

Package ‘bbotk’

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Title Black-Box Optimization Toolkit

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Description Features highly configurable search spaces via the 'paradox' package and optimizes every user-defined objective function. The package includes several optimization algorithms e.g. Random Search, Iterated Racing, Bayesian Optimization (in 'mlr3mbo') and Hyperband (in 'mlr3hyperband'). bbotk is the base package of 'mlr3tuning', 'mlr3fselect' and 'miesmuschel'.

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'Objective.R' 'ObjectiveRfun.R' 'ObjectiveRfunDt.R'
'ObjectiveRfunMany.R' 'OptimInstance.R' 'OptimInstanceAsync.R'
'OptimInstanceAsyncMultiCrit.R'
'OptimInstanceAsyncSingleCrit.R' 'OptimInstanceBatch.R'
'OptimInstanceBatchMultiCrit.R'

'OptimInstanceBatchSingleCrit.R' 'OptimInstanceMultiCrit.R'
 'OptimInstanceSingleCrit.R' 'mlr_optimizers.R' 'Optimizer.R'
 'OptimizerAsync.R' 'OptimizerAsyncDesignPoints.R'
 'OptimizerAsyncGridSearch.R' 'OptimizerAsyncRandomSearch.R'
 'OptimizerBatch.R' 'OptimizerBatchChain.R'
 'OptimizerBatchCmaes.R' 'OptimizerBatchDesignPoints.R'
 'OptimizerBatchFocusSearch.R' 'OptimizerBatchGenSA.R'
 'OptimizerBatchGridSearch.R' 'OptimizerBatchIrace.R'
 'OptimizerBatchLocalSearch.R' 'OptimizerBatchNLOptr.R'
 'OptimizerBatchRandomSearch.R' 'Progressor.R'
 'mlr_terminators.R' 'Terminator.R' 'TerminatorClockTime.R'
 'TerminatorCombo.R' 'TerminatorEvals.R' 'TerminatorNone.R'
 'TerminatorPerfReached.R' 'TerminatorRunTime.R'
 'TerminatorStagnation.R' 'TerminatorStagnationBatch.R'
 'TerminatorStagnationHypervolume.R' 'as_terminator.R'
 'assertions.R' 'bb_optimize.R' 'bbotk_reflections.R'
 'bibentries.R' 'conditions.R' 'helper.R' 'local_search.R'
 'mlr_callbacks.R' 'nds_selection.R' 'reexport.R' 'sugar.R'
 'worker_loops.R' 'zzz.R'

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bbotk-package	<i>bbotk: Black-Box Optimization Toolkit</i>
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Description

Features highly configurable search spaces via the 'paradox' package and optimizes every user-defined objective function. The package includes several optimization algorithms e.g. Random Search, Iterated Racing, Bayesian Optimization (in 'mlr3mbo') and Hyperband (in 'mlr3hyperband'). bbotk is the base package of 'mlr3tuning', 'mlr3select' and 'miesmuschel'.

Package Options

- "bbotk.debug": If set to TRUE, asynchronous optimization is run in the main process.
- "bbotk.tiny_logging": If set to TRUE, the logging is simplified to only show points and results. NA values are removed.

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See Also

Useful links:

- <https://bbotk.mlr-org.com>
- <https://github.com/mlr-org/bbotk>
- Report bugs at <https://github.com/mlr-org/bbotk/issues>

Archive

Data Storage

Description

The Archive class stores all evaluated points and performance scores

Details

The Archive is an abstract class that implements the base functionality each archive must provide.

Public fields

- `search_space` ([paradox::ParamSet](#))
Specification of the search space for the [Optimizer](#).
- `codomain` ([Codomain](#))
Codomain of objective function.
- `start_time` ([POSIXct](#))
Time stamp of when the optimization started. The time is set by the [Optimizer](#).
- `check_values` (`logical(1)`)
Determines if points and results are checked for validity.

Active bindings

- `label` (`character(1)`)
Label for this object. Can be used in tables, plot and text output instead of the ID.
- `man` (`character(1)`)
String in the format `[pkg]::[topic]` pointing to a manual page for this object. The referenced help package can be opened via method `$help()`.
- `cols_x` (`character()`)
Column names of search space parameters.
- `cols_y` (`character()`)
Column names of codomain target parameters.

Methods

Public methods:

- [Archive\\$new\(\)](#)
- [Archive\\$format\(\)](#)
- [Archive\\$print\(\)](#)
- [Archive\\$clear\(\)](#)
- [Archive\\$help\(\)](#)
- [Archive\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
Archive$new(
  search_space,
  codomain,
  check_values = FALSE,
  label = NA_character_,
  man = NA_character_
)
```

Arguments:

`search_space` ([paradox::ParamSet](#))

Specifies the search space for the [Optimizer](#). The [paradox::ParamSet](#) describes either a subset of the domain of the [Objective](#) or it describes a set of parameters together with a trafo function that transforms values from the search space to values of the domain. Depending on the context, this value defaults to the domain of the objective.

`codomain` ([paradox::ParamSet](#))

Specifies codomain of function. Most importantly the tags of each output "Parameter" define whether it should be minimized or maximized. The default is to minimize each component.

`check_values` (logical(1))

Should x-values that are added to the archive be checked for validity? Search space that is logged into archive.

`label` (character(1))

Label for this object. Can be used in tables, plot and text output instead of the ID.

`man` (character(1))

String in the format `[pkg]::[topic]` pointing to a manual page for this object. The referenced help package can be opened via method `$help()`.

Method `format()`: Helper for print outputs.

Usage:

```
Archive$format(...)
```

Arguments:

... (ignored).

Method `print()`: Printer.

Usage:

```
Archive$print()
```

Arguments:

... (ignored).

Method `clear()`: Clear all evaluation results from archive.

Usage:

```
Archive$clear()
```

Method `help()`: Opens the corresponding help page referenced by field `$man`.

Usage:

Archive\$help()

Method clone(): The objects of this class are cloneable with this method.

Usage:

Archive\$clone(deep = FALSE)

Arguments:

deep Whether to make a deep clone.

See Also

[ArchiveBatch](#), [ArchiveAsync](#)

ArchiveAsync

Rush Data Storage

Description

The ArchiveAsync stores all evaluated points and performance scores in a [rush::Rush](#) data base.

S3 Methods

- `as.data.table(archive)`
[ArchiveAsync](#) -> `data.table::data.table()`
Returns a tabular view of all performed function calls of the Objective. The `x_domain` column is unnested to separate columns.

Super class

[bbotk::Archive](#) -> ArchiveAsync

Public fields

rush (Rush)
Rush controller for parallel optimization.

Active bindings

data ([data.table::data.table](#))
Data table with all finished points.
queued_data ([data.table::data.table](#))
Data table with all queued points.
running_data ([data.table::data.table](#))
Data table with all running points.
finished_data ([data.table::data.table](#))
Data table with all finished points.

failed_data ([data.table::data.table](#))
 Data table with all failed points.

n_queued ([integer\(1\)](#))
 Number of queued points.

n_running ([integer\(1\)](#))
 Number of running points.

n_finished ([integer\(1\)](#))
 Number of finished points.

n_failed ([integer\(1\)](#))
 Number of failed points.

n_evals ([integer\(1\)](#))
 Number of evaluations stored in the archive.

Methods

Public methods:

- [ArchiveAsync\\$new\(\)](#)
- [ArchiveAsync\\$push_points\(\)](#)
- [ArchiveAsync\\$pop_point\(\)](#)
- [ArchiveAsync\\$push_running_point\(\)](#)
- [ArchiveAsync\\$push_result\(\)](#)
- [ArchiveAsync\\$push_failed_point\(\)](#)
- [ArchiveAsync\\$data_with_state\(\)](#)
- [ArchiveAsync\\$best\(\)](#)
- [ArchiveAsync\\$nds_selection\(\)](#)
- [ArchiveAsync\\$clear\(\)](#)
- [ArchiveAsync\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
ArchiveAsync$new(search_space, codomain, check_values = FALSE, rush)
```

Arguments:

search_space ([paradox::ParamSet](#))

Specifies the search space for the [Optimizer](#). The [paradox::ParamSet](#) describes either a subset of the domain of the [Objective](#) or it describes a set of parameters together with a trafo function that transforms values from the search space to values of the domain. Depending on the context, this value defaults to the domain of the objective.

codomain ([paradox::ParamSet](#))

Specifies codomain of function. Most importantly the tags of each output "Parameter" define whether it should be minimized or maximized. The default is to minimize each component.

check_values ([logical\(1\)](#))

Should points before the evaluation and the results be checked for validity?

rush (Rush)

If a rush instance is supplied, the tuning runs without batches.

Method `push_points()`: Push queued points to the archive.

Usage:

```
ArchiveAsync$push_points(xss)
```

Arguments:

`xss` (list of named list())

List of named lists of point values.

Method `pop_point()`: Pop a point from the queue.

Usage:

```
ArchiveAsync$pop_point()
```

Method `push_running_point()`: Push running point to the archive.

Usage:

```
ArchiveAsync$push_running_point(xs, extra = NULL)
```

Arguments:

`xs` (named list)

Named list of point values.

`extra` (list())

Named list of additional information.

Method `push_result()`: Push result to the archive.

Usage:

```
ArchiveAsync$push_result(key, ys, x_domain, extra = NULL)
```

Arguments:

`key` (character())

Key of the point.

`ys` (list())

Named list of results.

`x_domain` (list())

Named list of transformed point values.

`extra` (list())

Named list of additional information.

Method `push_failed_point()`: Push failed point to the archive.

Usage:

```
ArchiveAsync$push_failed_point(key, message)
```

Arguments:

`key` (character())

Key of the point.

`message` (character())

Error message.

Method `data_with_state()`: Fetch points with a specific state.

Usage:

```
ArchiveAsync$data_with_state(
  fields = c("xs", "ys", "xs_extra", "worker_extra", "ys_extra", "condition"),
  states = c("queued", "running", "finished", "failed")
)
```

Arguments:

`fields` (character())

Fields to fetch. Defaults to `c("xs", "ys", "xs_extra", "worker_extra", "ys_extra")`.

`states` (character())

States of the tasks to be fetched. Defaults to `c("queued", "running", "finished", "failed")`.

Method `best()`: Returns the best scoring evaluation(s). For single-crit optimization, the solution that minimizes / maximizes the objective function. For multi-crit optimization, the Pareto set / front.

Usage:

```
ArchiveAsync$best(n_select = 1, ties_method = "first")
```

Arguments:

`n_select` (integer(1L))

Amount of points to select. Ignored for multi-crit optimization.

`ties_method` (character(1L))

Method to break ties when multiple points have the same score. Either "first" (default) or "random". Ignored for multi-crit optimization. If `n_select > 1L`, the tie method is ignored and the first point is returned.

Returns: `data.table::data.table()`

Method `nds_selection()`: Calculate best points w.r.t. non dominated sorting with hypervolume contribution.

Usage:

```
ArchiveAsync$nds_selection(n_select = 1, ref_point = NULL)
```

Arguments:

`n_select` (integer(1L))

Amount of points to select.

`ref_point` (numeric())

Reference point for hypervolume.

Returns: `data.table::data.table()`

Method `clear()`: Clear all evaluation results from archive.

Usage:

```
ArchiveAsync$clear()
```

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
ArchiveAsync$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

Examples

```
if (mlr3misc::require_namespaces(c("rush", "redux", "mirai"), quietly = TRUE) &&
    redux::redis_available()) {
  fun = function(xs) {
    list(y = - (xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
  }

  # set domain
  domain = ps(
    x1 = p_dbl(-10, 10),
    x2 = p_dbl(-5, 5)
  )

  # set codomain
  codomain = ps(
    y = p_dbl(tags = "maximize")
  )

  # create objective
  objective = ObjectiveRFun$new(
    fun = fun,
    domain = domain,
    codomain = codomain,
    properties = "deterministic"
  )

  # start workers
  rush::rush_plan(worker_type = "remote")
  mirai::daemons(1)

  # initialize instance
  instance = oi_async(
    objective = objective,
    terminator = trm("evals", n_evals = 20)
  )

  # load optimizer
  optimizer = opt("async_random_search")

  # trigger optimization
  optimizer$optimize(instance)

  # all evaluated configuration
  instance$archive

  # best performing configuration
  instance$archive$best()

  # covert to data.table
  as.data.table(instance$archive)

  # reset the rush data base
```

```
instance$rush$reset()
}
```

ArchiveAsyncFrozen *Frozen Rush Data Storage*

Description

Freezes the Redis data base of an [ArchiveAsync](#) to a `data.table::data.table()`. No further points can be added to the archive but the data can be accessed and analyzed. Useful when the Redis data base is not permanently available. Use the callback [bbotk.async_freeze_archive](#) to freeze the archive after the optimization has finished.

S3 Methods

- `as.data.table(archive)`
[ArchiveAsync](#) -> `data.table::data.table()`
Returns a tabular view of all performed function calls of the Objective. The `x_domain` column is unnested to separate columns.

Super classes

[bbotk::Archive](#) -> [bbotk::ArchiveAsync](#) -> ArchiveAsyncFrozen

Active bindings

`data` ([data.table::data.table](#))
Data table with all finished points.

`queued_data` ([data.table::data.table](#))
Data table with all queued points.

`running_data` ([data.table::data.table](#))
Data table with all running points.

`finished_data` ([data.table::data.table](#))
Data table with all finished points.

`failed_data` ([data.table::data.table](#))
Data table with all failed points.

`n_queued` (`integer(1)`)
Number of queued points.

`n_running` (`integer(1)`)
Number of running points.

`n_finished` (`integer(1)`)
Number of finished points.

`n_failed` (`integer(1)`)
Number of failed points.

`n_evals` (`integer(1)`)
Number of evaluations stored in the archive.

Methods

Public methods:

- `ArchiveAsyncFrozen$new()`
- `ArchiveAsyncFrozen$push_points()`
- `ArchiveAsyncFrozen$pop_point()`
- `ArchiveAsyncFrozen$push_running_point()`
- `ArchiveAsyncFrozen$push_result()`
- `ArchiveAsyncFrozen$push_failed_point()`
- `ArchiveAsyncFrozen$data_with_state()`
- `ArchiveAsyncFrozen$clear()`
- `ArchiveAsyncFrozen$clone()`

Method `new()`: Creates a new instance of this R6 class.

Usage:

```
ArchiveAsyncFrozen$new(archive)
```

Arguments:

`archive` (`ArchiveAsync`)

The archive to freeze.

Method `push_points()`: Push queued points to the archive.

Usage:

```
ArchiveAsyncFrozen$push_points(xss)
```

Arguments:

`xss` (`list of named list()`)

List of named lists of point values.

Method `pop_point()`: Pop a point from the queue.

Usage:

```
ArchiveAsyncFrozen$pop_point()
```

Method `push_running_point()`: Push running point to the archive.

Usage:

```
ArchiveAsyncFrozen$push_running_point(xs, extra = NULL)
```

Arguments:

`xs` (`named list`)

Named list of point values.

`extra` (`list()`)

Named list of additional information.

Method `push_result()`: Push result to the archive.

Usage:

```
ArchiveAsyncFrozen$push_result(key, ys, x_domain, extra = NULL)
```

Arguments:

key (character())
 Key of the point.
 ys (list())
 Named list of results.
 x_domain (list())
 Named list of transformed point values.
 extra (list())
 Named list of additional information.

Method push_failed_point(): Push failed point to the archive.

Usage:

```
ArchiveAsyncFrozen$push_failed_point(key, message)
```

Arguments:

key (character())
 Key of the point.
 message (character())
 Error message.

Method data_with_state(): Fetch points with a specific state.

Usage:

```
ArchiveAsyncFrozen$data_with_state(
  fields = c("xs", "ys", "xs_extra", "worker_extra", "ys_extra", "condition"),
  states = c("queued", "running", "finished", "failed"),
  reset_cache = FALSE
)
```

Arguments:

fields (character())
 Fields to fetch. Defaults to c("xs", "ys", "xs_extra", "worker_extra", "ys_extra").
 states (character())
 States of the tasks to be fetched. Defaults to c("queued", "running", "finished", "failed").
 reset_cache (logical(1))
 Whether to reset the cache of the finished points.

Method clear(): Clear all evaluation results from archive.

Usage:

```
ArchiveAsyncFrozen$clear()
```

Method clone(): The objects of this class are cloneable with this method.

Usage:

```
ArchiveAsyncFrozen$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

See Also[ArchiveAsync](#)**Examples**

```
# example only runs if a Redis server is available
if (mlr3misc::require_namespaces(c("rush", "redux", "mirai"), quietly = TRUE) &&
    redux::redis_available()) {
  # define the objective function
  fun = function(xs) {
    list(y = - (xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
  }

  # set domain
  domain = ps(
    x1 = p_dbl(-10, 10),
    x2 = p_dbl(-5, 5)
  )

  # set codomain
  codomain = ps(
    y = p_dbl(tags = "maximize")
  )

  # create objective
  objective = ObjectiveRFun$new(
    fun = fun,
    domain = domain,
    codomain = codomain,
    properties = "deterministic"
  )

  # start workers
  rush::rush_plan(worker_type = "remote")
  mirai::daemons(1)

  # initialize instance
  instance = oi_async(
    objective = objective,
    terminator = trm("evals", n_evals = 20),
    callback = clbk("bbotk.async_freeze_archive")
  )

  # load optimizer
  optimizer = opt("async_random_search")

  # trigger optimization
  optimizer$optimize(instance)

  # frozen archive
  instance$archive
}
```

```

# best performing configuration
instance$archive$best()

# covert to data.table
as.data.table(instance$archive)
}

```

ArchiveBatch

Data Table Storage

Description

The ArchiveBatch stores all evaluated points and performance scores in a `data.table::data.table()`.

S3 Methods

- `as.data.table(archive)`
[ArchiveBatch](#) -> `data.table::data.table()`
Returns a tabular view of all performed function calls of the Objective. The `x_domain` column is unnested to separate columns.

Super class

[bbotk::Archive](#) -> ArchiveBatch

Public fields

`data` (`data.table::data.table`)
Contains all performed [Objective](#) function calls.

`data_extra` (named list)
Data created by specific [Optimizers](#) that does not relate to any individual function evaluation and can therefore not be held in `$data`. Every optimizer should create and refer to its own entry in this list, named by its `class()`.

Active bindings

`n_evals` (`integer(1)`)
Number of evaluations stored in the archive.

`n_batch` (`integer(1)`)
Number of batches stored in the archive.

Methods

Public methods:

- [ArchiveBatch\\$new\(\)](#)
- [ArchiveBatch\\$add_evals\(\)](#)
- [ArchiveBatch\\$best\(\)](#)

- [ArchiveBatch\\$nds_selection\(\)](#)
- [ArchiveBatch\\$clear\(\)](#)
- [ArchiveBatch\\$clone\(\)](#)

Method `new()`: Creates a new instance of this R6 class.

Usage:

```
ArchiveBatch$new(search_space, codomain, check_values = FALSE)
```

Arguments:

`search_space` ([paradox::ParamSet](#))

Specifies the search space for the [Optimizer](#). The [paradox::ParamSet](#) describes either a subset of the domain of the [Objective](#) or it describes a set of parameters together with a trafo function that transforms values from the search space to values of the domain. Depending on the context, this value defaults to the domain of the objective.

`codomain` ([paradox::ParamSet](#))

Specifies codomain of function. Most importantly the tags of each output "Parameter" define whether it should be minimized or maximized. The default is to minimize each component.

`check_values` (`logical(1)`)

Should x-values that are added to the archive be checked for validity? Search space that is logged into archive.

Method `add_evals()`: Adds function evaluations to the archive table.

Usage:

```
ArchiveBatch$add_evals(xdt, xss_trafoed = NULL, ydt)
```

Arguments:

`xdt` ([data.table::data.table\(\)](#))

Set of untransformed points / points from the *search space*. One point per row, e.g. `data.table(x1 = c(1, 3), x2 = c(2, 4))`. Column names have to match ids of the *search_space*. However, `xdt` can contain additional columns.

`xss_trafoed` (`list()`)

Transformed point(s) in the *domain space*.

`ydt` ([data.table::data.table\(\)](#))

Optimal outcome.

Method `best()`: Returns the best scoring evaluation(s). For single-crit optimization, the solution that minimizes / maximizes the objective function. For multi-crit optimization, the Pareto set / front.

Usage:

```
ArchiveBatch$best(batch = NULL, n_select = 1L, ties_method = "first")
```

Arguments:

`batch` (`integer()`)

The batch number(s) to limit the best results to. Default is all batches.

`n_select` (`integer(1L)`)

Amount of points to select. Ignored for multi-crit optimization.

`ties_method` (character(1L))

Method to break ties when multiple points have the same score. Either "first" (default) or "random". Ignored for multi-crit optimization. If `n_select > 1L`, the tie method is ignored and the first point is returned.

Returns: `data.table::data.table()`

Method `nds_selection()`: Calculate best points w.r.t. non dominated sorting with hypervolume contribution.

Usage:

```
ArchiveBatch$nds_selection(batch = NULL, n_select = 1, ref_point = NULL)
```

Arguments:

`batch` (integer())

The batch number(s) to limit the best points to. Default is all batches.

`n_select` (integer(1L))

Amount of points to select.

`ref_point` (numeric())

Reference point for hypervolume.

Returns: `data.table::data.table()`

Method `clear()`: Clear all evaluation results from archive.

Usage:

```
ArchiveBatch$clear()
```

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
ArchiveBatch$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

Examples

```
fun = function(xs) {
  list(y = - (xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
}

# set domain
domain = ps(
  x1 = p_dbl(-10, 10),
  x2 = p_dbl(-5, 5)
)

# set codomain
codomain = ps(
  y = p_dbl(tags = "maximize")
)

# create objective
```

```

objective = ObjectiveRfun$new(
  fun = fun,
  domain = domain,
  codomain = codomain,
  properties = "deterministic"
)

# initialize instance
instance = oi(
  objective = objective,
  terminator = trm("evals", n_evals = 20)
)

# load optimizer
optimizer = opt("random_search")

# trigger optimization
optimizer$optimize(instance)

# all evaluated configuration
instance$archive

# best performing configuration
instance$archive$best()

# covert to data.table
as.data.table(instance$archive)

```

as_terminator	<i>Convert to a Terminator</i>
---------------	--------------------------------

Description

Convert object to a [Terminator](#) or a list of [Terminator](#).

Usage

```

as_terminator(x, ...)

