCV property), 113
predict_proba () (optuna.integration.OptunaSearchCV property), 113
prune () (optuna.pruners.BasePruner method), 144
  (optuna.pruners.HyperbandPruner method), 155
prune () (optuna.pruners.MedianPruner method), 146
prune () (optuna.pruners.NopPruner method), 147
prune () (optuna.pruners.PatientPruner method), 149
prune () (optuna.pruners.PercentilePruner method), 150
prune () (optuna.pruners.SuccessiveHalvingPruner method), 152
prune() (optuna.pruners.ThresholdPruner method), 156
PRUNED (optuna.structs.TrialState attribute), 208
PRUNED (optuna.trial.TrialState attribute), 208
PyCmaSampler (class in optuna.integration), 101
PyTorchIgnitePruningHandler (class in optuna.integration), 107
PyTorchLightningPruningCallback (class in optuna.integration), 107
Q
q (optuna.distributions.DiscreteUniformDistribution attribute), 68
qehvi_candidates_func() (in module optuna.integration.botorch), 85
qei_candidates_func() (in module optuna.integration.botorch), 85
qparego_candidates_func() (in module optuna.integration.botorch), 86
R
RandomMultiObjectiveSampler (class in optuna.multi_objective.samplers), 127
RandomSampler (class in optuna.samplers), 164
RDBStorage (class in optuna.storages), 187
read_trials_from_remote_storage() (optuna.storages.RDBStorage method), 194
read_trials_from_remote_storage() (optuna.storages.RedisStorage method), 203
record_heartbeat() (optuna.storages.RDBStorage method), 194
record_heartbeat() (optuna.storages.RedisStorage method), 203
RedisStorage (class in optuna.storages), 197
refit_time_ (optuna.integration.OptunaSearchCV attribute), 111
register() (optuna.integration.AllenNLPPruningCallback class method), 81
remove_session() (optuna.storages.RDBStorage method), 194
remove_session() (optuna.storages.RedisStorage method), 203
report() (optuna.multi_objective.trial.MultiObjectiveTrial method), 139
report() (optuna.structs.FrozenTrial method), 208
report() (optuna.trial.FrozenTrial method), 242
report() (optuna.trial.Trial method), 229
reseed_rng() (optuna.integration.BoTorchSampler method), 84
reseed_rng() (optuna.integration.CmaEsSampler method), 105
reseed_rng() (optuna.integration.CmaEsSampler method), 105
reseed_rng() (optuna.integration.PyCmaSampler method), 103
reseed_rng() (optuna.integration.PyCmaSampler method), 103
reseed_rng() (optuna.integration.SkoptSampler method), 116
reseed_rng() (optuna.multi_objective.samplers.BaseMultiObjectiveSampler method), 128
reseed_rng() (optuna.multi_objective.samplers.MOTPEMultiObjective method), 131
reseed_rng() (optuna.multi_objective.samplers.NSGAIIMultiObjective method), 126
reseed_rng() (optuna.multi_objective.samplers.RandomMultiObjectiveSampler method), 128
reseed_rng() (optuna.samplers.BaseSampler method), 159
reseed_rng() (optuna.samplers.CmaEsSampler method), 174
reseed_rng() (optuna.samplers.GridSampler method), 163
reseed_rng() (optuna.samplers.MOTPESampler method), 184
reseed_rng() (optuna.samplers.NSGAIISampler method), 180
reseed_rng() (optuna.samplers.RandomSampler method), 177
reseed_rng() (optuna.samplers.RandomSampler method), 165
reseed_rng() (optuna.samplers.TPESampler method), 170
retried_trial_number() (optuna.storages.RetryFailedTrialCallback static method), 207
RetryFailedTrialCallback (class in optuna.storages), 206
run() (optuna.integration.AllenNLPExecutor method), 80
run() (optuna.integration.lightgbm.LightGBMTuner method), 94
run() (optuna.integration.lightgbm.LightGBMTunerCV method), 97
RUNNING (optuna.structs.TrialState attribute), 208
RUNNING (optuna.trial.TrialState attribute), 243
S
sample_independent() (optuna.integration.BoTorchSampler method), 84
sample_independent() (optuna.integration.CmaEsSampler method), 106
sample_independent() (optuna.integration.PyCmaSampler method), 103
sample_independent() (optuna.integration.SkoptSampler method), 116

