Package ‘MOEADr’

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Type Package

Title Component-Wise MOEA/D Implementation

Description Modular implementation of Multiobjective Evolutionary Algorithms based on Decomposition (MOEA/D) [Zhang and Li (2007), <DOI:10.1109/TEVC.2007.892759>] for quick assembling and testing of new algorithmic components, as well as easy replication of published MOEA/D proposals.

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R topics documented:

box_constraints .................................................. 3
calcIGD ................................................................. 4
check_stop_criteria .................................................. 4
constraint_none ....................................................... 5
constraint_penalty ................................................... 5
constraint_vbr ........................................................ 6
create_population ................................................... 8
decomposition_mslid ............................................... 9
decomposition_sld ................................................... 10
decomposition_uniform ............................................ 11
define_neighborhood ............................................... 12
evaluate_population ................................................ 13
example_problem .................................................... 14
find_nondominated_points ....................................... 14
generate_weights ................................................... 15
get_constraint_methods .......................................... 16
get_decomposition_methods ..................................... 16
get_localsearch_methods ........................................ 17
get_scalarization_methods ....................................... 18
get_stop_criteria .................................................. 18
get_update_methods ............................................... 19
get_variation_operators ......................................... 20
ls_dvls ................................................................. 20
ls_tpqa .............................................................. 22
make_vectorized_smoof .......................................... 23
moead ................................................................. 24
order_neighborhood .............................................. 29
perform_variation .................................................. 30
plot.moeadoutput .................................................. 30
preset_moead ........................................................ 31
print_progress ...................................................... 33
scalarization_awt .................................................. 33
scalarization_ipbi ................................................. 34
scalarization_pbi ................................................. 35
scalarization_ws .................................................... 36
scalarization_wt .................................................... 37
scalarize_values .................................................... 38
scale_objectives ................................................... 39
stop_maxeval ....................................................... 39
stop_maxiter ....................................................... 40
stop_maxtime ....................................................... 41
summary.moeadoutput ............................................ 42
unitary_constraints ............................................... 43
update_population ................................................ 43
updt_best .......................................................... 44
updt_restricted ..................................................... 45
**Description**

Calculates the constraint values and violations when only box constraints are present.

**Usage**

```
box_constraints(X, ...)
```

**Arguments**

- `X` Population matrix of the MOEA/D (each row is a candidate solution). If NULL, the function searches for `X` in the calling environment.
- `...` other parameters (unused, included for compatibility with generic call)

**Details**

This routine calculates the constraint values and violations for a population matrix in the MOEA/D. Each row of the matrix is considered as a candidate solution. This routine expects the candidate solutions to be standardized, i.e., that the variable limits given in `problem$xmin` and `problem$xmax` are mapped to 0 and 1, respectively.

**Value**

List objective containing a matrix of constraint values `cmatrix`, a matrix of individual constraint violations `vmatrix`, and a vector of total constraint violations `v`. 
calcIGD  

**Inverted Generational Distance**

**Description**

Calculate IGD

**Usage**

```r
calcIGD(Y, Yref)
```

**Arguments**

- `Y`  
  Matrix of points in the objective space

- `Yref`  
  Matrix of Pareto-optimal reference points

**Value**

-  `igd` value (scalar)

---

check_stop_criteria  

*Stop criteria for MOEA/D*

**Description**

Verifies stop criteria for the MOEA/D package.

**Usage**

```r
check_stop_criteria(stopcrit, call.env)
```

**Arguments**

- `stopcrit`  
  list containing the parameters defining the stop handling method. See Section Constraint Handling of the `moead()` documentation for details.

- `call.env`  
  List vector containing the stop criteria to be used. See `moead()` for details.

**Details**

This routine is intended to be used internally by `moead()`, and should not be called directly by the user.