## S3 method for class 'Terminator'
as_terminator(x, clone = FALSE, ...)

as_terminators(x, ...)

## Default S3 method:
as_terminators(x, ...)

## S3 method for class 'list'
as_terminators(x, ...)

```

Arguments

x	(any) Object to convert.
...	(any) Additional arguments.
clone	(logical(1)) If TRUE, ensures that the returned object is not the same as the input x.

See Also

[Terminator](#)

bbotk.async_freeze_archive
Freeze Archive Callback

Description

This [CallbackAsync](#) freezes the [ArchiveAsync](#) to [ArchiveAsyncFrozen](#) after the optimization has finished.

Examples

```
clbk("bbotk.async_freeze_archive")
```

bbotk.backup *Backup Archive Callback*

Description

This [CallbackBatch](#) writes the [Archive](#) after each batch to disk.

Examples

```
clbk("bbotk.backup", path = "backup.rds")
```

bbotk_conditions	<i>Condition Classes for bbotk</i>
------------------	------------------------------------

Description

Condition classes for bbotk.

Usage

```
error_bbotk(msg, ..., class = NULL, signal = TRUE, parent = NULL)
```

```
error_bbotk_terminated(msg, ..., class = NULL, signal = TRUE, parent = NULL)
```

Arguments

msg	(character(1)) Error message.
...	(any) Passed to <code>sprintf()</code> .
class	(character) Additional class(es).
signal	(logical(1)) If FALSE, the condition object is returned instead of being signaled.
parent	(condition) Parent condition.

Errors

- `error_bbotk()` for the `Mlr3ErrorBbotk` class, signalling a general bbotk error.
- `error_bbotk_terminated()` for the `Mlr3ErrorBbotkTerminated` class, signalling a termination error.

bb_optimize	<i>Black-Box Optimization</i>
-------------	-------------------------------

Description

This function optimizes a function or [Objective](#) with a given method.

Usage

```

bb_optimize(
  x,
  method = "random_search",
  max_evals = 1000,
  max_time = NULL,
  ...
)

## S3 method for class ``function``
bb_optimize(
  x,
  method = "random_search",
  max_evals = 1000,
  max_time = NULL,
  lower = NULL,
  upper = NULL,
  maximize = FALSE,
  ...
)

## S3 method for class 'Objective'
bb_optimize(
  x,
  method = "random_search",
  max_evals = 1000,
  max_time = NULL,
  search_space = NULL,
  ...
)

```

Arguments

x	(function Objective).
method	(character(1) Optimizer) Key to retrieve optimizer from mlr_optimizers dictionary or Optimizer .
max_evals	(integer(1)) Number of allowed evaluations.
max_time	(integer(1)) Maximum allowed time in seconds.
...	(named list()) Named arguments passed to objective function. Ignored if Objective is optimized.
lower	(numeric()) Lower bounds on the parameters. If named, names are used to create the domain.
upper	(numeric()) Upper bounds on the parameters.

maximize (logical())
 Logical vector used to create the codomain e.g. `c(TRUE, FALSE)` -> `ps(y1 = p_dbl(tags = "maximize"), y2 = pd_dbl(tags = "minimize"))`. If named, names are used to create the codomain.

search_space (paradox::ParamSet).

Value

list of

- "par" - Best found parameters
- "value" - Optimal outcome
- "instance" - [OptimInstanceBatchSingleCrit](#) | [OptimInstanceBatchMultiCrit](#)

Note

If both `max_evals` and `max_time` are NULL, [TerminatorNone](#) is used. This is useful if the [Optimizer](#) can terminate itself. If both are given, [TerminatorCombo](#) is created and the optimization stops if the time or evaluation budget is exhausted.

Examples

```

# function and bounds
fun = function(xs) {
  -(xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10
}

bb_optimize(fun, lower = c(-10, -5), upper = c(10, 5), max_evals = 10)

# function and constant
fun = function(xs, c) {
  -(xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + c
}

bb_optimize(fun, lower = c(-10, -5), upper = c(10, 5), max_evals = 10, c = 1)

# objective
fun = function(xs) {
  c(z = -(xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
}

# define domain and codomain using a `ParamSet` from paradox
domain = ps(x1 = p_dbl(-10, 10), x2 = p_dbl(-5, 5))
codomain = ps(z = p_dbl(tags = "minimize"))
objective = ObjectiveRFun$new(fun, domain, codomain)

bb_optimize(objective, method = "random_search", max_evals = 10)

```

branin	<i>Branin Function</i>
--------	------------------------

Description

Classic 2-D Branin function with noise `branin(x1, x2, noise)` and Branin function with fidelity parameter `branin_wu(x1, x2, fidelity)`.

Usage

```
branin(x1, x2, noise = 0)

branin_wu(x1, x2, fidelity)
```

Arguments

<code>x1</code>	(numeric()).
<code>x2</code>	(numeric()).
<code>noise</code>	(numeric()).
<code>fidelity</code>	(numeric()).

Value

numeric()

Source

Wu J, Toscano-Palmerin S, Frazier PI, Wilson AG (2019). “Practical Multi-fidelity Bayesian Optimization for Hyperparameter Tuning.” 1903.04703.

Examples

```
branin(x1 = 12, x2 = 2, noise = 0.05)
branin_wu(x1 = 12, x2 = 2, fidelity = 1)
```

CallbackAsync	<i>Create Asynchronous Optimization Callback</i>
---------------	--

Description

Specialized `mlr3misc::Callback` for asynchronous optimization. Callbacks allow to customize the behavior of processes in `bbotk`. The `callback_async()` function creates a `CallbackAsync`. Pre-defined callbacks are stored in the dictionary `mlr_callbacks` and can be retrieved with `clbk()`. For more information on optimization callbacks see `callback_async()`.

Super class

[mlr3misc::Callback](#) -> CallbackAsync

Public fields

`on_optimization_begin` (function())
Stage called at the beginning of the optimization in the main process. Called in `Optimizer$optimize()`.

`on_worker_begin` (function())
Stage called at the beginning of the optimization on the worker. Called in the worker loop.

`on_optimizer_before_eval` (function())
Stage called after the optimizer proposes points. Called in `OptimInstance$.eval_point()`.

`on_optimizer_after_eval` (function())
Stage called after points are evaluated. Called in `OptimInstance$.eval_point()`.

`on_optimizer_queue_before_eval` (function())
Stage called after the optimizer proposes points. Called in `OptimInstance$.eval_queue()`.

`on_optimizer_queue_after_eval` (function())
Stage called after points are evaluated. Called in `OptimInstance$.eval_queue()`.

`on_worker_end` (function())
Stage called at the end of the optimization on the worker. Called in the worker loop.

`on_result_begin` (function())
Stage called before the results are written. Called in `OptimInstance$assign_result()`.

`on_result_end` (function())
Stage called after the results are written. Called in `OptimInstance$assign_result()`.

`on_optimization_end` (function())
Stage called at the end of the optimization in the main process. Called in `Optimizer$optimize()`.

Methods**Public methods:**

- [CallbackAsync\\$clone\(\)](#)

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
CallbackAsync$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

See Also

[callback_async\(\)](#)

CallbackBatch

Create Batch Optimization Callback

Description

Specialized `mlr3misc::Callback` for batch optimization. Callbacks allow to customize the behavior of processes in `bbotk`. The `callback_batch()` function creates a `CallbackBatch`. Predefined callbacks are stored in the dictionary `mlr_callbacks` and can be retrieved with `clbk()`. For more information on optimization callbacks see `callback_batch()`.

Super class

`mlr3misc::Callback` -> `CallbackBatch`

Public fields

`on_optimization_begin` (function())

Stage called at the beginning of the optimization. Called in `Optimizer$optimize()`.

`on_optimizer_before_eval` (function())

Stage called after the optimizer proposes points. Called in `OptimInstance$eval_batch()`.

`on_optimizer_after_eval` (function())

Stage called after points are evaluated. Called in `OptimInstance$eval_batch()`.

`on_result_begin` (function())

Stage called before the results are written. Called in `OptimInstance$assign_result()`.

`on_result_end` (function())

Stage called after the results are written. Called in `OptimInstance$assign_result()`.

`on_optimization_end` (function())

Stage called at the end of the optimization. Called in `Optimizer$optimize()`.

Methods

Public methods:

- `CallbackBatch$clone()`

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
CallbackBatch$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

See Also

`callback_batch()`

Examples

```
# write archive to disk
callback_batch("bbotk.backup",
  on_optimization_end = function(callback, context) {
    saveRDS(context$instance$archive, "archive.rds")
  }
)
```

callback_async	<i>Create Asynchronous Optimization Callback</i>
----------------	--

Description

Function to create a [CallbackAsync](#).

Optimization callbacks can be called from different stages of optimization process. The stages are prefixed with on_*

```
Start Optimization
  - on_optimization_begin
Start Worker
  - on_worker_begin
  Start Optimization on Worker
    - on_optimizer_before_eval
    - on_optimizer_after_eval
  End Optimization on Worker
  - on_worker_end
End Worker
  - on_result_begin
  - on_result_end
  - on_optimization_end
End Optimization
```

See also the section on parameters for more information on the stages. A optimization callback works with [ContextAsync](#).

Usage

```
callback_async(
  id,
  label = NA_character_,
  man = NA_character_,
  on_optimization_begin = NULL,
  on_worker_begin = NULL,
  on_optimizer_before_eval = NULL,
  on_optimizer_after_eval = NULL,
  on_optimizer_queue_before_eval = NULL,
```

```

    on_optimizer_queue_after_eval = NULL,
    on_worker_end = NULL,
    on_result_begin = NULL,
    on_result_end = NULL,
    on_result = NULL,
    on_optimization_end = NULL
)

```

Arguments

id	(character(1)) Identifier for the new instance.
label	(character(1)) Label for the new instance.
man	(character(1)) String in the format [pkg]::[topic] pointing to a manual page for this object. The referenced help package can be opened via method \$help().
on_optimization_begin	(function()) Stage called at the beginning of the optimization in the main process. Called in Optimizer\$optimize(). The functions must have two arguments named callback and context.
on_worker_begin	(function()) Stage called at the beginning of the optimization on the worker. Called in the worker loop. The functions must have two arguments named callback and context.
on_optimizer_before_eval	(function()) Stage called after the optimizer proposes points. Called in OptimInstance\$.eval_point(). The functions must have two arguments named callback and context. The argument of instance\$.eval_point(xs) and xs_trafoed and extra are available in the context. Or xs and xs_trafoed of instance\$.eval_queue() are available in the context.
on_optimizer_after_eval	(function()) Stage called after points are evaluated. Called in OptimInstance\$.eval_point(). The functions must have two arguments named callback and context. The outcome y is available in the context.
on_optimizer_queue_before_eval	(function()) Stage called before a point in the queue is evaluated. Called in OptimInstance\$.eval_queue(). The functions must have two arguments named callback and context. The argument of instance\$.eval_queue(xs) and xs_trafoed and extra are available in the context.
on_optimizer_queue_after_eval	(function()) Stage called after a point in the queue is evaluated. Called in OptimInstance\$.eval_queue().

The functions must have two arguments named `callback` and `context`. The outcome `y` is available in the context.

<code>on_worker_end</code>	(function()) Stage called at the end of the optimization on the worker. Called in the worker loop. The functions must have two arguments named <code>callback</code> and <code>context</code> .
<code>on_result_begin</code>	(function()) Stage called before result are written. Called in <code>OptimInstance\$assign_result()</code> . The functions must have two arguments named <code>callback</code> and <code>context</code> . The arguments of <code>\$.assign_result(xdt, y, extra)</code> are available in the context.
<code>on_result_end</code>	(function()) Stage called after result are written. Called in <code>OptimInstance\$assign_result()</code> . The functions must have two arguments named <code>callback</code> and <code>context</code> . The final result <code>instance\$result</code> is available in the context.
<code>on_result</code>	(function()) Deprecated. Use <code>on_result_end</code> instead. Stage called after result are written. Called in <code>OptimInstance\$assign_result()</code> . The functions must have two arguments named <code>callback</code> and <code>context</code> .
<code>on_optimization_end</code>	(function()) Stage called at the end of the optimization in the main process. Called in <code>Optimizer\$optimize()</code> . The functions must have two arguments named <code>callback</code> and <code>context</code> .

Details

A callback can write data to its state (`$state`), e.g. settings that affect the callback itself. The [ContextAsync](#) allows to modify the instance, archive, optimizer and final result.

Value

[CallbackAsync](#)

<code>callback_batch</code>	<i>Create Batch Optimization Callback</i>
-----------------------------	---

Description

Function to create a [CallbackBatch](#).

Optimization callbacks can be called from different stages of optimization process. The stages are prefixed with `on_*`.

Start Optimization
 - `on_optimization_begin`
 Start Optimizer Batch

```

        - on_optimizer_before_eval
        - on_optimizer_after_eval
    End Optimizer Batch
    - on_result_begin
    - on_result_end
    - on_optimization_end
End Optimization

```

See also the section on parameters for more information on the stages. A optimization callback works with [ContextBatch](#).

Usage

```

callback_batch(
  id,
  label = NA_character_,
  man = NA_character_,
  on_optimization_begin = NULL,
  on_optimizer_before_eval = NULL,
  on_optimizer_after_eval = NULL,
  on_result_begin = NULL,
  on_result_end = NULL,
  on_result = NULL,
  on_optimization_end = NULL
)

```

Arguments

id	(character(1)) Identifier for the new instance.
label	(character(1)) Label for the new instance.
man	(character(1)) String in the format [pkg]::[topic] pointing to a manual page for this object. The referenced help package can be opened via method \$help().
on_optimization_begin	(function()) Stage called at the beginning of the optimization. Called in Optimizer\$optimize(). The functions must have two arguments named callback and context.
on_optimizer_before_eval	(function()) Stage called after the optimizer proposes points. Called in OptimInstance\$eval_batch(). The functions must have two arguments named callback and context. The argument of \$eval_batch(xdt) is available in context.
on_optimizer_after_eval	(function()) Stage called after points are evaluated. Called in OptimInstance\$eval_batch().

The functions must have two arguments named `callback` and `context`. The new points and outcomes in `instance$archive` are available in `context`.

<code>on_result_begin</code>	(function()) Stage called before result are written to the instance. Called in <code>OptimInstance\$assign_result()</code> . The functions must have two arguments named <code>callback</code> and <code>context</code> . The arguments of <code>\$assign_result(xdt, y, extra)</code> are available in <code>context</code> .
<code>on_result_end</code>	(function()) Stage called after result are written to the instance. Called in <code>OptimInstance\$assign_result()</code> . The functions must have two arguments named <code>callback</code> and <code>context</code> . The final result <code>instance\$result</code> is available in <code>context</code> .
<code>on_result</code>	(function()) Deprecated. Use <code>on_result_end</code> instead. Stage called after result are written. Called in <code>OptimInstance\$assign_result()</code> . The functions must have two arguments named <code>callback</code> and <code>context</code> .
<code>on_optimization_end</code>	(function()) Stage called at the end of the optimization. Called in <code>Optimizer\$optimize()</code> . The functions must have two arguments named <code>callback</code> and <code>context</code> .

Details

A callback can write data to its state (`$state`), e.g. settings that affect the callback itself. The [ContextBatch](#) allows to modify the instance, archive, optimizer and final result.

Value

[CallbackBatch](#)

Examples

```
# write archive to disk
callback_batch("bbotk.backup",
  on_optimization_end = function(callback, context) {
    saveRDS(context$instance$archive, "archive.rds")
  }
)
```

`choose_search_space` *Choose Search Space*

Description

Determines the search space from an objective's domain, handling `TuneTokens`. Used internally by [OptimInstance](#) and [OptimInstanceAsync](#).

Usage

```
choose_search_space(objective, search_space)
```

Arguments

`objective` (**Objective**) The objective function.

`search_space` (`paradox::ParamSet` | `NULL`) Optional explicit search space.

Value

A `paradox::ParamSet` to use as the search space.

Codomain

Codomain of Function

Description

A `paradox::ParamSet` defining the codomain of a function. The parameter set must contain at least one target parameter tagged with "minimize", "maximize", or "learn". The codomain may contain extra parameters which are ignored when calling the `Archive` methods `$best()`, `$nds_selection()` and `$cols_y`. This class is usually constructed internally from a `paradox::ParamSet` when `Objective` is initialized.

Super class

`paradox::ParamSet` -> `Codomain`

Active bindings

`is_target` (`named logical()`)
Position is TRUE for target parameters.

`target_length` (`integer()`)
Returns number of target parameters.

`target_ids` (`character()`)
IDs of contained target parameters.

`target_tags` (`named list()` of `character()`)
Tags of target parameters.

`maximization_to_minimization` (`integer()`)
Returns a numeric vector with values -1 and 1. Multiply with the outcome of a maximization problem to turn it into a minimization problem.

`direction` (`integer()`)
Returns 1 for minimization, -1 for maximization, and 0 for learning. If the codomain contains multiple parameters an integer vector is returned. Multiply with the outcome of a maximization problem to turn it into a minimization problem.

Methods**Public methods:**

- [Codomain\\$new\(\)](#)
- [Codomain\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
Codomain$new(params)
```

Arguments:

```
params (list())
```

Named list with which to initialize the codomain. This argument is analogous to [paradox::ParamSet](#)'s `$initialize()` `params` argument.

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
Codomain$clone(deep = FALSE)
```

Arguments:

```
deep Whether to make a deep clone.
```

Examples

```
# define objective function
fun = function(xs) {
  c(y = -(xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
}

# set domain
domain = ps(
  x1 = p_dbl(-10, 10),
  x2 = p_dbl(-5, 5)
)

# set codomain
codomain = ps(
  y = p_dbl(tags = "maximize"),
  time = p_dbl()
)

# create Objective object
objective = ObjectiveRfun$new(
  fun = fun,
  domain = domain,
  codomain = codomain,
  properties = "deterministic"
)
```

ContextAsync

*Asynchronous Optimization Context***Description**

A [CallbackAsync](#) accesses and modifies data during the optimization via the ContextAsync. See the section on active bindings for a list of modifiable objects. See [callback_async\(\)](#) for a list of stages which access ContextAsync.

Details

Changes to `$instance` and `$optimizer` in the stages executed on the workers are not reflected in the main process.

Super class

[mlr3misc::Context](#) -> ContextAsync

Public fields

`instance` ([OptimInstance](#)).

`optimizer` ([Optimizer](#)).

Active bindings

`xs` (list())

The point to be evaluated in `instance$.eval_point()`.

`xs_trafoed` (list())

The transformed point to be evaluated in `instance$.eval_point()`.

`extra` (list())

Additional information of the point to be evaluated in `instance$.eval_point()`.

`ys` (list())

The result of the evaluation in `instance$.eval_point()`.

`result_xdt` ([data.table::data.table](#))

The xdt passed to `instance$assign_result()`.

`result_y` (numeric(1))

The y passed to `instance$assign_result()`. Only available for single criterion optimization.

`result_ydt` ([data.table::data.table](#))

The ydt passed to `instance$assign_result()`. Only available for multi criterion optimization.

`result_extra` ([data.table::data.table](#))

Additional information about the result passed to `instance$assign_result()`.

`result` ([data.table::data.table](#))

The result of the optimization in `instance$assign_result()`.

Methods

Public methods:

- [ContextAsync\\$new\(\)](#)
- [ContextAsync\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
ContextAsync$new(inst, optimizer)
```

Arguments:

`inst` ([OptimInstance](#)).