Index 293
sample_independent() (optuna.multi_objective.samplers.BaseMultiObjectiveSampler method), 124
sample_independent() (optuna.multi_objective.samplers.MOTPEMultiObjectiveSampler method), 131
sample_independent() (optuna.multi_objective.samplers.NSGAIIMultiObjectiveSampler method), 126
sample_independent() (optuna.multi_objective.samplers.RandomMultiObjectiveSampler method), 128
sample_independent() (optuna.samplers.BaseSampler method), 160
sample_independent() (optuna.samplers.CmaEsSampler method), 175
sample_independent() (optuna.samplers.GridSampler method), 163
sample_independent() (optuna.samplers.MOTPESampler method), 184
sample_independent() (optuna.samplers.NSGAISampler method), 180
sample_independent() (optuna.samplers.PartialFixedSampler method), 178
sample_independent() (optuna.samplers.RandomSampler method), 166
sample_relative() (optuna.samplers.MOTPESampler method), 185
sample_relative() (optuna.samplers.NSGAISampler method), 181
sample_relative() (optuna.samplers.PartialFixedSampler method), 178
sample_train_set() (optuna.integration.lightgbm.LightGBMTuner method), 94
sample_train_set() (optuna.integration.lightgbm.LightGBMTunerCV method), 97
sampler() (optuna.multi_objective.study.MultiObjectiveStudy property), 134
score() (optuna.integration.OptunaSearchCV method), 113
score_samples() (optuna.integration.OptunaSearchCV method), 113
scorer_ (optuna.integration.OptunaSearchCV attribute), 111
set_params() (optuna.integration.OptunaSearchCV method), 113
set_study_directions() (optuna.storages.RDBStorage method), 194
set_study_directions() (optuna.storages.RedisStorage method), 203
set_study_directions() (optuna.storages.RedisStorage method), 204
set_study_directions() (optuna.storages.RDBStorage method), 195

set_study_user_attr() (optuna.storages.RedisStorage method), 204
set_system_attr() (optuna.multi_objective.study.MultiObjectiveStudy method), 135
set_system_attr() (optuna.multi_objective.trial.MultiObjectiveTrial method), 139
set_system_attr() (optuna.study.Study method), 217
set_system_attr() (optuna.trial.Trial method), 230
set_trial_intermediate_value() (optuna.storages.RDBStorage method), 195
set_trial_intermediate_value() (optuna.storages.RedisStorage method), 195
set_trial_param() (optuna.storages.RDBStorage method), 195
set_trial_param() (optuna.storages.RedisStorage method), 195
set_trial_state() (optuna.storages.RDBStorage method), 205
set_trial_state() (optuna.storages.RedisStorage method), 205
set_system_attr() (optuna.storages.RDBStorage method), 196
set_system_attr() (optuna.storages.RedisStorage method), 205
set_trial_values() (optuna.storages.RDBStorage method), 196
set_trial_values() (optuna.storages.RedisStorage method), 206
set_user_attr() (optuna.integration.OptunaSearchCV property), 113
set_user_attr() (optuna.multi_objective.study.MultiObjectiveStudy method), 135
set_user_attr() (optuna.multi_objective.trial.MultiObjectiveTrial method), 139
set_user_attr() (optuna.study.Study method), 217
set_user_attr() (optuna.trial.Trial method), 230
set_verbosity() (in module optuna.logging), 120
should_prune() (optuna.structs.FrozenTrial method), 209
should_prune() (optuna.trial.FrozenTrial method), 243
should_prune() (optuna.trial.Trial method), 231
single() (optuna.distributions.DiscreteUniformDistribution method), 71
single() (optuna.distributions.IntLogUniformDistribution method), 68
single() (optuna.distributions.IntUniformDistribution method), 70
single() (optuna.distributions.LogUniformDistribution method), 69
single() (optuna.distributions.UniformDistribution method), 67
SkoptSampler (class in optuna.integration), 114
SkorchPruningCallback (class in optuna.integration), 117
state (optuna.multi_objective.trial.FrozenMultiObjectiveTrial attribute), 141
state (optuna.trial.FrozenTrial attribute), 241
step (optuna.distributions.IntLogUniformDistribution attribute), 70
step (optuna.distributions.IntUniformDistribution attribute), 69
stop() (optuna.study.Study method), 217
StorageInternalError, 74
Study (class in optuna.study), 210
study_ (optuna.integration.OptunaSearchCV attribute), 111
study_name (optuna.study.StudySummary attribute), 227
StudyDirection (class in optuna.structs), 208
StudyDirection (class in optuna.study), 227
StudySummary (class in optuna.structs), 209
StudySummary (class in optuna.study), 227
SuccessiveHalvingPruner (class in optuna.pruners), 151
suggest_categorical() (optuna.multi_objective.trial.MultiObjectiveTrial method), 140
suggest_categorical() (optuna.trial.Trial method), 232
suggest_discrete_uniform() (optuna.multi_objective.trial.MultiObjectiveTrial method), 140
suggest_discrete_uniform() (optuna.trial.Trial method), 232
suggest_float() (optuna.multi_objective.trial.MultiObjectiveTrial method), 140
suggest_float() (optuna.trial.Trial method), 233
suggest_int() (optuna.multi_objective.trial.MultiObjectiveTrial method), 140
suggest_int() (optuna.trial.Trial method), 235
suggest_loguniform() (optuna.multi_objective.trial.MultiObjectiveTrial method), 241
V
value (optuna.trial.FrozenTrial attribute), 241
values (optuna.multi_objective.trial.FrozenMultiObjectiveTrial attribute), 141
values (optuna.trial.FrozenTrial attribute), 241

W
WAITING (optuna.structs.TrialState attribute), 208
WAITING (optuna.trial.TrialState attribute), 243
WeightsAndBiasesCallback (class in optuna.integration), 99

X
XGBoostPruningCallback (class in optuna.integration), 119