**Value**

- `keep.running`, indicating whether the algorithm should continue (TRUE) or terminate (FALSE).
**constraint_none**

### NULL constraint handling method for MOEA/D

**Description**
Construct the preference index matrix based only on performance values.

**Usage**
```plaintext
constraint_none(B, bigZ, bigV, ...)
```

**Arguments**
- `B`: Matrix of neighborhoods (generated by `define_neighborhood(...)`)
- `bigZ`: Matrix of scalarized objective values for each neighborhood and the incumbent solution (generated by `scalarize_values`)
- `bigV`: Matrix of violation values for each neighborhood and the incumbent solution
- `...`: Other parameters (unused, included for compatibility with generic call)

**Details**
This function ignores the violation values when constructing the preference index matrix, using only the scalarized performance values.

**Value**

\[
\begin{bmatrix}
N \\
\times \\
(T+1)
\end{bmatrix}
\] matrix of preference indices. Each row \(i\) contains a permutation of \(\{1, 2, \ldots, (T+1)\}\), where \(1, \ldots, T\) correspond to the solutions contained in the neighborhood of the \(i\)-th subproblem, \(B[i, ]\), and \(T+1\) corresponds to the incumbent solution for that subproblem. The order of the permutation is defined by the increasing values of \(f(x_k)\), where \(f(x_k)\) is the aggregation function value of the \(k\)-th solution being compared.

---

**constraint_penalty**

### "Penalty" constraint handling method for MOEA/D

**Description**
Uses the Penalty Function constraint handling method to generate a preference index for the MOEADr framework.

**Usage**
```plaintext
constraint_penalty(B, bigZ, bigV, beta, ...)
```
Arguments

- **B**: Matrix of neighborhoods (generated by `define_neighborhood()`)
- **bigZ**: Matrix of scalarized objective values for each neighborhood and the incumbent solution (generated by `scalarize_values()`)
- **bigV**: Matrix of violation values for each neighborhood and the incumbent solution (generated in `order_neighborhood()`)
- **beta**: Penalization constant (non-negative value)
- **...**: other parameters (unused, included for compatibility with generic call)

Details

This function calculates the preference index of a set of neighborhoods based on the "penalty" constraint handling method. Please see `order_neighborhood()` for more information on the preference index matrix.

Value

A matrix of preference indices. Each row contains a permutation of \{1, 2, \ldots, (T+1)\}, where 1, \ldots, T correspond to the solutions contained in the neighborhood of the i-th subproblem, B[i, :) \], and T+1 corresponds to the incumbent solution for that subproblem. The order of the permutation is defined by the increasing values of \(f(x_k) + \beta \cdot v(x_k)\), where \(f(x_k)\) is the aggregation function value of the k-th solution being compared, and \(v(x_k)\) is its total constraint violation (calculated in `evaluate_population()`).

Description

Uses the Violation-based Ranking handling method to generate a preference index for the MOEADr framework.

Usage

```r
constraint_vbr(bigZ, bigV, type = c("ts", "sr", "vt"), pf = NULL, ...)
```

Arguments

- **bigZ**: Matrix of scalarized objective values for each neighborhood and the incumbent solution (generated by `scalarize_values()`)
- **bigV**: Matrix of violation values for each neighborhood and the incumbent solution (generated in `order_neighborhood()`)
- **type**: type of c(x) function to use (see c(x) Criteria for details).
- **pf**: probability parameter for type = "sr" (ignored in other modes).
- **...**: other parameters (unused, included for compatibility with generic call)
Details

This function calculates the preference index of a set of neighborhoods based on the "violation-based ranking" (VBR) constraint handling method. Please see order_neighborhood() for more information on the preference index matrix.

The VBR strategy generalizes some well-known methods for handling constraints in population-based metaheuristics (see Section c(x) Criteria). This strategy essentially ranks points within a given subproblem based on their aggregated function value ($f^{agg}(x|w_i)$) or their total constraint violation ($v(x)$). Specific variations of this strategy differ on the criteria for using one or the other.