`optimizer` ([Optimizer](#)).

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
ContextAsync$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

See Also

[CallbackAsync](#)

ContextBatch

Batch Optimization Context

Description

A [CallbackBatch](#) accesses and modifies data during the optimization via the `ContextBatch`. See the section on active bindings for a list of modifiable objects. See [callback_batch\(\)](#) for a list of stages which that `ContextBatch`.

Super class

```
m1r3misc::Context -> ContextBatch
```

Public fields

`instance` ([OptimInstance](#)).

`optimizer` ([Optimizer](#)).

Active bindings

- `xdt` ([data.table::data.table](#))
The points of the latest batch in `instance$eval_batch()`. Contains the values in the search space i.e. transformations are not yet applied.
- `result_xdt` ([data.table::data.table](#))
The xdt passed to `instance$assign_result()`.
- `result_y` (`numeric(1)`)
The y passed to `instance$assign_result()`. Only available for single criterion optimization.
- `result_ydt` ([data.table::data.table](#))
The ydt passed to `instance$assign_result()`. Only available for multi criterion optimization.
- `result_extra` ([data.table::data.table](#))
Additional information about the result passed to `instance$assign_result()`.
- `result` ([data.table::data.table](#))
The result of the optimization in `instance$assign_result()`.

Methods**Public methods:**

- [ContextBatch\\$new\(\)](#)
- [ContextBatch\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

`ContextBatch$new(inst, optimizer)`

Arguments:

`inst` ([OptimInstance](#)).

`optimizer` ([Optimizer](#)).

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

`ContextBatch$clone(deep = FALSE)`

Arguments:

`deep` Whether to make a deep clone.

See Also

[CallbackBatch](#)

EvalInstance

Evaluation Instance Base Class

Description

Abstract base class for instances that evaluate an objective function. This class provides common functionality shared between optimization ([OptimInstance](#)) and other evaluation patterns (e.g., active learning).

Details

EvalInstance contains the core components needed for any objective evaluation loop:

- An [Objective](#) to evaluate
- A search space defining valid inputs
- An [Archive](#) storing evaluation history
- A [Terminator](#) defining stopping conditions

Subclasses add specific functionality:

- [OptimInstance](#): Result tracking, optimization-specific methods
- External packages may define their own subclasses

Public fields

`objective` ([Objective](#))
Objective function of the instance.

`search_space` ([paradox::ParamSet](#))
Specification of the search space for the [Optimizer](#).

`terminator` [Terminator](#)
Termination criterion of the optimization.

`archive` ([Archive](#))
Contains all performed function calls of the Objective.

Active bindings

`label` (`character(1)`)
Label for this object. Can be used in tables, plot and text output instead of the ID.

`man` (`character(1)`)
String in the format `[pkg]::[topic]` pointing to a manual page for this object. The referenced help package can be opened via method `$help()`.

`is_terminated` (`logical(1)`)
Whether the terminator says we should stop.

`n_evals` (`integer(1)`)
Number of evaluations performed.

Methods

Public methods:

- [EvalInstance\\$new\(\)](#)
- [EvalInstance\\$format\(\)](#)
- [EvalInstance\\$print\(\)](#)
- [EvalInstance\\$clear\(\)](#)
- [EvalInstance\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
EvalInstance$new(
  objective,
  search_space,
  terminator,
  archive,
  label = NA_character_,
  man = NA_character_
)
```

Arguments:

`objective` ([Objective](#))

Objective function.

`search_space` ([paradox::ParamSet](#))

Specifies the search space for the [Optimizer](#). The [paradox::ParamSet](#) describes either a subset of the domain of the [Objective](#) or it describes a set of parameters together with a trafo function that transforms values from the search space to values of the domain. Depending on the context, this value defaults to the domain of the objective.

`terminator` [Terminator](#)

Termination criterion.

`archive` ([Archive](#)).

`label` (character(1))

Label for this object. Can be used in tables, plot and text output instead of the ID.

`man` (character(1))

String in the format `[pkg]::[topic]` pointing to a manual page for this object. The referenced help package can be opened via method `$help()`.

Method `format()`: Helper for print outputs.

Usage:

```
EvalInstance$format(...)
```

Arguments:

... (ignored).

Method `print()`: Printer.

Usage:

```
EvalInstance$print(...)
```

Arguments:

... (ignored).

Method clear(): Clear all evaluation results from archive.

Usage:

```
EvalInstance$clear()
```

Method clone(): The objects of this class are cloneable with this method.

Usage:

```
EvalInstance$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

is_dominated

Calculate which points are dominated

Description

Returns which points from a set are dominated by another point in the set.

Usage

```
is_dominated(yamat)
```

Arguments

yamat (matrix())
A numeric matrix. Each column (!) contains one point.

Value

logical() with TRUE if a point (column of ymat) is dominated.

local_search	<i>Local Search</i>
--------------	---------------------

Description

Runs a local search on the objective function. Somewhat similar to what is used in **SMAC** for acquisition function optimization of mixed type search spaces with hierarchical dependencies.

The function always minimizes. If the objective is to be maximized, we handle it by multiplying with "obj_mult" (which will be -1).

'Currently, automatically applying the search space transformations is not supported, if you need this, do this yourself in the objective function or use `OptimInstanceBatchLocalSearch`.

Usage

```
local_search(
  objective,
  search_space,
  control = local_search_control(),
  init_points = NULL
)
```

Arguments

objective	(function(xdt)) Objective to optimize. The first arg (name 'xdt' is not enforced) will be a <code>data.table</code> with (scalar) columns corresponding exactly the search space, in the same order. The function should must return numeric vector of exactly the same length as the number of rows in the dt, containing the objective values.
search_space	(paradox::ParamSet) Search space for decision variables. Must be non-empty, can only contain <code>p_int</code> , <code>p_dbl</code> , <code>p_fct</code> , <code>p_lgl</code> , all must be bounded.
control	(local_search_control) Control parameters for the local search, generated by local_search_control() .
init_points	(<code>data.table</code>) Initial points to start the local search from, same format as described for the argument of 'objective'. Must have as many rows as 'control\$n_searches'. If NULL, we generate "n_searches" random points.

Details

We run "n_searches" in parallel. Each search runs "n_steps" iterations. For each search in every iteration we generate "n_neighs" neighbors. A neighbor is the current point, but with exactly one parameter mutated.

Mutation works like this: For num params: we scale to 0,1, add Gaussian noise with sd "mut_sd", and scale back. We then clip to the lower and upper bounds. For int params: We do the same as

for numeric parameters, but round at the end. For factor params: We sample a new level from the unused levels of the parameter. For logical params: We flip the bit.

Hierarchical dependencies are handled like this: Only active params can be mutated. After a mutation has happened, we check the conditions of the search space in topological order. If a condition is not met, we set the param to NA (making it inactive); if all conditions are met for a param, but it currently has is NA, we set it a random valid value.

After the neighbors are generated, we evaluate them. We go to the best neighbor, or stay at the current point if the best neighbor is worse.

There is a restart mechanism to avoid local minima. For each search, we keep track of the number of no-improvement steps. If this number exceeds "stagnate_max", we restart the search with a random point.

Value

(named list). List with elements:

- 'x': (list)
The best point found, length and element names and their order correspond exactly to the search space.
- 'y': (numeric(1))
The objective value of the best point.

local_search_control *Local Search Control*

Description

Control parameters for local search optimizer, see [local_search\(\)](#) for details.

Usage

```
local_search_control(
  minimize = TRUE,
  n_searches = 10L,
  n_steps = 5L,
  n_neighs = 10L,
  mut_sd = 0.1,
  stagnate_max = 10L
)
```

Arguments

minimize	(logical(1)) Whether to minimize the objective.
n_searches	(integer(1)) Number of local searches.

n_steps	(integer(1)) Number of steps per local search.
n_neighs	(integer(1)) Number of neighbors per local search.
mut_sd	(numeric(1)) Standard deviation of the mutation.
stagnate_max	(integer(1)) Maximum number of no-improvement steps for a local search before it is randomly restarted.

Value

(local_search_control)
List with control params as S3 object.

mlr_optimizers	<i>Dictionary of Optimizer</i>
----------------	--------------------------------

Description

A simple [mlr3misc::Dictionary](#) storing objects of class [Optimizer](#). Each optimizer has an associated help page, see `mlr_optimizer_[id]`.

This dictionary can get populated with additional optimizer by add-on packages.

For a more convenient way to retrieve and construct optimizer, see [opt\(\)/opts\(\)](#).

Format

[R6::R6Class](#) object inheriting from [mlr3misc::Dictionary](#).

Methods

See [mlr3misc::Dictionary](#).

S3 methods

- `as.data.table(dict, ..., objects = FALSE)`
`mlr3misc::Dictionary -> data.table::data.table()`
Returns a `data.table::data.table()` with fields "key", "label", "param_classes", "properties" and "packages" as columns. If `objects` is set to `TRUE`, the constructed objects are returned in the list column named `object`.

See Also

Sugar functions: [opt\(\)](#), [opts\(\)](#)

Examples

```
as.data.table(mlr_optimizers)
mlr_optimizers$get("random_search")
opt("random_search")
```

```
mlr_optimizers_async_design_points
```

Asynchronous Optimization via Design Points

Description

OptimizerAsyncDesignPoints class that implements optimization w.r.t. fixed design points. We simply search over a set of points fully specified by the ser.

Dictionary

This [Optimizer](#) can be instantiated via the [dictionary mlr_optimizers](#) or with the associated sugar function `opt()`:

```
mlr_optimizers$get("async_design_points")
opt("async_design_points")
```

Parameters

design [data.table::data.table](#)
Design points to try in search, one per row.

Super classes

```
bbotk::Optimizer -> bbotk::OptimizerAsync -> OptimizerAsyncDesignPoints
```

Methods

Public methods:

- [OptimizerAsyncDesignPoints\\$new\(\)](#)
- [OptimizerAsyncDesignPoints\\$optimize\(\)](#)
- [OptimizerAsyncDesignPoints\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
OptimizerAsyncDesignPoints$new()
```

Method `optimize()`: Starts the asynchronous optimization.

Usage:

```
OptimizerAsyncDesignPoints$optimize(inst)
```

Arguments:

inst ([OptimInstance](#)).

Returns: [data.table::data.table](#).

Method clone(): The objects of this class are cloneable with this method.

Usage:

```
OptimizerAsyncDesignPoints$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

Examples

```
# example only runs if a Redis server is available
if (mlr3misc::require_namespaces(c("rush", "redux", "mirai"), quietly = TRUE) &&
    redux::redis_available()) {
  # define the objective function
  fun = function(xs) {
    list(y = - (xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
  }

  # set domain
  domain = ps(
    x1 = p_dbl(-10, 10),
    x2 = p_dbl(-5, 5)
  )

  # set codomain
  codomain = ps(
    y = p_dbl(tags = "maximize")
  )

  # create objective
  objective = ObjectiveRFun$new(
    fun = fun,
    domain = domain,
    codomain = codomain,
    properties = "deterministic"
  )

  # start workers
  rush::rush_plan(worker_type = "remote")
  mirai::daemons(1)

  # initialize instance
  instance = oi_async(
    objective = objective,
    terminator = trm("evals", n_evals = 20)
  )

  # load optimizer
  design = data.table::data.table(x1 = c(0, 1), x2 = c(0, 1))
  optimizer = opt("async_design_points", design = design)
```

```

# trigger optimization
optimizer$optimize(instance)

# all evaluated configurations
instance$archive

# best performing configuration
instance$archive$best()

# covert to data.table
as.data.table(instance$archive)
}

```

```
mlr_optimizers_async_grid_search
```

Asynchronous Optimization via Grid Search

Description

OptimizerAsyncGridSearch class that implements a grid search. The grid is constructed as a Cartesian product over discretized values per parameter, see `paradox::generate_design_grid()`. The points of the grid are evaluated in a random order.

Dictionary

This [Optimizer](#) can be instantiated via the [dictionary mlr_optimizers](#) or with the associated sugar function `opt()`:

```
mlr_optimizers$get("async_grid_search")
opt("async_grid_search")
```

Parameters

`batch_size` integer(1)
Maximum number of points to try in a batch.

Super classes

[bbotk::Optimizer](#) -> [bbotk::OptimizerAsync](#) -> [OptimizerAsyncGridSearch](#)

Methods

Public methods:

- [OptimizerAsyncGridSearch\\$new\(\)](#)
- [OptimizerAsyncGridSearch\\$optimize\(\)](#)
- [OptimizerAsyncGridSearch\\$clone\(\)](#)

Method `new()`: Creates a new instance of this R6 class.

Usage:

```
OptimizerAsyncGridSearch$new()
```

Method `optimize()`: Starts the asynchronous optimization.

Usage:

```
OptimizerAsyncGridSearch$optimize(inst)
```

Arguments:

`inst` ([OptimInstance](#)).

Returns: [data.table::data.table](#).

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
OptimizerAsyncGridSearch$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

Source

Bergstra J, Bengio Y (2012). “Random Search for Hyper-Parameter Optimization.” *Journal of Machine Learning Research*, **13**(10), 281–305. <https://jmlr.csail.mit.edu/papers/v13/bergstra12a.html>.

Examples

```
# example only runs if a Redis server is available
if (mlr3misc::require_namespaces(c("rush", "redux", "mirai"), quietly = TRUE) &&
    redux::redis_available()) {
  # define the objective function
  fun = function(xs) {
    list(y = - (xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
  }

  # set domain
  domain = ps(
    x1 = p_dbl(-10, 10),
    x2 = p_dbl(-5, 5)
  )

  # set codomain
  codomain = ps(
    y = p_dbl(tags = "maximize")
  )

  # create objective
  objective = ObjectiveRFun$new(
    fun = fun,
    domain = domain,
```

```

    codomain = codomain,
    properties = "deterministic"
  )

  # start workers
  rush::rush_plan(worker_type = "remote")
  mirai::daemons(1)

  # initialize instance
  instance = oi_async(
    objective = objective,
    terminator = trm("evals", n_evals = 20)
  )

  # load optimizer
  optimizer = opt("async_grid_search", resolution = 10)

  # trigger optimization
  optimizer$optimize(instance)

  # all evaluated configurations
  instance$archive

  # best performing configuration
  instance$archive$best()

  # covert to data.table
  as.data.table(instance$archive)
}

```

mlr_optimizers_async_random_search

Asynchronous Optimization via Random Search

Description

OptimizerAsyncRandomSearch class that implements a simple Random Search.

Dictionary

This [Optimizer](#) can be instantiated via the [dictionary mlr_optimizers](#) or with the associated sugar function `opt()`:

```

mlr_optimizers$get("async_random_search")
opt("async_random_search")

```

Super classes

[bbotk::Optimizer](#) -> [bbotk::OptimizerAsync](#) -> OptimizerAsyncRandomSearch

Methods

Public methods:

- [OptimizerAsyncRandomSearch\\$new\(\)](#)
- [OptimizerAsyncRandomSearch\\$clone\(\)](#)

Method `new()`: Creates a new instance of this R6 class.

Usage:

```
OptimizerAsyncRandomSearch$new()
```

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
OptimizerAsyncRandomSearch$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

Source

Bergstra J, Bengio Y (2012). “Random Search for Hyper-Parameter Optimization.” *Journal of Machine Learning Research*, **13**(10), 281–305. <https://jmlr.csail.mit.edu/papers/v13/bergstra12a.html>.

Examples

```
# example only runs if a Redis server is available
if (mlr3misc::require_namespaces(c("rush", "redux", "mirai"), quietly = TRUE) &&
    redux::redis_available()) {
  # define the objective function
  fun = function(xs) {
    list(y = - (xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
  }

  # set domain
  domain = ps(
    x1 = p_dbl(-10, 10),
    x2 = p_dbl(-5, 5)
  )

  # set codomain
  codomain = ps(
    y = p_dbl(tags = "maximize")
  )

  # create objective
  objective = ObjectiveRFun$new(
    fun = fun,
    domain = domain,
    codomain = codomain,
    properties = "deterministic"
  )
}
```

```
# start workers
rush::rush_plan(worker_type = "remote")
mirai::daemons(1)

# initialize instance
instance = oi_async(
  objective = objective,
  terminator = trm("evals", n_evals = 20)
)

# load optimizer
optimizer = opt("async_random_search")

# trigger optimization
optimizer$optimize(instance)

# all evaluated configurations
instance$archive

# best performing configuration
instance$archive$best()

# covert to data.table
as.data.table(instance$archive)
}
```

mlr_optimizers_chain *Run Optimizers Sequentially*

Description

`OptimizerBatchChain` allows to run multiple `OptimizerBatch` sequentially.

For each `OptimizerBatch` an (optional) additional `Terminator` can be specified during construction. While the original `Terminator` of the `OptimInstanceBatch` guards the optimization process as a whole, the additional `Terminators` guard each individual `OptimizerBatch`.

The optimization process works as follows: The first `OptimizerBatch` is run on the `OptimInstanceBatch` relying on a `TerminatorCombo` of the original `Terminator` of the `OptimInstanceBatch` and the (optional) additional `Terminator` as passed during construction. Once this `TerminatorCombo` indicates termination (usually via the additional `Terminator`), the second `OptimizerBatch` is run. This continues for all optimizers unless the original `Terminator` of the `OptimInstanceBatch` indicates termination.

`OptimizerBatchChain` can also be used for random restarts of the same `Optimizer` (if applicable) by setting the `Terminator` of the `OptimInstanceBatch` to `TerminatorNone` and setting identical additional `Terminators` during construction.

Dictionary

This [Optimizer](#) can be instantiated via the [dictionary mlr_optimizers](#) or with the associated sugar function `opt()`:

```
mlr_optimizers$get("chain")
opt("chain")
```

Parameters

Parameters are inherited from the individual [OptimizerBatch](#) and collected as a [paradox::ParamSetCollection](#) (with `set_ids` potentially postfixed via `_1`, `_2`, ..., if the same [OptimizerBatch](#) are used multiple times).

Progress Bars

`$optimize()` supports progress bars via the package [progressr](#) combined with a [Terminator](#). Simply wrap the function in `progressr::with_progress()` to enable them. We recommend to use package [progress](#) as backend; enable with `progressr::handlers("progress")`.

Super classes

```
bbotk::Optimizer -> bbotk::OptimizerBatch -> OptimizerBatchChain
```

Methods

Public methods:

- [OptimizerBatchChain\\$new\(\)](#)
- [OptimizerBatchChain\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
OptimizerBatchChain$new(
  optimizers,
  terminators = rep(list(NULL), length(optimizers))
)
```

Arguments:

`optimizers` (list of [Optimizers](#)).
`terminators` (list of [Terminators](#) | `NULL`).

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
OptimizerBatchChain$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

Examples

```
# example only runs if GenSA is available
if (mlr3misc::require_namespaces("GenSA", quietly = TRUE)) {
  # define the objective function
  fun = function(xs) {
    list(y = - (xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
  }

  # set domain
  domain = ps(
    x1 = p_dbl(-10, 10),
    x2 = p_dbl(-5, 5)
  )

  # set codomain
  codomain = ps(
    y = p_dbl(tags = "maximize")
  )

  # create objective
  objective = ObjectiveRFun$new(
    fun = fun,
    domain = domain,
    codomain = codomain,
    properties = "deterministic"
  )

  # initialize instance
  instance = oi(
    objective = objective,
    terminator = trm("evals", n_evals = 10)
  )

  # load optimizer
  optimizer = opt("chain",
    optimizers = list(opt("random_search"), opt("grid_search")),
    terminators = list(trm("evals", n_evals = 5), trm("evals", n_evals = 5))
  )

  # trigger optimization
  optimizer$optimize(instance)

  # all evaluated configurations
  instance$archive

  # best performing configuration
  instance$result
}
```

Description

OptimizerBatchCmaes class that implements CMA-ES. Calls `adagio::pureCMAES()` from package **adagio**. The algorithm is typically applied to search space dimensions between three and fifty. Lower search space dimensions might crash.

Dictionary

This [Optimizer](#) can be instantiated via the [dictionary mlr_optimizers](#) or with the associated sugar function `opt()`:

```
mlr_optimizers$get("cmaes")
opt("cmaes")
```

Parameters

`sigma` numeric(1)

`start_values` character(1)

Create "random" start values or based on "center" of search space? In the latter case, it is the center of the parameters before a trafo is applied. If set to "custom", the start values can be passed via the `start` parameter.

`start` numeric()

Custom start values. Only applicable if `start_values` parameter is set to "custom".

For the meaning of the control parameters, see `adagio::pureCMAES()`. Note that we have removed all control parameters which refer to the termination of the algorithm and where our terminators allow to obtain the same behavior.

Progress Bars

`$optimize()` supports progress bars via the package **progressr** combined with a [Terminator](#). Simply wrap the function in `progressr::with_progress()` to enable them. We recommend to use package **progress** as backend; enable with `progressr::handlers("progress")`.

Super classes

```
bbotk::Optimizer -> bbotk::OptimizerBatch -> OptimizerBatchCmaes
```

Methods

Public methods:

- `OptimizerBatchCmaes$new()`
- `OptimizerBatchCmaes$clone()`

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
OptimizerBatchCmaes$new()
```

Method `clone()`: The objects of this class are cloneable with this method.

