

# Hyperparameter Tuning with mlr3tuning::CHEAT SHEET

## Class Overview

The package provides a set of R6 classes which allow to (a) define general hyperparameter (HP) tuning instances, i.e., the black-box objective that maps HP configurations (HPCs) to resampled performance values; (b) run black-box optimizers; (c) combine learners with tuners (for nested resampling).



[NB: In many table prints we suppress cols for readability.]

## ParamSet - Parameters and Ranges

Scalar doubles, integers, factors or logicals are combined to define a multivariate search space (SS).

```
ss = ps(
  <id> = p_int(lower, upper),
  <id> = p_dbl(lower, upper),
  <id> = p_dct(levels),
  <id> = p_lgl())
```

id is identifier. lower/upper ranges, levels categories.

```
learner = lrn("classif.rpart",
  cp = to_tune(0.001, 0.1, logscale = TRUE))
learner$param_set$search_space() # for inspection
```

Or, use `to_tune()` to set SS for each param in Learner. SS is auto-generated when learner is tuned. Params can be arbitrarily transformed by setting a global trafo in SS, or `p_*` shortcuts, `logscale = TRUE` is short for most common choice.

## Terminators - When to stop

Construction: `trm(.key, ...)`

- `evals(n_evals)`  
After iterations.
- `run_time(secs)`  
After training time.
- `clock_time(stop_time)`  
At given timepoint.
- `perf_reached(level)`  
After performance was reached.
- `stagnation(iters, threshold)`  
After performance stagnated.
- `combo(list_of_terms, any=TRUE)`  
Combine terminators with AND or OR.

```
as.data.table(mlr_terminators) # list all
```

## TuningInstance\* - Search Scenario

Evaluator and container for resampled performances of HPCs. The (internal) `eval_batch(xdt)` calls `benchmark()` to eval a table of HPCs. Stores archive of all evaluated experiments and final result.

```
instance = TuningInstanceSingleCrit$new(task,
  learner, resampling, measure, terminator, ss)
```

`store_benchmark_result = TRUE` to store resampled evals and `store_models = TRUE` for fitted models.

## Example

```
# optimize HPs of RBF SVM on logscale
learner = lrn("classif.svm", kernel = "radial", type = "C-classification")
ss = ps(cost = p_dbl(1e-4, 1e4, logscale = TRUE),
  gamma = p_dbl(1e-4, 1e4, logscale = TRUE))
evals = trm("evals", n_evals = 20)
instance = TuningInstanceSingleCrit$new(task, learner, resampling, measure, evals, ss)

tuner = tnr("random_search")
tuner$optimize(instance)
instance$result
# >      cost      gamma learner_param_vals x_domain classif.ce
# > 1: 5.852743 -7.281365      <list[4]> <list[2]>      0.04
```

Use `TuningInstanceMultiCrit` for multi-criteria tuning.

## Tuner - Search Strategy

Generates HPCs and passes to tuning instance for evaluation until termination. Creation: `tnr(.key, ...)`

- `grid_search(resolution, batch_size)`  
Grid search.
- `random_search(batch_size)`  
Random search.
- `design_points(design)`  
Search at predefined points.
- `random_search(batch_size)`  
Random search.
- `nloptr(algorithm)`  
Non-linear optimization.
- `gensa(smooth, temperature)`  
Generalized Simulated Annealing.
- `irace`  
Iterated racing.

```
as.data.table(mlr_tuners) # list all
```

## Logging and Parallelization

```
lgr::get_logger("bbotk")$set_threshold("<level>")
```

Change log-level only for mlr3tuning.

```
future::plan(strategy)
```

Sets the parallelization backend. Speeds up tuning by running iterations in parallel.

## Execute Tuning and Access Results

```
tuner$optimize(instance)
as.data.table(instance$archive)
## >      cost gamma classif.ce      uhash x_domain_cost x_domain_gamma
## > 1: 3.13 5.55      0.56 b8744...      3.13      5.55
## > 2: -1.94 1.32      0.10 f5623...     -1.94      1.32
instance$result # datatable row with optimal HPC and estimated perf
```

Get evaluated HPCs and performances; and result. `x_domain_*` cols contain HP values after trafo (if any).

```
learner$param_set$values =
instance$result_learner_param_vals
```

Set optimal HPC in Learner.

## Example

```
learner = lrn("classif.svm", type = "C-classification", kernel = "radial",
  cost = to_tune(1e-4, 1e4, logscale = TRUE),
  gamma = to_tune(1e-4, 1e4, logscale = TRUE))
instance = tune(method = "grid_search", task = tsk("iris"), learner = learner,
  resampling = rsm("holdout"), measure = msr("classif.ce"), resolution = 5)
```

Use `tune()`-shortcut.

## AutoTuner - Tune before Train

Wraps learner and performs integrated tuning.

```
at = AutoTuner$new(learner, resampling, measure,
  terminator, tuner)
```

Inherits from class `Learner`. Training starts tuning on the training set. After completion the learner is trained with the "optimal" configuration on the given task.

```
at$train(task)
at$predict(task, row_ids)
```

```
at$learner
```

Returns tuned learner trained on full data set.

```
at$tuning_result
# >      cost      gamma learner_param_vals x_domain classif.ce
# > 1: 5.278814 -4.414869      <list[4]> <list[2]>      0.08
```

Access tuning result.

```
at = auto_tuner(method = "grid_search", learner,
  resampling, measure, term_evals = 20)
```

Use shortcut to create `AutoTuner`.

## Nested Resampling

Just resample `AutoTuner`; now has inner and outer loop.

## Example

```
inner = rsm("holdout")
at = auto_tuner(method = "gensa", learner, inner, measure, term_evals = 20)
outer = rsm("cv", folds = 2)
rr = resample(task, at, outer, store_models = TRUE)

as.data.table(rr)
## >      learner      resampling iteration
## > 1: <AutoTuner[37]> <ResamplingCV[19]>      1
## > 2: <AutoTuner[37]> <ResamplingCV[19]>      2
```

```
extract_inner_tuning_results(rr)
# >      iteration      cost      gamma classif.ce learner_param_vals x_domain
# > 1:      1 1.222198 -0.4974749      0.08      <list[4]> <list[2]>
# > 2:      2 2.616557 -3.1440839      0.08      <list[4]> <list[2]>
```

Check inner tuning results for stable HPs.

```
rr$score()
# >      learner iteration      prediction classif.ce
# > 1: <AutoTuner[40]>      1 <PredictionClassif[19]> 0.05333333
# > 2: <AutoTuner[40]>      2 <PredictionClassif[19]> 0.02666667
```

Predictive performances estimated on the outer resampling.

```
extract_inner_tuning_archives(rr)
# >      iteration      cost      gamma classif.ce runtime      resample_result
# > 1:      1 -7.4572 4.1506      0.68      0.013 <ResampleResult[20]>
# > 21:      2 1.0856 0.4003      0.12      0.014 <ResampleResult[20]>
```

All evaluated HP configurations.

```
rr$aggregate()
#>      classif.ce
#>      0.04
```

Aggregates performances of outer resampling iterations.

```
rr = tune_nested(method = "grid_search", task,
  learner, inner, outer, measure, term_evals = 20)
```

Use shortcut to execute nested resampling.