The value used for ranking a given point $x$ can be summarized as:

<table>
<thead>
<tr>
<th>Violation</th>
<th>$c(x)$ criterion</th>
<th>Rank using:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$v(x) &gt; 0$</td>
<td>$c(x) ==$ TRUE</td>
<td>$f^{agg}(x</td>
</tr>
<tr>
<td>$v(x) &gt; 0$</td>
<td>$c(x) ==$ FALSE</td>
<td>$f^{agg}(x</td>
</tr>
</tbody>
</table>

Points compared according to their $f^{agg}(x|w_i)$ values (i.e., feasible points and those for which $c(x) =$ TRUE) are ranked first (i.e., receive ranks between 1 and $n_{feas}$, where $n_{feas}$ is the number of feasible points in the i-th neighborhood), with points that are compared according to their $v(x)$ values receiving ranks between ($n_{feas} + 1$) and $T + 1$ ($T$ being the size of the neighborhood. The +1 comes from including the incumbent solution in the comparison).

Value

$[ N \times (T+1) ]$ matrix of preference indices. Each row $i$ contains a permutation of $\{1, 2, \ldots, (T+1)\}$, where 1,...,$T$ correspond to the solutions contained in the neighborhood of the i-th subproblem, $B[i, ]$, and $T+1$ corresponds to the incumbent solution for that subproblem. The order of the permutation is defined by the specific strategy defined by the input variable type).

$c(x)$ Criteria

Specific variations of the VBR differ on how the criterion $c(x)$ is implemented. Three variants are currently implemented in the MOEADr package:

<table>
<thead>
<tr>
<th>Method</th>
<th>ID</th>
<th>$c(x)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tournament Selection [Deb2000]</td>
<td>$s$type = &quot;ts&quot;</td>
<td>FALSE</td>
</tr>
<tr>
<td>Stochastic Ranking [Runarsson2000]</td>
<td>$s$type = &quot;sr&quot;</td>
<td>runif() &lt; pf</td>
</tr>
<tr>
<td>Violation Threshold [Asafuddoula2014]</td>
<td>$s$type = &quot;vt&quot;</td>
<td>$v(x) &lt; \text{eps}_v^i$</td>
</tr>
</tbody>
</table>

where $pf \in [0, 1]$ is a user-defined parameter for the "sr" method, and $\text{eps}_v^i$ is subproblem-dependent, adaptive quantity calculated internally in the routine (see [Asafuddoula2014] and [Campelo2017] for details).
Using an External Archive

For types "sr" and "vt", it is possible for the algorithm to lose feasible solutions during its update step, since there is a non-zero probability of unfeasible solutions replacing feasible ones. In these cases, it is recommended to set the `moead()` parameter `updateUseArchive = TRUE`, so that an external archive is built with the best feasible solutions found for each subproblem.

References


create_population

Create population

Description

Create a population for the MOEADr package

Usage

create_population(N, problem)

Arguments

N population size

problem list of named problem parameters. See Section Problem Description of the moead() documentation for details.

Details

This routine creates a population matrix for the MOEA/D. Currently only a multivariate uniform distribution is implemented. All points are created within the standardized space $0 \leq x_i \leq 1$, $i = 1, \ldots, n_v$.

Value

A population matrix X for the MOEA/D.
decomposition_msld

Description

Problem Decomposition using Multi-layered Simplex-lattice Design for MOEADr package

Usage

decomposition_msld(decomp, ...)

Arguments

decomp

list containing the relevant decomposition parameters. Besides decomp$name = "msld", this method requires the definition of the following key-value pairs in decomp:

• decomp$H: array of positive integers representing the H values to be used by the SLD decomposition at each layer (see decomposition_sld() for details).
• decomp$tau: array of scale multipliers for each layer, 0 < \tau_i \leq 1, \tau_i \neq \tau_j for all i \neq j. Must have the same length as decomp$H.
• decomp$obj: integer value, decomp$obj > 1. Number of objectives of the problem.

... other parameters (included for compatibility with generic call)

Details

This routine calculates the weight vectors for the MOEA/D using the Multi-layered Simplex-lattice Design.