Usage:`OptimizerBatchCmaes$clone(deep = FALSE)`*Arguments:*`deep` Whether to make a deep clone.**Examples**

```
# example only runs if GenSA is available
if (mlr3misc::require_namespaces("adagio", quietly = TRUE)) {
# define the objective function
fun = function(xs) {
  list(y = - (xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 - (xs[[3]] + 4)^2 + 10)
}

# set domain
domain = ps(
  x1 = p_dbl(-10, 10),
  x2 = p_dbl(-5, 5),
  x3 = p_dbl(-5, 5)
)

# set codomain
codomain = ps(
  y = p_dbl(tags = "maximize")
)

# create objective
objective = ObjectiveRFun$new(
  fun = fun,
  domain = domain,
  codomain = codomain,
  properties = "deterministic"
)

# initialize instance
instance = oi(
  objective = objective,
  terminator = trm("evals", n_evals = 20)
)

# load optimizer
optimizer = opt("cmaes")

# trigger optimization
optimizer$optimize(instance)

# all evaluated configurations
instance$archive

# best performing configuration
instance$result
}
```

mlr_optimizers_design_points

Optimization via Design Points

Description

`OptimizerBatchDesignPoints` class that implements optimization w.r.t. fixed design points. We simply search over a set of points fully specified by the user. The points in the design are evaluated in order as given.

In order to support general termination criteria and parallelization, we evaluate points in a batch-fashion of size `batch_size`. Larger batches mean we can parallelize more, smaller batches imply a more fine-grained checking of termination criteria.

Dictionary

This [Optimizer](#) can be instantiated via the [dictionary mlr_optimizers](#) or with the associated sugar function `opt()`:

```
mlr_optimizers$get("design_points")
opt("design_points")
```

Parameters

`batch_size` `integer(1)`
Maximum number of configurations to try in a batch.

`design` `data.table::data.table`
Design points to try in search, one per row.

Progress Bars

`$optimize()` supports progress bars via the package **progressr** combined with a [Terminator](#). Simply wrap the function in `progressr::with_progress()` to enable them. We recommend to use package **progress** as backend; enable with `progressr::handlers("progress")`.

Super classes

```
bbotk::Optimizer -> bbotk::OptimizerBatch -> OptimizerBatchDesignPoints
```

Methods

Public methods:

- `OptimizerBatchDesignPoints$new()`
- `OptimizerBatchDesignPoints$clone()`

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
OptimizerBatchDesignPoints$new()
```

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
OptimizerBatchDesignPoints$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

Examples

```
# define the objective function
fun = function(xs) {
  list(y = - (xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
}

# set domain
domain = ps(
  x1 = p_dbl(-10, 10),
  x2 = p_dbl(-5, 5)
)

# set codomain
codomain = ps(
  y = p_dbl(tags = "maximize")
)

# create objective
objective = ObjectiveRFun$new(
  fun = fun,
  domain = domain,
  codomain = codomain,
  properties = "deterministic"
)

# initialize instance
instance = oi(
  objective = objective,
  terminator = trm("evals", n_evals = 20)
)

# load optimizer
design = data.table::data.table(x1 = c(0, 1), x2 = c(0, 1))
optimizer = opt("design_points", design = design)

# trigger optimization
optimizer$optimize(instance)

# all evaluated configurations
instance$archive

# best performing configuration
instance$result
```

mlr_optimizers_focus_search

Optimization via Focus Search

Description

OptimizerBatchFocusSearch class that implements a Focus Search.

Focus Search starts with evaluating `n_points` drawn uniformly at random. For 1 to `maxit` batches, `n_points` are then drawn uniformly at random and if the best value of a batch outperforms the previous best value over all batches evaluated so far, the search space is shrunked around this new best point prior to the next batch being sampled and evaluated.

For details on the shrinking, see [shrink_ps](#).

Depending on the [Terminator](#) this procedure simply restarts after `maxit` is reached.

Dictionary

This [Optimizer](#) can be instantiated via the [dictionary mlr_optimizers](#) or with the associated sugar function `opt()`:

```
mlr_optimizers$get("focus_search")
opt("focus_search")
```

Parameters

`n_points` integer(1)

Number of points to evaluate in each random search batch.

`maxit` integer(1)

Number of random search batches to run.

Progress Bars

`$optimize()` supports progress bars via the package [progressr](#) combined with a [Terminator](#). Simply wrap the function in `progressr::with_progress()` to enable them. We recommend to use package [progress](#) as backend; enable with `progressr::handlers("progress")`.

Super classes

[bbotk::Optimizer](#) -> [bbotk::OptimizerBatch](#) -> [OptimizerBatchFocusSearch](#)

Methods

Public methods:

- [OptimizerBatchFocusSearch\\$new\(\)](#)
- [OptimizerBatchFocusSearch\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

OptimizerBatchFocusSearch\$new()

Method clone(): The objects of this class are cloneable with this method.

Usage:

OptimizerBatchFocusSearch\$clone(deep = FALSE)

Arguments:

deep Whether to make a deep clone.

Examples

```
# define the objective function
fun = function(xs) {
  list(y = - (xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
}

# set domain
domain = ps(
  x1 = p_dbl(-10, 10),
  x2 = p_dbl(-5, 5)
)

# set codomain
codomain = ps(
  y = p_dbl(tags = "maximize")
)

# create objective
objective = ObjectiveRFun$new(
  fun = fun,
  domain = domain,
  codomain = codomain,
  properties = "deterministic"
)

# initialize instance
instance = oi(
  objective = objective,
  terminator = trm("evals", n_evals = 20)
)

# load optimizer
optimizer = opt("focus_search", n_points = 10, maxit = 10)

# trigger optimization
optimizer$optimize(instance)

# all evaluated configurations
instance$archive

# best performing configuration
instance$result
```

mlr_optimizers_gensa *Generalized Simulated Annealing*

Description

OptimizerBatchGenSA class that implements generalized simulated annealing. Calls [GenSA::GenSA\(\)](#) from package **GenSA**.

Dictionary

This [Optimizer](#) can be instantiated via the [dictionary mlr_optimizers](#) or with the associated sugar function [opt\(\)](#):

```
mlr_optimizers$get("gensa")
opt("gensa")
```

Parameters

`par` numeric()
Initial parameter values. Default is NULL, in which case, default values will be generated automatically.

`start_values` character(1)
Create "random" start values or based on "center" of search space? In the latter case, it is the center of the parameters before a trafo is applied. By default, `nloptr` will generate start values automatically. Custom start values can be passed via the `par` parameter.

For the meaning of the control parameters, see [GenSA::GenSA\(\)](#). Note that [GenSA::GenSA\(\)](#) uses `smooth = TRUE` as a default. In the case of using this optimizer for Hyperparameter Optimization you may want to set `smooth = FALSE`.

Internal Termination Parameters

The algorithm can be terminated with all [Terminators](#). Additionally, the following internal termination parameters can be used:

`maxit` integer(1)
Maximum number of iterations. Original default is 5000. Overwritten with `.Machine$integer.max`.

`threshold.stop` numeric(1)
Threshold stop. Deactivated with NULL. Default is NULL.

`nb.stop.improvement` integer(1)
Number of stop improvement. Deactivated with -1L. Default is -1L.

`max.call` integer(1)
Maximum number of calls. Original default is 1e7. Overwritten with `.Machine$integer.max`.

`max.time` integer(1)
Maximum time. Deactivate with NULL. Default is NULL.

Progress Bars

`$optimize()` supports progress bars via the package **progressr** combined with a **Terminator**. Simply wrap the function in `progressr::with_progress()` to enable them. We recommend to use package **progress** as backend; enable with `progressr::handlers("progress")`.

Super classes

`bbotk::Optimizer` -> `bbotk::OptimizerBatch` -> `OptimizerBatchGenSA`

Methods

Public methods:

- `OptimizerBatchGenSA$new()`
- `OptimizerBatchGenSA$clone()`

Method `new()`: Creates a new instance of this **R6** class.

Usage:

```
OptimizerBatchGenSA$new()
```

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
OptimizerBatchGenSA$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

Source

Tsallis C, Stariolo DA (1996). “Generalized simulated annealing.” *Physica A: Statistical Mechanics and its Applications*, **233**(1-2), 395–406. doi:10.1016/s03784371(96)002713.

Xiang Y, Gubian S, Suomela B, Hoeng J (2013). “Generalized Simulated Annealing for Global Optimization: The GenSA Package.” *The R Journal*, **5**(1), 13. doi:10.32614/rj2013002.

Examples

```
# example only runs if GenSA is available
if (mlr3misc::require_namespaces("GenSA", quietly = TRUE)) {
  # define the objective function
  fun = function(xs) {
    list(y = - (xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
  }

  # set domain
  domain = ps(
    x1 = p_dbl(-10, 10),
    x2 = p_dbl(-5, 5)
  )

  # set codomain
```

```

codomain = ps(
  y = p_dbl(tags = "maximize")
)

# create objective
objective = ObjectiveRFun$new(
  fun = fun,
  domain = domain,
  codomain = codomain,
  properties = "deterministic"
)

# initialize instance
instance = oi(
  objective = objective,
  terminator = trm("evals", n_evals = 20)
)

# load optimizer
optimizer = opt("gensa")

# trigger optimization
optimizer$optimize(instance)

# all evaluated configurations
instance$archive

# best performing configuration
instance$result
}

```

mlr_optimizers_grid_search

Optimization via Grid Search

Description

OptimizerBatchGridSearch class that implements grid search. The grid is constructed as a Cartesian product over discretized values per parameter, see `paradox::generate_design_grid()`. The points of the grid are evaluated in a random order.

In order to support general termination criteria and parallelization, we evaluate points in a batch-fashion of size `batch_size`. Larger batches mean we can parallelize more, smaller batches imply a more fine-grained checking of termination criteria.

Dictionary

This [Optimizer](#) can be instantiated via the [dictionary mlr_optimizers](#) or with the associated sugar function `opt()`:

```

mlr_optimizers$get("grid_search")
opt("grid_search")

```

Parameters

resolution integer(1)
Resolution of the grid, see [paradox::generate_design_grid\(\)](#).

param_resolutions named integer()
Resolution per parameter, named by parameter ID, see [paradox::generate_design_grid\(\)](#).

batch_size integer(1)
Maximum number of points to try in a batch.

Progress Bars

\$optimize() supports progress bars via the package **progressr** combined with a [Terminator](#). Simply wrap the function in `progressr::with_progress()` to enable them. We recommend to use package **progress** as backend; enable with `progressr::handlers("progress")`.

Super classes

[bbotk::Optimizer](#) -> [bbotk::OptimizerBatch](#) -> [OptimizerBatchGridSearch](#)

Methods**Public methods:**

- [OptimizerBatchGridSearch\\$new\(\)](#)
- [OptimizerBatchGridSearch\\$clone\(\)](#)

Method `new()`: Creates a new instance of this R6 class.

Usage:

```
OptimizerBatchGridSearch$new()
```

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
OptimizerBatchGridSearch$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

Examples

```
# define the objective function
fun = function(xs) {
  list(y = - (xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
}

# set domain
domain = ps(
  x1 = p_dbl(-10, 10),
  x2 = p_dbl(-5, 5)
)

# set codomain
```

```

codomain = ps(
  y = p_dbl(tags = "maximize")
)

# create objective
objective = ObjectiveRFun$new(
  fun = fun,
  domain = domain,
  codomain = codomain,
  properties = "deterministic"
)

# initialize instance
instance = oi(
  objective = objective,
  terminator = trm("evals", n_evals = 20)
)

# load optimizer
optimizer = opt("grid_search", resolution = 10)

# trigger optimization
optimizer$optimize(instance)

# all evaluated configurations
instance$archive

# best performing configuration
instance$result

```

mlr_optimizers_irace *Iterated Racing*

Description

OptimizerBatchIrace class that implements iterated racing. Calls `irace::irace()` from package **irace**.

Parameters

`instances` `list()`

A list of instances where the configurations executed on.

`targetRunnerParallel` `function()`

A function that executes the objective function with a specific parameter configuration and instance. A default function is provided, see section "Target Runner and Instances".

For the meaning of all other parameters, see `irace::defaultScenario()`.

Internal Termination Parameters

The algorithm can be terminated with [TerminatorEvals](#). Other [Terminators](#) do not work with `OptimizerBatchIrace`. Additionally, the following internal termination parameters can be used:

`maxExperiments` `integer(1)`

Maximum number of runs (invocations of `targetRunner`) that will be performed. It determines the maximum budget of experiments for the tuning. Default is 0.

`minExperiments` `integer(1)`

Minimum number of runs (invocations of `targetRunner`) that will be performed. It determines the minimum budget of experiments for the tuning. The actual budget depends on the number of parameters and `minSurvival`. Default is NA.

`maxTime` `integer(1)`

Maximum total execution time for the executions of `targetRunner`. `targetRunner` must return two values: cost and time. This value and the one returned by `targetRunner` must use the same units (seconds, minutes, iterations, evaluations, ...). Default is 0.

`budgetEstimation` `numeric(1)`

Fraction (smaller than 1) of the budget used to estimate the mean computation time of a configuration. Only used when `maxTime > 0`. Default is 0.05.

`minMeasurableTime` `numeric(1)`

Minimum time unit that is still (significantly) measurable. Default is 0.01.

Initial parameter values

- `digits`:
 - Adjusted default: 15.
 - This represents double parameters with a higher precision and avoids rounding errors.

Target Runner and Instances

The `irace` package uses a `targetRunner` script or R function to evaluate a configuration on a particular instance. Usually it is not necessary to specify a `targetRunner` function when using `OptimizerBatchIrace`. A default function is used that forwards several configurations and instances to the user defined objective function. As usually, the user defined function has a `xs`, `xss` or `xdt` parameter depending on the used [Objective](#) class. For `irace`, the function needs an additional `instances` parameter.

```
fun = function(xs, instances) {
  # function to evaluate configuration in `xs` on instance `instances`
}
```

Archive

The [Archive](#) holds the following additional columns:

- `"race"` (`integer(1)`)
Race iteration.

- "step" (integer(1))
Step number of race.
- "instance" (integer(1))
Identifies instances across races and steps.
- "configuration" (integer(1))
Identifies configurations across races and steps.

Result

The optimization result (`instance$result`) is the best performing elite of the final race. The reported performance is the average performance estimated on all used instances.

Dictionary

This [Optimizer](#) can be instantiated via the [dictionary](#) `mlr_optimizers` or with the associated sugar function `opt()`:

```
mlr_optimizers$get("irace")
opt("irace")
```

Progress Bars

`$optimize()` supports progress bars via the package **progressr** combined with a [Terminator](#). Simply wrap the function in `progressr::with_progress()` to enable them. We recommend to use package **progress** as backend; enable with `progressr::handlers("progress")`.

Super classes

```
bbotk::Optimizer -> bbotk::OptimizerBatch -> OptimizerBatchIrace
```

Methods

Public methods:

- [OptimizerBatchIrace\\$new\(\)](#)
- [OptimizerBatchIrace\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
OptimizerBatchIrace$new()
```

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
OptimizerBatchIrace$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

Source

Lopez-Ibanez M, Dubois-Lacoste J, Caceres LP, Birattari M, Stuetzle T (2016). “The irace package: Iterated racing for automatic algorithm configuration.” *Operations Research Perspectives*, **3**, 43–58. [doi:10.1016/j.orp.2016.09.002](https://doi.org/10.1016/j.orp.2016.09.002).

Examples

```
# example only runs if irace is available
if (mlr3misc::require_namespaces("irace", quietly = TRUE)) {
  # runtime of the example is too long

  library(data.table)

  # set domain
  domain = ps(
    x1 = p_dbl(-5, 10),
    x2 = p_dbl(0, 15)
  )

  # set codomain
  codomain = ps(y = p_dbl(tags = "minimize"))

  # branin function with noise
  # the noise generates different instances of the branin function
  # the noise values are passed via the `instances` parameter
  fun = function(xdt, instances) {
    ys = branin(xdt[["x1"]], xdt[["x2"]], noise = as.numeric(instances))
    data.table(y = ys)
  }

  # define objective with instances as a constant
  objective = ObjectiveRFunction$new(
    fun = fun,
    domain = domain,
    codomain = codomain,
    constants = ps(instances = p_utry()))

  instance = oi(
    objective = objective,
    terminator = trm("evals", n_evals = 96))

  # create instances of branin function
  instances = rnorm(10, mean = 0, sd = 0.1)

  # load optimizer and set branin instances
  optimizer = opt("irace", instances = instances)

  # trigger optimization
  optimizer$optimize(instance)

  # all evaluated configurations
  instance$archive
}
```

```
# best performing configuration
instance$result

}
```

```
mlr_optimizers_local_search
      Local Search
```

Description

Implements a simple Local Search, see [local_search\(\)](#) for details. Currently, setting initial points is not supported.

Dictionary

This [Optimizer](#) can be instantiated via the [dictionary mlr_optimizers](#) or with the associated sugar function [opt\(\)](#):

```
mlr_optimizers$get("local_search")
opt("local_search")
```

Parameters

The same as for [local_search_control\(\)](#), with the same defaults (except for minimize).

Progress Bars

`$optimize()` supports progress bars via the package **progressr** combined with a [Terminator](#). Simply wrap the function in `progressr::with_progress()` to enable them. We recommend to use package **progress** as backend; enable with `progressr::handlers("progress")`.