References


Examples

decomp <- list(name = "msld", H = c(5, 3), tau = c(0.9, 0.5), .obj = 4)
W <- decomposition_msld(decomp)
Problem Decomposition using Simplex-lattice Design

Description

Problem Decomposition using Simplex-lattice Design for MOEADr package

Usage

decomposition_sld(decomp, ...)

Arguments

decomp : list containing the relevant decomposition parameters. Besides decomp$name = "sld", this method requires the definition of the following key-value pairs:

- decomp$H, decomposition constant. Suggested values for decomp$H are (use with caution):

<table>
<thead>
<tr>
<th>m</th>
<th>H</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>99</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>91</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>210</td>
</tr>
</tbody>
</table>

It is important to highlight that the number of vectors generated (N) must be greater than the number of neighbors declared in neighbors$T (see moead() for details).

- decomp$obj: integer value, decomp$obj > 1. Number of objectives of the problem.

... other parameters (included for compatibility with generic call)

Details

This routine calculates the weight vectors for the MOEA/D using the Simplex-lattice Design.

References


Examples

decomp <- list(name = "sld", H = 99, .obj = 2)
W <- decomposition_sld(decomp)
Problem Decomposition using Uniform Design

Description

Problem Decomposition using Uniform Design for MOEAdr package

Usage

decomposition_uniform(decomp, ...)

Arguments

decomp list containing the relevant decomposition parameters. Besides decomp$name = "uniform", this method requires the definition of the following key-value pairs:

- decomp$N, number of subproblems to generate. It is important to highlight that the number of subproblems must be greater than the number of neighbors declared in neighbors$T (see moead() for details).
- decomp$.nobj: integer value, decomp$.nobj > 1. Number of objectives of the problem.

... other parameters (included for compatibility with generic call)

Details

This routine calculates the weight vectors for the MOEA/D using the Uniform Design:

References


Examples

decomp <- list(name = "uniform", N = 50, .nobj = 3)
W <- decomposition_uniform(decomp)
**define_neighborhood**  
*Calculate neighborhood relations*

**Description**

Calculates neighborhood relations for the MOEADr package.

**Usage**

```r
define_neighborhood(neighbors, v.matrix, iter)
```

**Arguments**

- `neighbors`: List containing the decomposition method parameters. This list must contain the following key-value pairs:
  - `neighbors$name`, type of neighborhood to use. The following types are currently available:
    - `neighbors$name = "lambda"`: defines the neighborhood using the distance matrix for the weight vectors. The calculation is performed only once for the entire run.
    - `neighbors$name = "x"`: defines the neighborhood using the distance matrix for the incumbent solution associated with each subproblem. In this case the calculation is performed at each iteration.
  - `neighbors$t`: Neighborhood size. The value of `neighbors$t` must be smaller than the number of subproblems.
  - `neighbors$delta.p`: Probability of sampling from the neighborhood when performing variation. Must be a scalar value between 0 and 1.
- `v.matrix`: matrix of vectors to be used for defining the neighborhoods.
- `iter`: iteration counter of the MOEA/D

**Details**

This routine calculates the neighborhood relations for the MOEA/D.

**Warning**: this routine may access (but not directly modify) variables from the calling environment.

**Value**

List containing the matrix of selection probabilities ($P$) and the matrix of neighborhoods ($B$).
**evaluate_population**

**Evaluate population**

**Description**

Evaluate a population matrix on the objective functions for the MOEADr package

**Usage**

`evaluate_population(X, problem, nfe)`

**Arguments**

- **X**: Population matrix of the MOEA/D (each row is a candidate solution).
- **problem**: list of named problem parameters. See Section Problem Description of the moead() documentation for details.
- **nfe**: counter of function evaluations from the moead() routine.

**Details**

This routine evaluates a population matrix for the MOEA/D. Each row of the matrix is considered as a candidate solution. This routine expects the candidate solutions to be standardized, i.e., that the variable limits given in `problem$xmin` and `problemxmax` are mapped to 0 and 1, respectively.

**Value**

List object containing the matrix of objective function values, a list object containing information about the constraint violations (a matrix of constraint values `cmatrix`, a matrix of constraint violations `vmatrix`, and a vector of total violations `v`), and the updated counter `nfe`.

**Examples**

```r
ex.problem <- list(name = "example_problem",
xmin = rep(-1, 5),
xmax = rep(1, 5),
m = 2)
X <- create_population(20, ex.problem)
Y <- evaluate_population(X, ex.problem, nfe = 0)
```
### example_problem

**Example problem**

**Description**

Example problem - minimization of shifted sphere and rastrigin functions.

**Usage**

```r
example_problem(X)
```

**Arguments**

- `X`: population matrix (see `moead()` for details)

**Value**

Matrix of objective function values

### find_nondominated_points

**Find non-dominated points**

**Description**

Non-dominated point finding for minimization problems

**Usage**

```r
find_nondominated_points(Y)
```

**Arguments**

- `Y`: row matrix of points in the space of objectives.

**Details**

Non-dominated point finding, based on portions of function `fastNonDomatedSorting` from package NSGA2R ([https://CRAN.R-project.org/package=nsga2R](https://CRAN.R-project.org/package=nsga2R))

**Value**

logical vector of length `nrow(Y)` indicating the non-dominated points as TRUE.
generate_weights

Calculate weight vectors

Description

Calculates weight vectors for the MOEADr package

Usage

generate_weights(decomp, m, ...)

Arguments

decomp List containing the decomposition method parameters. See moead() for details.
m Number of objectives \((m \geq 2)\)
...
other parameters (included for compatibility with generic call)

Details

This routine calculates the weight vectors for the MOEA/D. The list of available methods for generating the weights, as well as information about their specific parameters, can be generated using get_decomposition_methods().

Value

Weight matrix \(W\)

Examples

decomp <- list(name = "sld", H = 99)
W <- generate_weights(decomp, m = 2)
get_constraint_methods

Print available constraint methods

Description
Prints the constraint handling methods available in the MOEADr package

Usage
get_constraint_methods()

Details
This routine prints the names of the constraint handling methods available in the MOEADr package, to be used as the constraint$name parameter in the moead(...) call. Instructions for obtaining more info on each operator are also returned.

Value
Formatted data frame containing reference name (for constraint$name) and instructions for More Info about each method.

Examples
get_constraint_methods()

get_decomposition_methods

Print available decomposition methods

Description
Prints the decomposition methods available in the MOEADr package

Usage
get_decomposition_methods()

Details
This routine prints the names of the decomposition methods available in the MOEADr package, to be used as the decomp$name parameter in the moead(...) call. Instructions for obtaining more info on each operator are also returned.
get_localsearch_methods

Value

Formatted data frame containing reference name (for decomp$name) and instructions for More Info about each method.

Examples

get_decomposition_methods()

---

get_localsearch_methods

*Print available local search methods*

Description

Prints the local search methods available in the MOEADr package

Usage

get_localsearch_methods()

Details

This routine prints the names of the local search methods available in the MOEADr package, to be used as the aggfun$name parameter in the moead(...) call. Instructions for obtaining more info on each operator are also returned.

Value

Formatted data frame containing reference name (for variation$localsearch$type) and instructions for More Info about each method.

Examples

get_localsearch_methods()
get_scalarization_methods

*Print available scalarization methods*

**Description**

Prints the scalarization methods available in the MOEADr package

**Usage**

`get_scalarization_methods()`

**Details**

This routine prints the names of the scalarization methods available in the MOEADr package, to be used as the `aggfun$name` parameter in the `moead(...)` call. Instructions for obtaining more info on each operator are also returned.

**Value**

Formatted data frame containing reference name (for `aggfun$name`) and instructions for More Info about each method.

**Examples**

`get_scalarization_methods()`

---

get_stop_criteria

*Print available stop criteria*

**Description**

Prints the stop criteria available in the MOEADr package

**Usage**

`get_stop_criteria()`

**Details**

This routine prints the names of the stop criteria available in the MOEADr package, to be used as the `stopcrit[[i]]$name` parameter in the `moead(...)` call. Instructions for obtaining more info on each criterion are also returned.
Value

Formatted data frame containing reference name (for \texttt{stopcrit[[i]]$name}) and instructions for More Info about each criterion.