Super classes

```
bbotk::Optimizer -> bbotk::OptimizerBatch -> OptimizerBatchLocalSearch
```

Methods

Public methods:

- [OptimizerBatchLocalSearch\\$new\(\)](#)
- [OptimizerBatchLocalSearch\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
OptimizerBatchLocalSearch$new()
```

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
OptimizerBatchLocalSearch$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

Examples

```
# define the objective function
fun = function(xs) {
  list(y = - (xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
}

# set domain
domain = ps(
  x1 = p_dbl(-10, 10),
  x2 = p_dbl(-5, 5)
)

# set codomain
codomain = ps(
  y = p_dbl(tags = "maximize")
)

# create objective
objective = ObjectiveRFun$new(
  fun = fun,
  domain = domain,
  codomain = codomain,
  properties = "deterministic"
)

# initialize instance
instance = oi(
  objective = objective,
  terminator = trm("evals", n_evals = 20)
)

# load optimizer
optimizer = opt("local_search")

# trigger optimization
optimizer$optimize(instance)

# all evaluated configurations
instance$archive

# best performing configuration
instance$result
```

mlr_optimizers_nloptr *Non-linear Optimization*

Description

OptimizerBatchNloptr class that implements non-linear optimization. Calls `nloptr::nloptr()` from package **nloptr**.

Parameters

`algorithm` character(1)

Algorithm to use. See `nloptr::nloptr.print.options()` for available algorithms.

`x0` numeric()

Initial parameter values. Use `start_values` parameter to create "random" or "center" start values.

`start_values` character(1)

Create "random" start values or based on "center" of search space? In the latter case, it is the center of the parameters before a trafo is applied. Custom start values can be passed via the `x0` parameter.

`approximate_eval_grad_f` logical(1)

Should gradients be numerically approximated via finite differences (`nloptr::nl.grad`). Only required for certain algorithms. Note that function evaluations required for the numerical gradient approximation will be logged as usual and are not treated differently than regular function evaluations by, e.g., **Terminators**.

For the meaning of other control parameters, see `nloptr::nloptr()` and `nloptr::nloptr.print.options()`.

Internal Termination Parameters

The algorithm can be terminated with all **Terminators**. Additionally, the following internal termination parameters can be used:

`stopval` numeric(1)

Stop value. Deactivate with `-Inf`. Default is `-Inf`.

`maxtime` integer(1)

Maximum time. Deactivate with `-1L`. Default is `-1L`.

`maxeval` integer(1)

Maximum number of evaluations. Deactivate with `-1L`. Default is `-1L`.

`xtol_rel` numeric(1)

Relative tolerance. Original default is 10^{-4} . Deactivate with `-1`. Overwritten with `-1`.

`xtol_abs` numeric(1)

Absolute tolerance. Deactivate with `-1`. Default is `-1`.

`ftol_rel` numeric(1)

Relative tolerance. Deactivate with `-1`. Default is `-1`.

`ftol_abs` numeric(1)

Absolute tolerance. Deactivate with `-1`. Default is `-1`.

Progress Bars

`$optimize()` supports progress bars via the package **progressr** combined with a **Terminator**. Simply wrap the function in `progressr::with_progress()` to enable them. We recommend to use package **progress** as backend; enable with `progressr::handlers("progress")`.

Super classes

`bbotk::Optimizer` -> `bbotk::OptimizerBatch` -> `OptimizerBatchNloptr`

Methods

Public methods:

- `OptimizerBatchNloptr$new()`
- `OptimizerBatchNloptr$clone()`

Method `new()`: Creates a new instance of this R6 class.

Usage:

```
OptimizerBatchNloptr$new()
```

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
OptimizerBatchNloptr$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

Source

Johnson, G S (2020). "The NLOpt nonlinear-optimization package." <https://github.com/stevengj/nlopt>.

Examples

```
# example only runs if nloptr is available
if (mlr3misc::require_namespaces("nloptr", quietly = TRUE)) {
  # define the objective function
  fun = function(xs) {
    list(y = - (xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
  }

  # set domain
  domain = ps(
    x1 = p_dbl(-10, 10),
    x2 = p_dbl(-5, 5)
  )

  # set codomain
  codomain = ps(
    y = p_dbl(tags = "maximize")
  )
}
```

```

# create objective
objective = ObjectiveRfun$new(
  fun = fun,
  domain = domain,
  codomain = codomain,
  properties = "deterministic"
)

# initialize instance
instance = oi(
  objective = objective,
  terminator = trm("evals", n_evals = 20)
)

# load optimizer
optimizer = opt("nloptr", algorithm = "NLOPT_LN_BOBYQA")

# trigger optimization
optimizer$optimize(instance)

# all evaluated configurations
instance$archive

# best performing configuration
instance$result
}

```

mlr_optimizers_random_search

Optimization via Random Search

Description

OptimizerBatchRandomSearch class that implements a simple Random Search.

In order to support general termination criteria and parallelization, we evaluate points in a batch-fashion of size `batch_size`. Larger batches mean we can parallelize more, smaller batches imply a more fine-grained checking of termination criteria.

Dictionary

This [Optimizer](#) can be instantiated via the [dictionary mlr_optimizers](#) or with the associated sugar function `opt()`:

```

mlr_optimizers$get("random_search")
opt("random_search")

```

Parameters

`batch_size` integer(1)
Maximum number of points to try in a batch.

Progress Bars

`$optimize()` supports progress bars via the package **progressr** combined with a **Terminator**. Simply wrap the function in `progressr::with_progress()` to enable them. We recommend to use package **progress** as backend; enable with `progressr::handlers("progress")`.

Super classes

`bbotk::Optimizer` -> `bbotk::OptimizerBatch` -> `OptimizerBatchRandomSearch`

Methods**Public methods:**

- `OptimizerBatchRandomSearch$new()`
- `OptimizerBatchRandomSearch$clone()`

Method `new()`: Creates a new instance of this R6 class.

Usage:

```
OptimizerBatchRandomSearch$new()
```

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
OptimizerBatchRandomSearch$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

Source

Bergstra J, Bengio Y (2012). “Random Search for Hyper-Parameter Optimization.” *Journal of Machine Learning Research*, **13**(10), 281–305. <https://jmlr.csail.mit.edu/papers/v13/bergstra12a.html>.

Examples

```
# define the objective function
fun = function(xs) {
  list(y = - (xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
}

# set domain
domain = ps(
  x1 = p_dbl(-10, 10),
  x2 = p_dbl(-5, 5)
)
```

```

# set codomain
codomain = ps(
  y = p_dbl(tags = "maximize")
)

# create objective
objective = ObjectiveRfun$new(
  fun = fun,
  domain = domain,
  codomain = codomain,
  properties = "deterministic"
)

# initialize instance
instance = oi(
  objective = objective,
  terminator = trm("evals", n_evals = 20)
)

# load optimizer
optimizer = opt("random_search", batch_size = 10)

# trigger optimization
optimizer$optimize(instance)

# all evaluated configurations
instance$archive

# best performing configuration
instance$result

```

mlr_terminators

Dictionary of Terminators

Description

A simple [mlr3misc::Dictionary](#) storing objects of class [Terminator](#). Each terminator has an associated help page, see `mlr_terminators_[id]`.

This dictionary can get populated with additional terminators by add-on packages.

For a more convenient way to retrieve and construct terminator, see [trm\(\)/trms\(\)](#).

Format

[R6::R6Class](#) object inheriting from [mlr3misc::Dictionary](#).

Methods

See [mlr3misc::Dictionary](#).

S3 methods

- `as.data.table(dict, ..., objects = FALSE)`
`mlr3misc::Dictionary -> data.table::data.table()`
Returns a `data.table::data.table()` with fields "key", "label", "properties" and "unit" as columns. If `objects` is set to `TRUE`, the constructed objects are returned in the list column named `object`.

See Also

Sugar functions: `trm()`, `trms()`

Other Terminator: `Terminator`, `mlr_terminators_clock_time`, `mlr_terminators_combo`, `mlr_terminators_evals`, `mlr_terminators_none`, `mlr_terminators_perf_reached`, `mlr_terminators_run_time`, `mlr_terminators_stagnation_batch`, `mlr_terminators_stagnation_batch`, `mlr_terminators_stagnation_hypervolume`

Examples

```
as.data.table(mlr_terminators)
mlr_terminators$get("evals")
trm("evals", n_evals = 10)
```

```
mlr_terminators_clock_time
      Clock Time Terminator
```

Description

Class to terminate the optimization after a fixed time point has been reached (as reported by `Sys.time()`).

Dictionary

This `Terminator` can be instantiated via the dictionary `mlr_terminators` or with the associated sugar function `trm()`:

```
mlr_terminators$get("clock_time")
trm("clock_time")
```

Parameters

`stop_time` `POSIXct(1)`
Terminator stops after this point in time.

Super class

`bbotk::Terminator -> TerminatorClockTime`

Methods

Public methods:

- [TerminatorClockTime\\$new\(\)](#)
- [TerminatorClockTime\\$is_terminated\(\)](#)
- [TerminatorClockTime\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
TerminatorClockTime$new()
```

Method `is_terminated()`: Is TRUE iff the termination criterion is positive, and FALSE otherwise.

Usage:

```
TerminatorClockTime$is_terminated(archive)
```

Arguments:

archive ([Archive](#)).

Returns: logical(1).

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
TerminatorClockTime$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

See Also

Other Terminator: [Terminator](#), [mlr_terminators](#), [mlr_terminators_combo](#), [mlr_terminators_evals](#), [mlr_terminators_none](#), [mlr_terminators_perf_reached](#), [mlr_terminators_run_time](#), [mlr_terminators_stagnation_batch](#), [mlr_terminators_stagnation_batch](#), [mlr_terminators_stagnation_hypervolume](#)

Examples

```
stop_time = as.POSIXct("2030-01-01 00:00:00")
trm("clock_time", stop_time = stop_time)
```

mlr_terminators_combo *Combine Terminators*

Description

This class takes multiple [Terminators](#) and terminates as soon as one or all of the included terminators are positive.

Dictionary

This [Terminator](#) can be instantiated via the [dictionary mlr_terminators](#) or with the associated sugar function `trm()`:

```
mlr_terminators$get("combo")
trm("combo")
```

Parameters

any logical(1)
Terminate iff any included terminator is positive? (not all). Default is TRUE.

Super class

```
bbotk: Terminator -> TerminatorCombo
```

Public fields

terminators (list())
List of objects of class [Terminator](#).

Methods

Public methods:

- [TerminatorCombo\\$new\(\)](#)
- [TerminatorCombo\\$is_terminated\(\)](#)
- [TerminatorCombo\\$print\(\)](#)
- [TerminatorCombo\\$remaining_time\(\)](#)
- [TerminatorCombo\\$status_long\(\)](#)
- [TerminatorCombo\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
TerminatorCombo$new(terminators = list(TerminatorNone$new()))
```

Arguments:

terminators (list())
List of objects of class [Terminator](#).

Method `is_terminated()`: Is TRUE iff the termination criterion is positive, and FALSE otherwise.

Usage:

```
TerminatorCombo$is_terminated(archive)
```

Arguments:

archive ([Archive](#)).

Returns: `logical(1)`.

Method `print()`: Printer.

Usage:

```
TerminatorCombo$print(...)
```

Arguments:

... (ignored).

Method `remaining_time()`: Returns the remaining runtime in seconds. If `any = TRUE`, the remaining runtime is determined by the time-based terminator with the shortest time remaining. If non-time-based terminators are used and `any = FALSE`, the the remaining runtime is always `Inf`.

Usage:

```
TerminatorCombo$remaining_time(archive)
```

Arguments:

archive ([Archive](#)).

Returns: `integer(1)`.

Method `status_long()`: Returns `max_steps` and `current_steps` for each terminator.

Usage:

```
TerminatorCombo$status_long(archive)
```

Arguments:

archive ([Archive](#)).

Returns: `data.table::data.table`.

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
TerminatorCombo$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

See Also

Other Terminator: [Terminator](#), [mlr_terminators](#), [mlr_terminators_clock_time](#), [mlr_terminators_evals](#), [mlr_terminators_none](#), [mlr_terminators_perf_reached](#), [mlr_terminators_run_time](#), [mlr_terminators_stagnation_batch](#), [mlr_terminators_stagnation_batch](#), [mlr_terminators_stagnation_hypervolume](#)

Examples

```
trm("combo",
  list(trm("clock_time", stop_time = Sys.time() + 60),
    trm("evals", n_evals = 10)), any = FALSE
)
```

mlr_terminators_evals *Terminator that stops after a number of evaluations*

Description

Class to terminate the optimization depending on the number of evaluations. An evaluation is defined by one resampling of a parameter value. The total number of evaluations B is defined as

$$B = n_evals + k * D$$

where D is the dimension of the search space.

Dictionary

This [Terminator](#) can be instantiated via the [dictionary mlr_terminators](#) or with the associated sugar function `trm()`:

```
mlr_terminators$get("evals")
trm("evals")
```

Parameters

`n_evals` integer(1)
See formula above. Default is 100.

`k` integer(1)
See formula above. Default is 0.

Super class

[bbotk::Terminator](#) -> TerminatorEvals

Methods**Public methods:**

- [TerminatorEvals\\$new\(\)](#)
- [TerminatorEvals\\$is_terminated\(\)](#)
- [TerminatorEvals\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
TerminatorEvals$new()
```

Method `is_terminated()`: Is TRUE iff the termination criterion is positive, and FALSE otherwise.

Usage:

```
TerminatorEvals$is_terminated(archive)
```

Arguments:

archive ([Archive](#)).

Returns: logical(1).

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
TerminatorEvals$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

See Also

Other Terminator: [Terminator](#), [mlr_terminators](#), [mlr_terminators_clock_time](#), [mlr_terminators_combo](#), [mlr_terminators_none](#), [mlr_terminators_perf_reached](#), [mlr_terminators_run_time](#), [mlr_terminators_stagnation](#), [mlr_terminators_stagnation_batch](#), [mlr_terminators_stagnation_hypervolume](#)

Examples

```
TerminatorEvals$new()

# 5 evaluations in total
trm("evals", n_evals = 5)

# 3 * [dimension of search space] evaluations in total
trm("evals", n_evals = 0, k = 3)

# (3 * [dimension of search space] + 1) evaluations in total
trm("evals", n_evals = 1, k = 3)
```

mlr_terminators_none *None Terminator*

Description

Mainly useful for optimization algorithms where the stopping is inherently controlled by the algorithm itself (e.g. [OptimizerBatchGridSearch](#)).

Dictionary

This [Terminator](#) can be instantiated via the dictionary [mlr_terminators](#) or with the associated sugar function [trm\(\)](#):

```
mlr_terminators$get("none")
trm("none")
```

Super class

```
bbotk::Terminator -> TerminatorNone
```

Methods

Public methods:

- [TerminatorNone\\$new\(\)](#)
- [TerminatorNone\\$is_terminated\(\)](#)
- [TerminatorNone\\$clone\(\)](#)

Method [new\(\)](#): Creates a new instance of this [R6](#) class.

Usage:

```
TerminatorNone$new()
```

Method [is_terminated\(\)](#): Is TRUE iff the termination criterion is positive, and FALSE otherwise.

Usage:

```
TerminatorNone$is_terminated(archive)
```

Arguments:

archive ([Archive](#)).

Returns: `logical(1)`.

Method [clone\(\)](#): The objects of this class are cloneable with this method.

Usage:

```
TerminatorNone$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

See Also

Other Terminator: [Terminator](#), [mlr_terminators](#), [mlr_terminators_clock_time](#), [mlr_terminators_combo](#), [mlr_terminators_evals](#), [mlr_terminators_perf_reached](#), [mlr_terminators_run_time](#), [mlr_terminators_stagnat](#), [mlr_terminators_stagnation_batch](#), [mlr_terminators_stagnation_hypervolume](#)

```
mlr_terminators_perf_reached
      Performance Level Terminator
```

Description

Class to terminate the optimization after a performance level has been hit.

Dictionary

This [Terminator](#) can be instantiated via the [dictionary mlr_terminators](#) or with the associated sugar function `trm()`:

```
mlr_terminators$get("perf_reached")
trm("perf_reached")
```

Parameters

`level` `numeric(1)`
 Performance level that needs to be reached. Default is 0. Terminates if the performance exceeds (respective measure has to be maximized) or falls below (respective measure has to be minimized) this value.

Super class

`bbotk::Terminator` -> `TerminatorPerfReached`

Methods

Public methods:

- `TerminatorPerfReached$new()`
- `TerminatorPerfReached$is_terminated()`
- `TerminatorPerfReached$clone()`

Method `new()`: Creates a new instance of this R6 class.

Usage:

```
TerminatorPerfReached$new()
```

Method `is_terminated()`: Is TRUE iff the termination criterion is positive, and FALSE otherwise.

Usage:

```
TerminatorPerfReached$is_terminated(archive)
```

Arguments:

`archive` ([Archive](#)).

Returns: `logical(1)`.

Method clone(): The objects of this class are cloneable with this method.

Usage:

```
TerminatorPerfReached$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

See Also

Other Terminator: [Terminator](#), [mlr_terminators](#), [mlr_terminators_clock_time](#), [mlr_terminators_combo](#), [mlr_terminators_evals](#), [mlr_terminators_none](#), [mlr_terminators_run_time](#), [mlr_terminators_stagnation](#), [mlr_terminators_stagnation_batch](#), [mlr_terminators_stagnation_hypervolume](#)

Examples

```
TerminatorPerfReached$new()
trm("perf_reached")
```

```
mlr_terminators_run_time
      Run Time Terminator
```

Description

Class to terminate the optimization after the optimization process took a number of seconds on the clock.

Dictionary

This [Terminator](#) can be instantiated via the [dictionary mlr_terminators](#) or with the associated sugar function [trm\(\)](#):

```
mlr_terminators$get("run_time")
trm("run_time")
```

Parameters

```
secs numeric(1)
      Maximum allowed time, in seconds, default is 100.
```

Super class

```
bbotk::Terminator -> TerminatorRunTime
```

Methods

Public methods:

- [TerminatorRunTime\\$new\(\)](#)
- [TerminatorRunTime\\$is_terminated\(\)](#)
- [TerminatorRunTime\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
TerminatorRunTime$new()
```

Method `is_terminated()`: Is TRUE iff the termination criterion is positive, and FALSE otherwise.

Usage:

```
TerminatorRunTime$is_terminated(archive)
```

Arguments:

archive ([Archive](#)).

Returns: `logical(1)`.

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
TerminatorRunTime$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

Note

This terminator only works if `archive$start_time` is set. This is usually done by the [Optimizer](#).

See Also

Other Terminator: [Terminator](#), [mlr_terminators](#), [mlr_terminators_clock_time](#), [mlr_terminators_combo](#), [mlr_terminators_evals](#), [mlr_terminators_none](#), [mlr_terminators_perf_reached](#), [mlr_terminators_stagnation](#), [mlr_terminators_stagnation_batch](#), [mlr_terminators_stagnation_hypervolume](#)

Examples

```
trm("run_time", secs = 1800)
```

mlr_terminators_stagnation

Terminator that stops when optimization does not improve

Description

Class to terminate the optimization after the performance stagnates, i.e. does not improve more than threshold over the last `iters` iterations.

Dictionary

This [Terminator](#) can be instantiated via the [dictionary](#) `mlr_terminators` or with the associated sugar function `trm()`:

```
mlr_terminators$get("stagnation")
trm("stagnation")
```

Parameters

`iters` `integer(1)`

Number of iterations to evaluate the performance improvement on, default is 10.

`threshold` `numeric(1)`

If the improvement is less than `threshold`, optimization is stopped, default is 0.

Super class

`bbotk::Terminator` -> `TerminatorStagnation`

Methods

Public methods:

- [TerminatorStagnation\\$new\(\)](#)
- [TerminatorStagnation\\$is_terminated\(\)](#)
- [TerminatorStagnation\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
TerminatorStagnation$new()
```

Method `is_terminated()`: Is TRUE iff the termination criterion is positive, and FALSE otherwise.

Usage:

```
TerminatorStagnation$is_terminated(archive)
```

Arguments:

`archive` ([Archive](#)).

Returns: logical(1).

Method clone(): The objects of this class are cloneable with this method.

Usage:

```
TerminatorStagnation$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

See Also

Other Terminator: [Terminator](#), [mlr_terminators](#), [mlr_terminators_clock_time](#), [mlr_terminators_combo](#), [mlr_terminators_evals](#), [mlr_terminators_none](#), [mlr_terminators_perf_reached](#), [mlr_terminators_run_time](#), [mlr_terminators_stagnation_batch](#), [mlr_terminators_stagnation_hypervolume](#)

Examples

```
TerminatorStagnation$new()
trm("stagnation", iters = 5, threshold = 1e-5)
```

```
mlr_terminators_stagnation_batch
```

Terminator that stops when optimization does not improve

Description

Class to terminate the optimization after the performance stagnates, i.e. does not improve more than threshold over the last n batches.

Dictionary

This [Terminator](#) can be instantiated via the [dictionary mlr_terminators](#) or with the associated sugar function [trm\(\)](#):

```
mlr_terminators$get("stagnation_batch")
trm("stagnation_batch")
```

Parameters

n integer(1)

Number of batches to evaluate the performance improvement on, default is 1.

threshold numeric(1)

If the improvement is less than threshold, optimization is stopped, default is 0.

Super class

[bbotk::Terminator](#) -> TerminatorStagnationBatch

Methods

Public methods:

- [TerminatorStagnationBatch\\$new\(\)](#)
- [TerminatorStagnationBatch\\$is_terminated\(\)](#)
- [TerminatorStagnationBatch\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
TerminatorStagnationBatch$new()
```

Method `is_terminated()`: Is TRUE iff the termination criterion is positive, and FALSE otherwise.

Usage:

```
TerminatorStagnationBatch$is_terminated(archive)
```

Arguments:

archive ([Archive](#)).

Returns: `logical(1)`.

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
TerminatorStagnationBatch$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

See Also

Other Terminator: [Terminator](#), [mlr_terminators](#), [mlr_terminators_clock_time](#), [mlr_terminators_combo](#), [mlr_terminators_evals](#), [mlr_terminators_none](#), [mlr_terminators_perf_reached](#), [mlr_terminators_run_time](#), [mlr_terminators_stagnation](#), [mlr_terminators_stagnation_hypervolume](#)

Examples

```
TerminatorStagnationBatch$new()  
trm("stagnation_batch", n = 1, threshold = 1e-5)
```

```
mlr_terminators_stagnation_hypervolume
  Stagnation Hypervolume Terminator
```

Description

Class to terminate the optimization after the hypervolume stagnates, i.e. does not improve more than threshold over the last `iters` iterations.

Dictionary

This [Terminator](#) can be instantiated via the [dictionary](#) `mlr_terminators` or with the associated sugar function `trm()`:

```
mlr_terminators$get("stagnation_hypervolume")
trm("stagnation_hypervolume")
```

Parameters

`iters` `integer(1)`
 Number of iterations to evaluate the performance improvement on, default is 10.

`threshold` `numeric(1)`
 If the improvement is less than threshold, optimization is stopped, default is 0.

Super class

`bbotk::Terminator` -> `TerminatorStagnationHypervolume`

Methods

Public methods:

- `TerminatorStagnationHypervolume$new()`
- `TerminatorStagnationHypervolume$is_terminated()`
- `TerminatorStagnationHypervolume$clone()`

Method `new()`: Creates a new instance of this R6 class.

Usage:

```
TerminatorStagnationHypervolume$new()
```

Method `is_terminated()`: Is TRUE if the termination criterion is positive, and FALSE otherwise.

Usage:

```
TerminatorStagnationHypervolume$is_terminated(archive)
```

Arguments:

`archive` ([Archive](#)).

Returns: `logical(1)`.

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
TerminatorStagnationHypervolume$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

See Also

Other Terminator: [Terminator](#), [mlr_terminators](#), [mlr_terminators_clock_time](#), [mlr_terminators_combo](#), [mlr_terminators_evals](#), [mlr_terminators_none](#), [mlr_terminators_perf_reached](#), [mlr_terminators_run_time](#), [mlr_terminators_stagnation](#), [mlr_terminators_stagnation_batch](#)

Examples

```
TerminatorStagnation$new()  
trm("stagnation", iters = 5, threshold = 1e-5)
```

Objective

Objective Function with Domain and Codomain

Description

The Objective class describes a black-box objective function that maps an arbitrary domain to a numerical codomain.

Details

Objective objects can have the following properties: "noisy", "deterministic", "single-crit" and "multi-crit".

Public fields

`callbacks` (list of [mlr3misc::Callback](#))

Callbacks applied during the optimization.

`context` ([ContextBatch](#))

Stores the context for the callbacks.

`id` (`character(1)`).

`properties` (`character()`).

`domain` ([paradox::ParamSet](#))

Specifies domain of function, hence its input parameters, their types and ranges.

`codomain` ([paradox::ParamSet](#))

Specifies codomain of function, hence its feasible values.

`constants` ([paradox::ParamSet](#)).

Changeable constants or parameters that are not subject to tuning can be stored and accessed here. Set constant values are passed to `$.eval()` and `$.eval_many()` as named arguments.

`check_values` (`logical(1)`)

Active bindings

- label (character(1))
Label for this object. Can be used in tables, plot and text output instead of the ID.
- man (character(1))
String in the format [pkg]::[topic] pointing to a manual page for this object. The referenced help package can be opened via method \$help().
- xdim (integer(1))
Dimension of domain.
- ydim (integer(1))
Dimension of codomain.
- packages (character())
Set of required packages to run the objective function. Packages are loaded on each worker when the objective is called by [OptimizerAsync](#).

Methods**Public methods:**

- [Objective\\$new\(\)](#)
- [Objective\\$format\(\)](#)
- [Objective\\$print\(\)](#)
- [Objective\\$eval\(\)](#)
- [Objective\\$eval_many\(\)](#)
- [Objective\\$eval_dt\(\)](#)
- [Objective\\$help\(\)](#)
- [Objective\\$clone\(\)](#)

Method new(): Creates a new instance of this [R6](#) class.

Usage:

```
Objective$new(
  id = "f",
  properties = character(),
  domain,
  codomain = ps(y = p_dbl(tags = "minimize")),
  constants = ps(),
  packages = character(),
  check_values = TRUE,
  label = NA_character_,
  man = NA_character_
)
```

Arguments:

id (character(1)).

properties (character()).

domain ([paradox::ParamSet](#))

Specifies domain of function. The [paradox::ParamSet](#) should describe all possible input parameters of the objective function. This includes their id, their types and the possible range.

`codomain` ([paradox::ParamSet](#))
 Specifies codomain of function. Most importantly the tags of each output "Parameter" define whether it should be minimized or maximized. The default is to minimize each component.

`constants` ([paradox::ParamSet](#))
 Changeable constants or parameters that are not subject to tuning can be stored and accessed here.

`packages` (`character()`)
 Set of required packages to run the objective function.

`check_values` (`logical(1)`)
 Should points before the evaluation and the results be checked for validity?

`label` (`character(1)`)
 Label for this object. Can be used in tables, plot and text output instead of the ID.

`man` (`character(1)`)
 String in the format `[pkg]::[topic]` pointing to a manual page for this object. The referenced help package can be opened via method `$help()`.

Method `format()`: Helper for print outputs.

Usage:

`Objective$format(...)`

Arguments:

... (ignored).

Method `print()`: Print method.

Usage:

`Objective$print()`

Returns: `character()`.

Method `eval()`: Evaluates a single input value on the objective function. If `check_values = TRUE`, the validity of the point as well as the validity of the result is checked.

Usage:

`Objective$eval(xs)`

Arguments:

`xs` (`list()`)

A list that contains a single `x` value, e.g. `list(x1 = 1, x2 = 2)`.

Returns: `list()` that contains the result of the evaluation, e.g. `list(y = 1)`. The list can also contain additional *named* entries that will be stored in the archive if called through the [OptimInstance](#). These extra entries are referred to as *extras*.

Method `eval_many()`: Evaluates multiple input values on the objective function. If `check_values = TRUE`, the validity of the points as well as the validity of the results are checked. *bbotk* does not take care of parallelization. If the function should make use of parallel computing, it has to be implemented by deriving from this class and overwriting this function.

Usage:

`Objective$eval_many(xss)`

Arguments:`xss (list())`

A list of lists that contains multiple x values, e.g. `list(list(x1 = 1, x2 = 2), list(x1 = 3, x2 = 4))`.

Returns: `data.table::data.table()` that contains one y-column for single-criteria functions and multiple y-columns for multi-criteria functions, e.g. `data.table(y = 1:2)` or `data.table(y1 = 1:2, y2 = 3:4)`. It may also contain additional columns that will be stored in the archive if called through the [OptimInstance](#). These extra columns are referred to as *extras*.

Method `eval_dt()`: Evaluates multiple input values on the objective function

Usage:`Objective$eval_dt(xdt)`*Arguments:*`xdt (data.table::data.table())`

Set of untransformed points / points from the *search space*. One point per row, e.g. `data.table(x1 = c(1, 3), x2 = c(2, 4))`. Column names have to match ids of the *search_space*. However, `xdt` can contain additional columns.

Returns: `data.table::data.table()` that contains one y-column for single-criteria functions and multiple y-columns for multi-criteria functions, e.g. `data.table(y = 1:2)` or `data.table(y1 = 1:2, y2 = 3:4)`.

Method `help()`: Opens the corresponding help page referenced by field `$man`.

Usage:`Objective$help()`

Method `clone()`: The objects of this class are cloneable with this method.

Usage:`Objective$clone(deep = FALSE)`*Arguments:*

`deep` Whether to make a deep clone.

See Also

[ObjectiveRFun](#), [ObjectiveRFunMany](#), [ObjectiveRFunDt](#)

 ObjectiveRFun

Objective interface with custom R function

Description

Objective interface where the user can pass a custom R function that expects a list as input. If the return of the function is unnamed, it is named with the ids of the codomain.

Super class

`bbotk::Objective` -> ObjectiveRFun

Active bindings

`fun` (function)
Objective function.

Methods**Public methods:**

- `ObjectiveRFun$new()`
- `ObjectiveRFun$eval()`
- `ObjectiveRFun$clone()`

Method `new()`: Creates a new instance of this R6 class.

Usage:

```
ObjectiveRFun$new(
  fun,
  domain,
  codomain = NULL,
  id = "function",
  properties = character(),
  constants = ps(),
  packages = character(),
  check_values = TRUE
)
```

Arguments:

`fun` (function)

R function that encodes objective and expects a list with the input for a single point (e.g. `list(x1 = 1, x2 = 2)`) and returns the result either as a numeric vector or a list (e.g. `list(y = 3)`).

`domain` (`paradox::ParamSet`)

Specifies domain of function. The `paradox::ParamSet` should describe all possible input parameters of the objective function. This includes their id, their types and the possible range.

`codomain` (`paradox::ParamSet`)

Specifies codomain of function. Most importantly the tags of each output "Parameter" define whether it should be minimized or maximized. The default is to minimize each component.

`id` (`character(1)`).

`properties` (`character()`).

`constants` (`paradox::ParamSet`)

Changeable constants or parameters that are not subject to tuning can be stored and accessed here.

packages (character())

Set of required packages to run the objective function.

check_values (logical(1))

Should points before the evaluation and the results be checked for validity?

Method eval(): Evaluates input value(s) on the objective function. Calls the R function supplied by the user.

Usage:

ObjectiveRFun\$eval(xs)

Arguments:

xs Input values.

Method clone(): The objects of this class are cloneable with this method.

Usage:

ObjectiveRFun\$clone(deep = FALSE)

Arguments:

deep Whether to make a deep clone.

See Also

[ObjectiveRFunMany](#), [ObjectiveRFunDt](#)

Examples

```
# define the objective function
fun = function(xs) {
  list(y = - (xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
}

# set domain
domain = ps(
  x1 = p_dbl(-10, 10),
  x2 = p_dbl(-5, 5)
)

# set codomain
codomain = ps(
  y = p_dbl(tags = "maximize")
)

# create objective
objective = ObjectiveRFun$new(
  fun = fun,
  domain = domain,
  codomain = codomain,
  properties = "deterministic"
)

# evaluate objective function
```

```
objective$eval(list(x1 = 1, x2 = 2))

# evaluate multiple input values
objective$eval_many(list(list(x1 = 1, x2 = 2), list(x1 = 3, x2 = 4)))

# evaluate multiple input values as data.table
objective$eval_dt(data.table::data.table(x1 = 1:2, x2 = 3:4))
```

ObjectiveRFuncDt *Objective interface for basic R functions.*

Description

Objective interface where user can pass an R function that works on an `data.table()`.

Super class

```
bbotk::Objective -> ObjectiveRFuncDt
```

Active bindings

```
fun (function)
  Objective function.
```

Methods

Public methods:

- `ObjectiveRFuncDt$new()`
- `ObjectiveRFuncDt$eval_many()`
- `ObjectiveRFuncDt$eval_dt()`
- `ObjectiveRFuncDt$clone()`

Method `new()`: Creates a new instance of this R6 class.

Usage:

```
ObjectiveRFuncDt$new(
  fun,
  domain,
  codomain = NULL,
  id = "function",
  properties = character(),
  constants = ps(),
  packages = character(),
  check_values = TRUE
)
```

Arguments:

- `fun` (function)
R function that encodes objective and expects an `data.table()` as input whereas each point is represented by one row.
- `domain` ([paradox::ParamSet](#))
Specifies domain of function. The [paradox::ParamSet](#) should describe all possible input parameters of the objective function. This includes their id, their types and the possible range.
- `codomain` ([paradox::ParamSet](#))
Specifies codomain of function. Most importantly the tags of each output "Parameter" define whether it should be minimized or maximized. The default is to minimize each component.
- `id` (character(1)).
- `properties` (character()).
- `constants` ([paradox::ParamSet](#))
Changeable constants or parameters that are not subject to tuning can be stored and accessed here.
- `packages` (character())
Set of required packages to run the objective function.
- `check_values` (logical(1))
Should points before the evaluation and the results be checked for validity?

Method `eval_many()`: Evaluates multiple input values received as a list, converted to a `data.table()` on the objective function. Missing columns in `xss` are filled with NAs in `xdt`.

Usage:

`ObjectiveRFDt$eval_many(xss)`

Arguments:

`xss` (`list()`)

A list of lists that contains multiple x values, e.g. `list(list(x1 = 1, x2 = 2), list(x1 = 3, x2 = 4))`.

Returns: `data.table::data.table()` that contains one y-column for single-criteria functions and multiple y-columns for multi-criteria functions, e.g. `data.table(y = 1:2)` or `data.table(y1 = 1:2, y2 = 3:4)`.

Method `eval_dt()`: Evaluates multiple input values on the objective function supplied by the user.

Usage:

`ObjectiveRFDt$eval_dt(xdt)`

Arguments:

`xdt` (`data.table::data.table()`)

Set of untransformed points / points from the *search space*. One point per row, e.g. `data.table(x1 = c(1, 3), x2 = c(2, 4))`. Column names have to match ids of the `search_space`. However, `xdt` can contain additional columns.

Returns: `data.table::data.table()` that contains one y-column for single-criteria functions and multiple y-columns for multi-criteria functions, e.g. `data.table(y = 1:2)` or `data.table(y1 = 1:2, y2 = 3:4)`.

Method clone(): The objects of this class are cloneable with this method.

Usage:

```
ObjectiveRFunDt$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

See Also

[ObjectiveRFun](#), [ObjectiveRFunMany](#)

Examples

```
# define objective function
fun = function(xdt) {
  data.table::data.table(y = xdt$x1 + xdt$x2)
}

# set domain
domain = ps(
  x1 = p_dbl(-10, 10),
  x2 = p_dbl(-5, 5)
)

# set codomain
codomain = ps(
  y = p_dbl(tags = "maximize")
)

# create objective
objective = ObjectiveRFunDt$new(
  fun = fun,
  domain = domain,
  codomain = codomain,
  properties = "deterministic"
)

# evaluate objective function
objective$eval(list(x1 = 1, x2 = 2))

# evaluate multiple input values
objective$eval_many(list(list(x1 = 1, x2 = 2), list(x1 = 3, x2 = 4)))

# evaluate multiple input values as data.table
objective$eval_dt(data.table::data.table(x1 = 1:2, x2 = 3:4))
```

Description

Objective interface where the user can pass a custom R function that expects a list of configurations as input. If the return of the function is unnamed, it is named with the ids of the codomain.

Super class

`bbotk::Objective` -> ObjectiveRFunMany

Active bindings

`fun` (function)
Objective function.

Methods**Public methods:**

- `ObjectiveRFunMany$new()`
- `ObjectiveRFunMany$eval_many()`
- `ObjectiveRFunMany$clone()`

Method `new()`: Creates a new instance of this R6 class.

Usage:

```
ObjectiveRFunMany$new(
  fun,
  domain,
  codomain = NULL,
  id = "function",
  properties = character(),
  constants = ps(),
  packages = character(),
  check_values = TRUE
)
```

Arguments:

`fun` (function)

R function that encodes objective and expects a list of lists that contains multiple x values, e.g. `list(list(x1 = 1, x2 = 2), list(x1 = 3, x2 = 4))`. The function must return a `data.table::data.table()` that contains one y-column for single-criteria functions and multiple y-columns for multi-criteria functions, e.g. `data.table(y = 1:2)` or `data.table(y1 = 1:2, y2 = 3:4)`.

`domain` (`paradox::ParamSet`)

Specifies domain of function. The `paradox::ParamSet` should describe all possible input parameters of the objective function. This includes their id, their types and the possible range.

`codomain` (`paradox::ParamSet`)

Specifies codomain of function. Most importantly the tags of each output "Parameter" define whether it should be minimized or maximized. The default is to minimize each component.

id (character(1)).
 properties (character()).
 constants ([paradox::ParamSet](#))
 Changeable constants or parameters that are not subject to tuning can be stored and accessed here.
 packages (character())
 Set of required packages to run the objective function.
 check_values (logical(1))
 Should points before the evaluation and the results be checked for validity?

Method `eval_many()`: Evaluates input value(s) on the objective function. Calls the R function supplied by the user.

Usage:

```
ObjectiveRFunMany$eval_many(xss)
```

Arguments:

`xss` (`list()`)

A list of lists that contains multiple x values, e.g. `list(list(x1 = 1, x2 = 2), list(x1 = 3, x2 = 4))`.

Returns: `data.table::data.table()` that contains one y-column for single-criteria functions and multiple y-columns for multi-criteria functions, e.g. `data.table(y = 1:2)` or `data.table(y1 = 1:2, y2 = 3:4)`. It may also contain additional columns that will be stored in the archive if called through the [OptimInstance](#). These extra columns are referred to as *extras*.

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
ObjectiveRFunMany$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

See Also

[ObjectiveRFun](#), [ObjectiveRFunDt](#)

Examples

```

# define objective function
fun = function(xss) {
  res = lapply(xss, function(xs) -(xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
  data.table::data.table(y = as.numeric(res))
}

# set domain
domain = ps(
  x1 = p_dbl(-10, 10),
  x2 = p_dbl(-5, 5)
)

```

```

# set codomain
codomain = ps(
  y = p_dbl(tags = "maximize")
)

# create objective
objective = ObjectiveRFunMany$new(
  fun = fun,
  domain = domain,
  codomain = codomain,
  properties = "deterministic"
)

# evaluate objective function
objective$eval(list(x1 = 1, x2 = 2))

# evaluate multiple input values
objective$eval_many(list(list(x1 = 1, x2 = 2), list(x1 = 3, x2 = 4)))

# evaluate multiple input values as data.table
objective$eval_dt(data.table::data.table(x1 = 1:2, x2 = 3:4))

```

oi

*Syntactic Sugar for Optimization Instance Construction***Description**

Function to construct a [OptimInstanceBatchSingleCrit](#) and [OptimInstanceBatchMultiCrit](#).

Usage

```

oi(
  objective,
  search_space = NULL,
  terminator,
  callbacks = NULL,
  check_values = TRUE,
  keep_evals = "all"
)

```

Arguments

objective	(Objective) Objective function.
search_space	(paradox::ParamSet) Specifies the search space for the Optimizer . The paradox::ParamSet describes either a subset of the domain of the Objective or it describes a set of parameters together with a trafo function that transforms values from the search space to values of the domain. Depending on the context, this value defaults to the domain of the objective.

terminator	Terminator Termination criterion.
callbacks	(list of mlr3misc::Callback) List of callbacks.
check_values	(logical(1)) Should points before the evaluation and the results be checked for validity?
keep_evals	(character(1)) Keep all or only best evaluations in archive?

Examples

```
# define the objective function
fun = function(xs) {
  list(y = - (xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
}

# set domain
domain = ps(
  x1 = p_dbl(-10, 10),
  x2 = p_dbl(-5, 5)
)

# set codomain
codomain = ps(
  y = p_dbl(tags = "maximize")
)

# create objective
objective = ObjectiveRFun$new(
  fun = fun,
  domain = domain,
  codomain = codomain,
  properties = "deterministic"
)

# initialize instance
instance = oi(
  objective = objective,
  terminator = trm("evals", n_evals = 20)
)
```

oi_async

Syntactic Sugar for Asynchronous Optimization Instance Construction

Description

Function to construct an [OptimInstanceAsyncSingleCrit](#) and [OptimInstanceAsyncMultiCrit](#).

Usage

```
oi_async(
  objective,
  search_space = NULL,
  terminator,
  check_values = FALSE,
  callbacks = NULL,
  rush = NULL
)
```

Arguments

objective	(Objective) Objective function.
search_space	(paradox::ParamSet) Specifies the search space for the Optimizer . The paradox::ParamSet describes either a subset of the domain of the Objective or it describes a set of parameters together with a trafo function that transforms values from the search space to values of the domain. Depending on the context, this value defaults to the domain of the objective.
terminator	(Terminator) Termination criterion.
check_values	(logical(1)) Should points before the evaluation and the results be checked for validity?
callbacks	(list of mlr3misc::Callback) List of callbacks.
rush	(Rush) If a rush instance is supplied, the tuning runs without batches.

Examples

```
# example only runs if a Redis server is available
if (mlr3misc::require_namespaces(c("rush", "redux", "mirai"), quietly = TRUE) &&
    redux::redis_available()) {
  # define the objective function
  fun = function(xs) {
    list(y = - (xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
  }

  # set domain
  domain = ps(
    x1 = p_dbl(-10, 10),
    x2 = p_dbl(-5, 5)
  )

  # set codomain
  codomain = ps(
    y = p_dbl(tags = "maximize")
  )
}
```

```

)

# create objective
objective = ObjectiveRFun$new(
  fun = fun,
  domain = domain,
  codomain = codomain,
  properties = "deterministic"
)

# start workers
rush::rush_plan(worker_type = "remote")
mirai::daemons(1)

# initialize instance
instance = oi_async(
  objective = objective,
  terminator = trm("evals", n_evals = 20)
)
}

```

opt

Syntactic Sugar Optimizer Construction

Description

This function complements [mlr_optimizers](#) with functions in the spirit of `mlr_sugar` from **mlr3**.

Usage

```
opt(.key, ...)
```

```
opts(.keys, ...)
```

Arguments

<code>.key</code>	(character(1)) Key passed to the respective dictionary to retrieve the object.
<code>...</code>	(named list()) Named arguments passed to the constructor, to be set as parameters in the paradox::ParamSet , or to be set as public field. See mlr3misc::dictionary_sugar_get() for more details.
<code>.keys</code>	(character()) Keys passed to the respective dictionary to retrieve multiple objects.

Value

- [Optimizer](#) for `opt()`.
- list of [Optimizer](#) for `opts()`.

Examples

```
opt("random_search", batch_size = 10)
```

OptimInstance	<i>Optimization Instance</i>
---------------	------------------------------

Description

The `OptimInstance` specifies an optimization problem for an [Optimizer](#). Inherits from [EvalInstance](#) and adds optimization-specific functionality.

Details

`OptimInstance` is an abstract base class that implements the base functionality each instance must provide. The [Optimizer](#) writes the final result to the `.result` field by using the `$assign_result()` method. `.result` stores a [data.table::data.table](#) consisting of x values in the *search space*, (transformed) x values in the *domain space* and y values in the *codomain space* of the [Objective](#). The user can access the results with active bindings (see below).

Super class

```
bbotk::EvalInstance -> OptimInstance
```

Public fields

```
progressor (progressor())
  Stores progressor function.
```

Active bindings

```
result (data.table::data.table)
  Get result
result_x_search_space (data.table::data.table)
  x part of the result in the search space.
```

Methods**Public methods:**

- [OptimInstance\\$new\(\)](#)
- [OptimInstance\\$print\(\)](#)
- [OptimInstance\\$assign_result\(\)](#)
- [OptimInstance\\$clear\(\)](#)
- [OptimInstance\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```

OptimInstance$new(
  objective,
  search_space = NULL,
  terminator,
  check_values = TRUE,
  callbacks = NULL,
  archive = NULL,
  label = NA_character_,
  man = NA_character_
)

```

Arguments:

`objective` ([Objective](#))

Objective function.