Examples

\texttt{get_stop_criteria()}

---

\texttt{get_update_methods} \hspace{1cm} \textit{Print available update methods}

Description

Prints the update methods available in the MOEADr package

Usage

\texttt{get_update_methods()}

Details

This routine prints the names of the update methods available in the MOEADr package, to be used as the \texttt{update$name} parameter in the \texttt{moead(...) }call. Instructions for obtaining more info on each operator are also returned.

Value

Formatted data frame containing reference name (for \texttt{update$name}) and instructions for More Info about each method.

Examples

\texttt{get_update_methods()}

get_variation_operators

*Print available variation operators*

**Description**

Prints the variation operators available in the MOEADr package

**Usage**

```r
get_variation_operators()
```

**Details**

This routine prints the names of the variation operators available in the MOEADr package, to be used as the `variation$name` parameter in the `moead(...)` call. Instructions for obtaining more info on each operator are also returned.

**Value**

Formatted data frame containing reference name (for `variation$name`) and instructions for More Info about each operator.

**Examples**

```r
get_variation_operators()
```

---

**ls_dvls**

*Differential vector-based local search*

**Description**

Differential vector-based local search (DVLS) implementation for the MOEA/D

**Usage**

```r
ls_dvls(Xt, Yt, Vt, B, W, which.x, trunc.x, problem, scaling, aggfun, constraint, ...)
```
Arguments

- **xt**: Matrix of incumbent solutions
- **yt**: Matrix of objective function values for xt
- **vt**: List object containing information about the constraint violations of the incumbent solutions, generated by `evaluate_population()`
- **B**: Neighborhood matrix, generated by `define_neighborhood()`. 
- **W**: Matrix of weights (generated by `generate_weights()`).
- **which.x**: Logical vector indicating which subproblems should undergo local search
- **trunc.x**: Logical flag indicating whether candidate solutions generated by local search should be truncated to the variable limits of the problem.
- **problem**: List of named problem parameters. See Section Problem Description of the `moead()` documentation for details.
- **scaling**: List containing the scaling parameters (see `moead()` for details).
- **aggfun**: List containing the aggregation function parameters. See Section Scalar Aggregation Functions of the `moead()` documentation for details.
- **constraint**: List containing the parameters defining the constraint handling method. See Section Constraint Handling of the `moead()` documentation for details.
- **...**: Other parameters (included for compatibility with generic call)

Details

This routine implements the differential vector-based local search for the MOEADr package. Check the references for details.

This routine is intended to be used internally by `variation_localsearch()`, and should not be called directly by the user.

Value

List object with fields `X` (matrix containing the modified points, with points that did not undergo local search indicated as NA) and `nfe` (integer value informing how many additional function evaluations were performed).

References

ls_tpqa

Three-point quadratic approximation local search

Description

Three-point quadratic approximation (TPQA) local search implementation for the MOEA/D

Usage

ls_tpqa(Xt, Yt, W, B, Vt, scaling, aggfun, constraint, epsilon = 1e-06, which.x, ...)

Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xt</td>
<td>Matrix of incumbent solutions</td>
</tr>
<tr>
<td>Yt</td>
<td>Matrix of objective function values for Xt</td>
</tr>
<tr>
<td>W</td>
<td>matrix of weights (generated by generate_weights())</td>
</tr>
<tr>
<td>B</td>
<td>Neighborhood matrix, generated by define_neighborhood()</td>
</tr>
<tr>
<td>Vt</td>
<td>List object containing information about the constraint violations of the incumbent solutions, generated by evaluate_population()</td>
</tr>
<tr>
<td>scaling</td>
<td>list containing the scaling parameters (see moead() for details).</td>
</tr>
<tr>
<td>aggfun</td>
<td>List containing the aggregation function parameters. See Section Scalar Aggregation Functions of the moead() documentation for details.</td>
</tr>
<tr>
<td>constraint</td>
<td>list containing the parameters defining the constraint handling method. See Section Constraint Handling of the moead() documentation for details.</td>
</tr>
<tr>
<td>epsilon</td>
<td>threshold for using the quadratic approximation value</td>
</tr>
<tr>
<td>which.x</td>
<td>logical vector indicating which subproblems should undergo local search</td>
</tr>
<tr>
<td>...</td>
<td>other parameters (included for compatibility with generic call)</td>
</tr>
</tbody>
</table>

Details

This routine implements the 3-point quadratic approximation local search for the MOEADr package. Check the references for details.