`search_space` ([paradox::ParamSet](#))

Specifies the search space for the [Optimizer](#). The [paradox::ParamSet](#) describes either a subset of the domain of the [Objective](#) or it describes a set of parameters together with a trafo function that transforms values from the search space to values of the domain. Depending on the context, this value defaults to the domain of the objective.

`terminator` [Terminator](#)

Termination criterion.

`check_values` (`logical(1)`)

Should points before the evaluation and the results be checked for validity?

`callbacks` (list of [mlr3misc::Callback](#))

List of callbacks.

`archive` ([Archive](#)).

`label` (`character(1)`)

Label for this object. Can be used in tables, plot and text output instead of the ID.

`man` (`character(1)`)

String in the format `[pkg]::[topic]` pointing to a manual page for this object. The referenced help package can be opened via method `$help()`.

Method `print()`: Printer.

Usage:

```
OptimInstance$print(...)
```

Arguments:

... (ignored).

Method `assign_result()`: The [Optimizer](#) object writes the best found point and estimated performance value here. For internal use.

Usage:

```
OptimInstance$assign_result(xdt, y, ...)
```

Arguments:

`xdt` (`data.table::data.table()`)

x values as `data.table::data.table()` with one row. Contains the value in the *search space* of the [OptimInstance](#) object. Can contain additional columns for extra information.

y (numeric(1))
 Optimal outcome.
 ... (any)
 ignored.

Method clear(): Reset terminator and clear all evaluation results from archive and results.

Usage:
 OptimInstance\$clear()

Method clone(): The objects of this class are cloneable with this method.

Usage:
 OptimInstance\$clone(deep = FALSE)
Arguments:
 deep Whether to make a deep clone.

See Also

[EvalInstance](#), [OptimInstanceBatch](#), [OptimInstanceAsync](#)

OptimInstanceAsync	<i>Optimization Instance for Asynchronous Optimization</i>
--------------------	--

Description

The OptimInstanceAsync specifies an optimization problem for an [OptimizerAsync](#). The function [oi_async\(\)](#) creates an [OptimInstanceAsyncSingleCrit](#) or [OptimInstanceAsyncMultiCrit](#).

Details

OptimInstanceAsync is an abstract base class that implements the base functionality each instance must provide.

Super classes

[bbotk::EvalInstance](#) -> [bbotk::OptimInstance](#) -> OptimInstanceAsync

Public fields

rush (Rush)
 Rush controller for parallel optimization.

Methods**Public methods:**

- [OptimInstanceAsync\\$new\(\)](#)
- [OptimInstanceAsync\\$print\(\)](#)
- [OptimInstanceAsync\\$clear\(\)](#)
- [OptimInstanceAsync\\$reconnect\(\)](#)
- [OptimInstanceAsync\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
OptimInstanceAsync$new(
  objective,
  search_space = NULL,
  terminator,
  check_values = FALSE,
  callbacks = NULL,
  archive = NULL,
  rush = NULL,
  label = NA_character_,
  man = NA_character_
)
```

Arguments:

`objective` ([Objective](#))

Objective function.

`search_space` ([paradox::ParamSet](#))

Specifies the search space for the [Optimizer](#). The [paradox::ParamSet](#) describes either a subset of the domain of the [Objective](#) or it describes a set of parameters together with a trafo function that transforms values from the search space to values of the domain. Depending on the context, this value defaults to the domain of the objective.

`terminator` [Terminator](#)

Termination criterion.

`check_values` (`logical(1)`)

Should points before the evaluation and the results be checked for validity?

`callbacks` (list of [mlr3misc::Callback](#))

List of callbacks.

`archive` ([Archive](#)).

`rush` ([Rush](#))

If a rush instance is supplied, the tuning runs without batches.

`label` (`character(1)`)

Label for this object. Can be used in tables, plot and text output instead of the ID.

`man` (`character(1)`)

String in the format `[pkg]::[topic]` pointing to a manual page for this object. The referenced help package can be opened via method `$help()`.

Method `print()`: Printer.

Usage:

```
OptimInstanceAsync#print(...)
```

Arguments:

... (ignored).

Method `clear()`: Reset terminator and clear all evaluation results from archive and results.

Usage:

```
OptimInstanceAsync$clear()
```

Method `reconnect()`: Reconnect to Redis. The connection breaks when the `rush::Rush` is saved to disk. Call this method to reconnect after loading the object.

Usage:

```
OptimInstanceAsync$reconnect()
```

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
OptimInstanceAsync$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

See Also

[oi_async\(\)](#), [OptimInstanceAsyncSingleCrit](#), [OptimInstanceAsyncMultiCrit](#)

OptimInstanceAsyncMultiCrit

Multi Criteria Optimization Instance for Asynchronous Optimization

Description

The [OptimInstanceAsyncMultiCrit](#) specifies an optimization problem for an [OptimizerAsync](#). The function [oi_async\(\)](#) creates an [OptimInstanceAsyncMultiCrit](#).

Super classes

[bbotk::EvalInstance](#) -> [bbotk::OptimInstance](#) -> [bbotk::OptimInstanceAsync](#) -> [OptimInstanceAsyncMultiCrit](#)

Active bindings

`result_x_domain` (`list()`)

(transformed) `x` part of the result in the *domain space* of the objective.

`result_y` (`numeric(1)`)

Optimal outcome.

Methods**Public methods:**

- [OptimInstanceAsyncMultiCrit\\$new\(\)](#)
- [OptimInstanceAsyncMultiCrit\\$assign_result\(\)](#)
- [OptimInstanceAsyncMultiCrit\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
OptimInstanceAsyncMultiCrit$new(
  objective,
  search_space = NULL,
  terminator,
  check_values = FALSE,
  callbacks = NULL,
  archive = NULL,
  rush = NULL
)
```

Arguments:

`objective` ([Objective](#))

Objective function.

`search_space` ([paradox::ParamSet](#))

Specifies the search space for the [Optimizer](#). The [paradox::ParamSet](#) describes either a subset of the domain of the [Objective](#) or it describes a set of parameters together with a trafo function that transforms values from the search space to values of the domain. Depending on the context, this value defaults to the domain of the objective.

`terminator` [Terminator](#)

Termination criterion.

`check_values` (`logical(1)`)

Should points before the evaluation and the results be checked for validity?

`callbacks` (list of [mlr3misc::Callback](#))

List of callbacks.

`archive` ([Archive](#)).

`rush` (`Rush`)

If a rush instance is supplied, the tuning runs without batches.

Method `assign_result()`: The [OptimizerAsync](#) writes the best found points and estimated performance values here (probably the Pareto set / front). For internal use.

Usage:

```
OptimInstanceAsyncMultiCrit$assign_result(xdt, ydt, extra = NULL, ...)
```

Arguments:

`xdt` ([data.table::data.table\(\)](#))

Set of untransformed points / points from the *search space*. One point per row, e.g. `data.table(x1 = c(1, 3), x2 = c(2, 4))`. Column names have to match ids of the `search_space`. However, `xdt` can contain additional columns.

```

ydt (numeric(1))
  Optimal outcomes, e.g. the Pareto front.
extra (data.table::data.table())
  Additional information.
... (any)
  ignored.

```

Method clone(): The objects of this class are cloneable with this method.

Usage:

```
OptimInstanceAsyncMultiCrit$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

Examples

```

# example only runs if a Redis server is available
if (mlr3misc::require_namespaces(c("rush", "redux", "mirai"), quietly = TRUE) &&
    redux::redis_available()) {
  # define the objective function
  fun = function(xs) {
    data.table(
      y1 = xs$x1^2 + xs$x2^2,
      y2 = (xs$x1 - 2)^2 + (xs$x2 - 1)^2
    )
  }

  # set domain
  domain = ps(
    x1 = p_dbl(-5, 5),
    x2 = p_dbl(-5, 5)
  )

  # set codomain
  codomain = ps(
    y1 = p_dbl(tags = "minimize"),
    y2 = p_dbl(tags = "minimize")
  )

  # create objective
  objective = ObjectiveRFun$new(
    fun = fun,
    domain = domain,
    codomain = codomain,
    properties = "deterministic"
  )

  # start workers
  rush::rush_plan(worker_type = "remote")
  mirai::daemons(1)

  # initialize instance

```

```
instance = oi_async(
  objective = objective,
  terminator = trm("evals", n_evals = 100))
}
```

OptimInstanceAsyncSingleCrit

Single Criterion Optimization Instance for Asynchronous Optimization

Description

The `OptimInstanceAsyncSingleCrit` specifies an optimization problem for an [OptimizerAsync](#). The function `oi_async()` creates an `OptimInstanceAsyncSingleCrit`.

Super classes

`bbotk::EvalInstance` -> `bbotk::OptimInstance` -> `bbotk::OptimInstanceAsync` -> `OptimInstanceAsyncSingleCrit`

Active bindings

`result_x_domain` (`list()`)
 (transformed) x part of the result in the *domain space* of the objective.

`result_y` (`numeric()`)
 Optimal outcome.

Methods

Public methods:

- `OptimInstanceAsyncSingleCrit$new()`
- `OptimInstanceAsyncSingleCrit$assign_result()`
- `OptimInstanceAsyncSingleCrit$clone()`

Method `new()`: Creates a new instance of this R6 class.

Usage:

```
OptimInstanceAsyncSingleCrit$new(
  objective,
  search_space = NULL,
  terminator,
  check_values = FALSE,
  callbacks = NULL,
  archive = NULL,
  rush = NULL
)
```

Arguments:

objective ([Objective](#))
Objective function.

search_space ([paradox::ParamSet](#))
Specifies the search space for the [Optimizer](#). The [paradox::ParamSet](#) describes either a subset of the domain of the [Objective](#) or it describes a set of parameters together with a trafo function that transforms values from the search space to values of the domain. Depending on the context, this value defaults to the domain of the objective.

terminator [Terminator](#)
Termination criterion.

check_values (logical(1))
Should points before the evaluation and the results be checked for validity?

callbacks (list of [mlr3misc::Callback](#))
List of callbacks.

archive ([Archive](#)).

rush (Rush)
If a rush instance is supplied, the tuning runs without batches.

Method `assign_result()`: The [OptimizerAsync](#) object writes the best found point and estimated performance value here. For internal use.

Usage:

```
OptimInstanceAsyncSingleCrit$assign_result(xdt, y, extra = NULL, ...)
```

Arguments:

xdt ([data.table::data.table\(\)](#))

Set of untransformed points / points from the *search space*. One point per row, e.g. `data.table(x1 = c(1, 3), x2 = c(2, 4))`. Column names have to match ids of the `search_space`. However, xdt can contain additional columns.

y (numeric(1))

Optimal outcome.

extra ([data.table::data.table\(\)](#))

Additional information.

... (any)

ignored.

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
OptimInstanceAsyncSingleCrit$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

Examples

```
# example only runs if a Redis server is available
if (mlr3misc::require_namespaces(c("rush", "redux", "mirai"), quietly = TRUE) &&
    redux::redis_available()) {
  # define the objective function
  fun = function(xs) {
```

```

    list(y = - (xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
  }

  # set domain
  domain = ps(
    x1 = p_dbl(-10, 10),
    x2 = p_dbl(-5, 5)
  )

  # set codomain
  codomain = ps(
    y = p_dbl(tags = "maximize")
  )

  # create objective
  objective = ObjectiveRFun$new(
    fun = fun,
    domain = domain,
    codomain = codomain,
    properties = "deterministic"
  )

  # start workers
  rush::rush_plan(worker_type = "remote")
  mirai::daemons(1)

  # initialize instance
  instance = oi_async(
    objective = objective,
    terminator = trm("evals", n_evals = 20)
  )
}

```

OptimInstanceBatch *Optimization Instance for Batch Optimization*

Description

The `OptimInstanceBatch` specifies an optimization problem for an `OptimizerBatch`. The function `oi()` creates an `OptimInstanceAsyncSingleCrit` or `OptimInstanceAsyncMultiCrit`.

Super classes

```
bbotk::EvalInstance -> bbotk::OptimInstance -> OptimInstanceBatch
```

Public fields

`objective_multiplier` (`integer()`).

Active bindings

result ([data.table::data.table](#))
 Get result
 result_x_search_space ([data.table::data.table](#))
 x part of the result in the *search space*.
 result_x_domain (list())
 (transformed) x part of the result in the *domain space* of the objective.
 result_y (numeric())
 Optimal outcome.
 is_terminated (logical(1)).

Methods**Public methods:**

- [OptimInstanceBatch\\$new\(\)](#)
- [OptimInstanceBatch\\$eval_batch\(\)](#)
- [OptimInstanceBatch\\$objective_function\(\)](#)
- [OptimInstanceBatch\\$clone\(\)](#)

Method [new\(\)](#): Creates a new instance of this [R6](#) class.

Usage:

```

OptimInstanceBatch$new(
  objective,
  search_space = NULL,
  terminator,
  check_values = TRUE,
  callbacks = NULL,
  archive = NULL,
  label = NA_character_,
  man = NA_character_
)

```

Arguments:

objective ([Objective](#))

Objective function.

search_space ([paradox::ParamSet](#))

Specifies the search space for the [Optimizer](#). The [paradox::ParamSet](#) describes either a subset of the domain of the [Objective](#) or it describes a set of parameters together with a trafo function that transforms values from the search space to values of the domain. Depending on the context, this value defaults to the domain of the objective.

terminator [Terminator](#)

Termination criterion.

check_values (logical(1))

Should points before the evaluation and the results be checked for validity?

callbacks (list of [mlr3misc::Callback](#))

List of callbacks.

archive ([Archive](#)).

label (character(1))

Label for this object. Can be used in tables, plot and text output instead of the ID.

man (character(1))

String in the format [pkg]::[topic] pointing to a manual page for this object. The referenced help package can be opened via method `$help()`.

Method `eval_batch()`: Evaluates all input values in `xdt` by calling the [Objective](#). Applies possible transformations to the input values and writes the results to the [Archive](#).

Before each batch-evaluation, the [Terminator](#) is checked, and if it is positive, an exception of class `terminated_error` is raised. This function should be internally called by the [Optimizer](#).

Usage:

```
OptimInstanceBatch$eval_batch(xdt)
```

Arguments:

`xdt` (`data.table::data.table()`)

`x` values as `data.table()` with one point per row. Contains the value in the *search space* of the [OptimInstance](#) object. Can contain additional columns for extra information.

Method `objective_function()`: Evaluates (untransformed) points of only numeric values. Returns a numeric scalar for single-crit or a numeric vector for multi-crit. The return value(s) are negated if the measure is maximized. Internally, `$eval_batch()` is called with a single row. This function serves as a objective function for optimizers of numeric spaces - which should always be minimized.

Usage:

```
OptimInstanceBatch$objective_function(x)
```

Arguments:

`x` (`numeric()`)

Untransformed points.

Returns: Objective value as `numeric(1)`, negated for maximization problems.

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
OptimInstanceBatch$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

See Also

[oi\(\)](#), [OptimInstanceBatchSingleCrit](#), [OptimInstanceBatchMultiCrit](#)

 OptimInstanceBatchMultiCrit

Multi Criteria Optimization Instance for Batch Optimization

Description

The `OptimInstanceBatchMultiCrit` specifies an optimization problem for an `OptimizerBatch`. The function `oi()` creates an `OptimInstanceBatchMultiCrit`.

Super classes

`bbotk::EvalInstance` -> `bbotk::OptimInstance` -> `bbotk::OptimInstanceBatch` -> `OptimInstanceBatchMultiCrit`

Active bindings

`result_x_domain (list())`
 (transformed) x part of the result in the *domain space* of the objective.

`result_y (numeric(1))`
 Optimal outcome.

Methods

Public methods:

- `OptimInstanceBatchMultiCrit$new()`
- `OptimInstanceBatchMultiCrit$assign_result()`
- `OptimInstanceBatchMultiCrit$clone()`

Method `new()`: Creates a new instance of this `R6` class.

Usage:

```
OptimInstanceBatchMultiCrit$new(
  objective,
  search_space = NULL,
  terminator,
  check_values = TRUE,
  callbacks = NULL,
  archive = NULL
)
```

Arguments:

`objective` (`Objective`)
 Objective function.

`search_space` (`paradox::ParamSet`)

Specifies the search space for the `Optimizer`. The `paradox::ParamSet` describes either a subset of the domain of the `Objective` or it describes a set of parameters together with a `trafo` function that transforms values from the search space to values of the domain. Depending on the context, this value defaults to the domain of the objective.

terminator [Terminator](#)
 Termination criterion.
 check_values (logical(1))
 Should points before the evaluation and the results be checked for validity?
 callbacks (list of [mlr3misc::Callback](#))
 List of callbacks.
 archive ([Archive](#)).

Method `assign_result()`: The [Optimizer](#) object writes the best found points and estimated performance values here (probably the Pareto set / front). For internal use.

Usage:

```
OptimInstanceBatchMultiCrit$assign_result(xdt, ydt, extra = NULL, ...)
```

Arguments:

xdt ([data.table::data.table\(\)](#))

Set of untransformed points / points from the *search space*. One point per row, e.g. `data.table(x1 = c(1, 3), x2 = c(2, 4))`. Column names have to match ids of the `search_space`. However, xdt can contain additional columns.

ydt ([data.table::data.table\(\)](#))

Optimal outcome.

extra ([data.table::data.table\(\)](#))

Additional information.

... (any)

ignored.

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
OptimInstanceBatchMultiCrit$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

Examples

```
# define the objective function
fun = function(xs) {
  data.table(
    y1 = xs$x1^2 + xs$x2^2,
    y2 = (xs$x1 - 2)^2 + (xs$x2 - 1)^2
  )
}

# set domain
domain = ps(
  x1 = p_dbl(-5, 5),
  x2 = p_dbl(-5, 5)
)

# set codomain
```

```

codomain = ps(
  y1 = p_dbl(tags = "minimize"),
  y2 = p_dbl(tags = "minimize")
)

# create objective
objective = ObjectiveRfun$new(
  fun = fun,
  domain = domain,
  codomain = codomain,
  properties = "deterministic"
)

# initialize instance
instance = oi(
  objective = objective,
  terminator = trm("evals", n_evals = 100))

```

OptimInstanceBatchSingleCrit

Single Criterion Optimization Instance for Batch Optimization

Description

The `OptimInstanceBatchSingleCrit` specifies an optimization problem for an `OptimizerBatch`. The function `oi()` creates an `OptimInstanceBatchSingleCrit`.

Super classes

`bbotk::EvalInstance` -> `bbotk::OptimInstance` -> `bbotk::OptimInstanceBatch` -> `OptimInstanceBatchSingleCrit`

Methods

Public methods:

- `OptimInstanceBatchSingleCrit$new()`
- `OptimInstanceBatchSingleCrit$assign_result()`
- `OptimInstanceBatchSingleCrit$clone()`

Method `new()`: Creates a new instance of this R6 class.

Usage:

```

OptimInstanceBatchSingleCrit$new(
  objective,
  search_space = NULL,
  terminator,
  check_values = TRUE,
  callbacks = NULL,
  archive = NULL
)

```

Arguments:

objective ([Objective](#))

Objective function.

search_space ([paradox::ParamSet](#))

Specifies the search space for the [Optimizer](#). The [paradox::ParamSet](#) describes either a subset of the domain of the [Objective](#) or it describes a set of parameters together with a trafo function that transforms values from the search space to values of the domain. Depending on the context, this value defaults to the domain of the objective.

terminator [Terminator](#)

Termination criterion.

check_values (logical(1))

Should points before the evaluation and the results be checked for validity?

callbacks (list of [mlr3misc::Callback](#))

List of callbacks.

archive ([Archive](#)).

Method `assign_result()`: The [Optimizer](#) object writes the best found point and estimated performance value here. For internal use.

Usage:

```
OptimInstanceBatchSingleCrit$assign_result(xdt, y, extra = NULL, ...)
```

Arguments:

xdt ([data.table::data.table\(\)](#))

Set of untransformed points / points from the *search space*. One point per row, e.g. `data.table(x1 = c(1, 3), x2 = c(2, 4))`. Column names have to match ids of the `search_space`. However, xdt can contain additional columns.

y (numeric(1))

Optimal outcome.

extra ([data.table::data.table\(\)](#))

Additional information.

... (any)

ignored.

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
OptimInstanceBatchSingleCrit$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

Examples

```
# define the objective function
fun = function(xs) {
  list(y = - (xs[[1]] - 2)^2 - (xs[[2]] + 3)^2 + 10)
}

# set domain
```

```

domain = ps(
  x1 = p_dbl(-10, 10),
  x2 = p_dbl(-5, 5)
)

# set codomain
codomain = ps(
  y = p_dbl(tags = "maximize")
)

# create objective
objective = ObjectiveRFun$new(
  fun = fun,
  domain = domain,
  codomain = codomain,
  properties = "deterministic"
)

# initialize instance
instance = oi(
  objective = objective,
  terminator = trm("evals", n_evals = 20)
)

```

OptimInstanceMultiCrit

Multi Criteria Optimization Instance for Batch Optimization

Description

OptimInstanceMultiCrit is a deprecated class that is now a wrapper around [OptimInstanceBatchMultiCrit](#).

Super classes

```

bbotk::EvalInstance -> bbotk::OptimInstance -> bbotk::OptimInstanceBatch -> bbotk::OptimInstanceBatchMultiCrit -> OptimInstanceMultiCrit

```

Methods

Public methods:

- [OptimInstanceMultiCrit\\$new\(\)](#)
- [OptimInstanceMultiCrit\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
OptimInstanceMultiCrit$new(
  objective,
  search_space = NULL,
  terminator,
  keep_evals = "all",
  check_values = TRUE,
  callbacks = NULL
)
```

Arguments:

objective ([Objective](#))

Objective function.

search_space ([paradox::ParamSet](#))

Specifies the search space for the [Optimizer](#). The [paradox::ParamSet](#) describes either a subset of the domain of the [Objective](#) or it describes a set of parameters together with a trafo function that transforms values from the search space to values of the domain. Depending on the context, this value defaults to the domain of the objective.

terminator [Terminator](#)

Termination criterion.

keep_evals (character(1))

Keep all or only best evaluations in archive?

check_values (logical(1))

Should points before the evaluation and the results be checked for validity?

callbacks (list of [mlr3misc::Callback](#))

List of callbacks.

Method clone(): The objects of this class are cloneable with this method.

Usage:

```
OptimInstanceMultiCrit$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

See Also

[OptimInstanceBatchMultiCrit](#)

OptimInstanceSingleCrit

Single Criterion Optimization Instance for Batch Optimization

Description

OptimInstanceSingleCrit is a deprecated class that is now a wrapper around [OptimInstanceBatchSingleCrit](#).

Super classes

[bbotk::EvalInstance](#) -> [bbotk::OptimInstance](#) -> [bbotk::OptimInstanceBatch](#) -> [bbotk::OptimInstanceBatchSingle](#)
-> [OptimInstanceSingleCrit](#)

Methods**Public methods:**

- [OptimInstanceSingleCrit\\$new\(\)](#)
- [OptimInstanceSingleCrit\\$clone\(\)](#)

Method [new\(\)](#): Creates a new instance of this [R6](#) class.

Usage:

```
OptimInstanceSingleCrit$new(
  objective,
  search_space = NULL,
  terminator,
  keep_evals = "all",
  check_values = TRUE,
  callbacks = NULL
)
```

Arguments:

`objective` ([Objective](#))

Objective function.

`search_space` ([paradox::ParamSet](#))

Specifies the search space for the [Optimizer](#). The [paradox::ParamSet](#) describes either a subset of the domain of the [Objective](#) or it describes a set of parameters together with a trafo function that transforms values from the search space to values of the domain. Depending on the context, this value defaults to the domain of the objective.

`terminator` [Terminator](#)

Termination criterion.

`keep_evals` ([character\(1\)](#))

Keep all or only best evaluations in archive?

`check_values` ([logical\(1\)](#))

Should points before the evaluation and the results be checked for validity?

`callbacks` (list of [mlr3misc::Callback](#))

List of callbacks.

Method [clone\(\)](#): The objects of this class are cloneable with this method.

Usage:

```
OptimInstanceSingleCrit$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

See Also

[OptimInstanceBatchSingleCrit](#)

 Optimizer

Optimizer

Description

The Optimizer implements the optimization algorithm.

Details

Optimizer is an abstract base class that implements the base functionality each optimizer must provide. A Optimizer object describes the optimization strategy. A Optimizer object must write its result to the `$assign_result()` method of the [OptimInstance](#) at the end in order to store the best point and its estimated performance vector.

Progress Bars

`$optimize()` supports progress bars via the package **progress** combined with a [Terminator](#). Simply wrap the function in `progressr::with_progress()` to enable them. We recommend to use package **progress** as backend; enable with `progressr::handlers("progress")`.

Public fields

`id` (character(1))
 Identifier of the object. Used in tables, plot and text output.

Active bindings

`param_set` [paradox::ParamSet](#)
 Set of control parameters.

`label` (character(1))
 Label for this object. Can be used in tables, plot and text output instead of the ID.

`man` (character(1))
 String in the format `[pkg]::[topic]` pointing to a manual page for this object. The referenced help package can be opened via method `$help()`.

`param_classes` (character())
 Supported parameter classes that the optimizer can optimize, as given in the [paradox::ParamSet](#) `$class` field.

`properties` (character())
 Set of properties of the optimizer. Must be a subset of `bbotk_reflections$optimizer_properties`.

`packages` (character())
 Set of required packages. A warning is signaled by the constructor if at least one of the packages is not installed, but loaded (not attached) later on-demand via [requireNamespace\(\)](#).

Methods**Public methods:**

- [Optimizer\\$new\(\)](#)
- [Optimizer\\$format\(\)](#)
- [Optimizer\\$print\(\)](#)
- [Optimizer\\$help\(\)](#)
- [Optimizer\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
Optimizer$new(
  id = "optimizer",
  param_set,
  param_classes,
  properties,
  packages = character(),
  label = NA_character_,
  man = NA_character_
)
```

Arguments:

`id` ([character\(1\)](#))

Identifier for the new instance.

`param_set` ([paradox::ParamSet](#))

Set of control parameters.

`param_classes` ([character\(\)](#))

Supported parameter classes that the optimizer can optimize, as given in the [paradox::ParamSet](#) `$class` field.

`properties` ([character\(\)](#))

Set of properties of the optimizer. Must be a subset of [bbotk_reflections\\$optimizer_properties](#).

`packages` ([character\(\)](#))

Set of required packages. A warning is signaled by the constructor if at least one of the packages is not installed, but loaded (not attached) later on-demand via [requireNamespace\(\)](#).

`label` ([character\(1\)](#))

Label for this object. Can be used in tables, plot and text output instead of the ID.

`man` ([character\(1\)](#))

String in the format `[pkg]::[topic]` pointing to a manual page for this object. The referenced help package can be opened via method `$help()`.

Method `format()`: Helper for print outputs.

Usage:

```
Optimizer$format(...)
```

Arguments:

... (ignored).

Method `print()`: Print method.

Usage:

Optimizer\$print()

Returns: (character()).

Method help(): Opens the corresponding help page referenced by field \$man.

Usage:

Optimizer\$help()

Method clone(): The objects of this class are cloneable with this method.

Usage:

Optimizer\$clone(deep = FALSE)

Arguments:

deep Whether to make a deep clone.

See Also

[OptimizerAsync](#), [OptimizerBatch](#)

OptimizerAsync

Asynchronous Optimizer

Description

The [OptimizerAsync](#) implements the asynchronous optimization algorithm. The optimization is performed asynchronously on a set of workers.

Details

[OptimizerAsync](#) is the abstract base class for all asynchronous optimizers. It provides the basic structure for asynchronous optimization algorithms. The public method `$optimize()` is the main entry point for the optimization and runs in the main process. The method starts the optimization process by starting the workers and pushing the necessary objects to the workers. Optionally, a set of points can be created, e.g. an initial design, and pushed to the workers. The private method `$.optimize()` is the actual optimization algorithm that runs on the workers. Usually, the method proposes new points, evaluates them, and updates the archive.

Optimization

The `rush::rush_plan()` function defines the number of workers and their type. There are three types of workers:

- "local": Workers are started as local processes with **processx**. See `$start_local_workers()` in [rush::Rush](#) for more details.
- "remote": Workers are started with **mirai** on local or remote machines. `mirai::daemons()` must be created before starting the optimization. See `$start_remote_workers()` in [rush::Rush](#) for more details.

- "script": Workers are started by the user with a custom script. See `$create_worker_script()` in [rush::Rush](#) for more details.

The workers are started when the `$optimize()` method is called. The main process waits until at least one worker is running. The optimization starts directly after the workers are running. The main process prints the evaluation results and other log messages from the workers. The optimization is terminated when the terminator criterion is satisfied. The result is assigned to the [OptimInstanceAsync](#) field. The main loop periodically checks the status of the workers. If all workers crash the optimization is terminated.

Debug Mode

The debug mode runs the optimization loop in the main process. This is useful for debugging the optimization algorithm. The debug mode is enabled by setting `options(bbotk.debug = TRUE)`.

Tiny Logging

The tiny logging mode is enabled by setting the option `bbotk.tiny_logging` to `TRUE`. In the tiny logging mode, the evaluated points are printed in a compact format and the currently best performing point is shown. Deactivated depending parameters are not printed.

Super class

`bbotk::Optimizer -> OptimizerAsync`

Methods

Public methods:

- [OptimizerAsync\\$optimize\(\)](#)
- [OptimizerAsync\\$clone\(\)](#)

Method `optimize()`: Performs the optimization on a [OptimInstanceAsyncSingleCrit](#) or [OptimInstanceAsyncMultiCrit](#) until termination. The single evaluations will be written into the [ArchiveAsync](#). The result will be written into the instance object.

Usage:

```
OptimizerAsync$optimize(inst)
```

Arguments:

`inst` ([OptimInstanceAsyncSingleCrit](#) | [OptimInstanceAsyncMultiCrit](#)).

Returns: `data.table::data.table()`

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
OptimizerAsync$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

See Also

[OptimizerAsyncDesignPoints](#), [OptimizerAsyncGridSearch](#), [OptimizerAsyncRandomSearch](#)

OptimizerBatch

Batch Optimizer

Description

Abstract OptimizerBatch class that implements the base functionality each OptimizerBatch subclass must provide. A OptimizerBatch object describes the optimization strategy. A OptimizerBatch object must write its result to the `$assign_result()` method of the [OptimInstance](#) at the end in order to store the best point and its estimated performance vector.

Progress Bars

`$optimize()` supports progress bars via the package **progress** combined with a [Terminator](#). Simply wrap the function in `progressr::with_progress()` to enable them. We recommend to use package **progress** as backend; enable with `progressr::handlers("progress")`.

Super class

`bbotk::Optimizer` -> OptimizerBatch

Methods

Public methods:

- [OptimizerBatch\\$optimize\(\)](#)
- [OptimizerBatch\\$clone\(\)](#)

Method `optimize()`: Performs the optimization and writes optimization result into [OptimInstanceBatch](#). The optimization result is returned but the complete optimization path is stored in [ArchiveBatch](#) of [OptimInstanceBatch](#).

Usage:

```
OptimizerBatch$optimize(inst)
```

Arguments:

`inst` ([OptimInstanceBatch](#)).

Returns: `data.table::data.table`.

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
OptimizerBatch$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

See Also

[OptimizerBatchDesignPoints](#), [OptimizerBatchGridSearch](#), [OptimizerBatchRandomSearch](#)

shrink_ps

*Shrink a ParamSet towards a point.***Description**

Shrinks a `paradox::ParamSet` towards a point. Boundaries of numeric values are shrunk to an interval around the point of half of the previous length, while for discrete variables, a random (currently not chosen) level is dropped.

Note that for `paradox::p_lgl()`s the value to be shrunk around is set as the default value instead of dropping a level. Also, a tag shrunk is added.

Note that the returned `paradox::ParamSet` has lost all its original defaults, as they may have become infeasible.

If the `paradox::ParamSet` has a trafo, `x` is expected to contain the transformed values.

Usage

```
shrink_ps(param_set, x, check.feasible = FALSE)
```

Arguments

<code>param_set</code>	<code>(paradox::ParamSet)</code> The <code>paradox::ParamSet</code> to be shrunk.
<code>x</code>	<code>(data.table::data.table)</code> <code>data.table::data.table</code> with one row containing the point to shrink around.
<code>check.feasible</code>	<code>(logical(1))</code> Should feasibility of the parameters be checked? If feasibility is not checked, and invalid values are present, no shrinking will be done. Must be turned off in the case of the <code>paradox::ParamSet</code> having a trafo. Default is FALSE.

Value

`paradox::ParamSet`

Examples

```
library(paradox)
library(data.table)
param_set = ps(
  x = p_dbl(lower = 0, upper = 10),
  x2 = p_int(lower = -10, upper = 10),
  x3 = p_fct(levels = c("a", "b", "c")),
  x4 = p_lgl()
)
x = data.table(x1 = 5, x2 = 0, x3 = "b", x4 = FALSE)
shrink_ps(param_set, x = x)
```

terminated_error	<i>Termination Error</i>
------------------	--------------------------

Description

Error class for termination.

Usage

```
terminated_error(optim_instance)
```

Arguments

optim_instance [OptimInstance](#)
 OptimInstance that terminated.

Value

A Mlr3ErrorBbotkTerminated condition.

Terminator	<i>Abstract Terminator Class</i>
------------	----------------------------------

Description

Abstract Terminator class that implements the base functionality each terminator must provide. A terminator is an object that determines when to stop the optimization.

Termination of optimization works as follows:

- Evaluations in a instance are performed in batches.
- Before each batch evaluation, the [Terminator](#) is checked, and if it is positive, we stop.
- The optimization algorithm itself might decide not to produce any more points, or even might decide to do a smaller batch in its last evaluation.

Therefore the following note seems in order: While it is definitely possible to execute a fine-grained control for termination, and for many optimization algorithms we can specify exactly when to stop, it might happen that too few or even too many evaluations are performed, especially if multiple points are evaluated in a single batch (c.f. batch size parameter of many optimization algorithms). So it is advised to check the size of the returned archive, in particular if you are benchmarking multiple optimization algorithms.

Technical details

Terminator subclasses can overwrite `.status()` to support progress bars via the package **progressr**. The method must return the maximum number of steps (`max_steps`) and the currently achieved number of steps (`current_steps`) as a named integer vector.

Public fields

`id` (`character(1)`)
Identifier of the object. Used in tables, plot and text output.

Active bindings

`param_set` [paradox::ParamSet](#)
Set of control parameters.

`label` (`character(1)`)
Label for this object. Can be used in tables, plot and text output instead of the ID.

`man` (`character(1)`)
String in the format `[pkg]::[topic]` pointing to a manual page for this object. The referenced help package can be opened via method `$help()`.

`properties` (`character()`)
Set of properties of the terminator. Must be a subset of `bbotk_reflections$terminator_properties`.

`unit` (`character()`)
Unit of steps.

Methods**Public methods:**

- [Terminator\\$new\(\)](#)
- [Terminator\\$format\(\)](#)
- [Terminator\\$print\(\)](#)
- [Terminator\\$status\(\)](#)
- [Terminator\\$remaining_time\(\)](#)
- [Terminator\\$clone\(\)](#)

Method `new()`: Creates a new instance of this [R6](#) class.

Usage:

```
Terminator$new(
  id,
  param_set = ps(),
  properties = character(),
  unit = "percent",
  label = NA_character_,
  man = NA_character_
)
```

Arguments:

`id` (`character(1)`)
Identifier for the new instance.

`param_set` ([paradox::ParamSet](#))
Set of control parameters.

`properties` (`character()`)
Set of properties of the terminator. Must be a subset of `bbotk_reflections$terminator_properties`.

`unit` (character())
Unit of steps.

`label` (character(1))
Label for this object. Can be used in tables, plot and text output instead of the ID.

`man` (character(1))
String in the format `[pkg]::[topic]` pointing to a manual page for this object. The referenced help package can be opened via method `$help()`.

Method `format()`: Helper for print outputs.

Usage:
`Terminator$format(with_params = FALSE, ...)`

Arguments:
`with_params` (logical(1))
Add parameter values to format string.
... (ignored).

Method `print()`: Printer.

Usage:
`Terminator$print(...)`

Arguments:
... (ignored).

Method `status()`: Returns how many progression steps are made (`current_steps`) and the amount steps needed for termination (`max_steps`).

Usage:
`Terminator$status(archive)`

Arguments:
`archive` ([Archive](#)).

Returns: named integer(2).

Method `remaining_time()`: Returns remaining runtime in seconds. If the terminator is not time-based, the remaining runtime is `Inf`.

Usage:
`Terminator$remaining_time(archive)`

Arguments:
`archive` ([Archive](#)).

Returns: integer(1).

Method `clone()`: The objects of this class are cloneable with this method.

Usage:
`Terminator$clone(deep = FALSE)`

Arguments:
`deep` Whether to make a deep clone.

See Also

Other Terminator: [mlr_terminators](#), [mlr_terminators_clock_time](#), [mlr_terminators_combo](#), [mlr_terminators_evals](#), [mlr_terminators_none](#), [mlr_terminators_perf_reached](#), [mlr_terminators_run_time](#), [mlr_terminators_stagnation](#), [mlr_terminators_stagnation_batch](#), [mlr_terminators_stagnation_hypervolume](#)

trafo_xs	<i>Calculate the transformed x-values</i>
----------	---

Description

Transforms a given `list()` to a list with transformed x values.

Usage

```
trafo_xs(xs, search_space)
```

Arguments

xs	(<code>list()</code>) List of x-values.
search_space	paradox::ParamSet Search space.

Value

`list()` with transformed x values.

trm	<i>Syntactic Sugar Terminator Construction</i>
-----	--

Description

This function complements [mlr_terminators](#) with functions in the spirit of `mlr_sugar` from **mlr3**.

Usage

```
trm(.key, ...)
trms(.keys, ...)
```

Arguments

<code>.key</code>	(character(1)) Key passed to the respective dictionary to retrieve the object.
<code>...</code>	(named list()) Named arguments passed to the constructor, to be set as parameters in the paradox::ParamSet , or to be set as public field. See mlr3misc::dictionary_sugar_get() for more details.
<code>.keys</code>	(character()) Keys passed to the respective dictionary to retrieve multiple objects.

Value

- [Terminator](#) for `trm()`.
- list of [Terminator](#) for `trms()`.

Examples

```
trm("evals", n_evals = 10)
```

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