This routine is intended to be used internally by variation_localsearch(), and should not be called directly by the user.

Value

Matrix $X'$ containing the modified population
make_vectorized_smoof

References


make_vectorized_smoof Make vectorized smoof function

Description

Make a vectorized version of test functions available in package "smoof".

Usage

make_vectorized_smoof(prob.name, ...)

Arguments

prob.name name of the problem to build
...
other parameters passed to each specific function

Details

This routine builds MOEADr-compliant versions of the classic multiobjective test functions available in package smoof. The most commonly used ones are:

- prob.name = ZDT1, ..., ZDT6, in which case the function requires additional parameter dimensions (positive integer)
- prob.name = DTLZ1, ..., DTLZ7, in which case the function requires additional parameters dimensions (positive integer), n.objectives (= 2 or 3) and, for DTLZ4, alpha (positive integer, defaults to 100).
- prob.name = UF, in which case the function requires additional parameters dimensions (positive integer) and id (= 1, ..., 10).

Examples

```r
## Not run:
library(smoof)
DTLZ2 <- make_vectorized_smoof(prob.name = "DTLZ2",
                               dimensions = 10,
                               n.objectives = 2)
DTLZ2(X = matrix(runif(100), ncol = 10))

## End(Not run)
```
Description

MOEA/D implementation in R

Usage

moead(preset = NULL, problem = NULL, decomp = NULL, aggfun = NULL, neighbors = NULL, variation = NULL, update = NULL, constraint = NULL, scaling = NULL, stopcrit = NULL, showpars = NULL, seed = NULL, ...)

Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>preset</td>
<td>List object containing preset values for one or more of the other parameters of the moead function. Values provided in the preset list will override any other value provided. Presets should be generated by the <code>preset_moead()</code> function.</td>
</tr>
<tr>
<td>problem</td>
<td>List containing the problem parameters. See Problem Description for details.</td>
</tr>
<tr>
<td>decomp</td>
<td>List containing the decomposition method parameters See Decomposition methods for details.</td>
</tr>
<tr>
<td>aggfun</td>
<td>List containing the aggregation function parameters See Scalarization methods for details.</td>
</tr>
<tr>
<td>neighbors</td>
<td>List containing the decomposition method parameters See Neighborhood strategies for details.</td>
</tr>
<tr>
<td>variation</td>
<td>List containing the variation operator parameters See Variation operators for details.</td>
</tr>
<tr>
<td>update</td>
<td>List containing the population update parameters See Update strategies for details.</td>
</tr>
<tr>
<td>constraint</td>
<td>List containing the constraint handing parameters See Constraint operators for details.</td>
</tr>
<tr>
<td>scaling</td>
<td>List containing the objective scaling parameters See Objective scaling for details.</td>
</tr>
<tr>
<td>stopcrit</td>
<td>List containing the stop criteria parameters. See Stop criteria for details.</td>
</tr>
<tr>
<td>showpars</td>
<td>List containing the echoing behavior parameters. See <code>print_progress()</code> for details.</td>
</tr>
<tr>
<td>seed</td>
<td>Seed for the pseudorandom number generator. Defaults to NULL, in which case <code>as.integer(Sys.time())</code> is used for the definition.</td>
</tr>
<tr>
<td>...</td>
<td>Other parameters (useful for development and debugging, not necessary in regular use)</td>
</tr>
</tbody>
</table>

Details

Component-wise implementation of the Multiobjective Evolutionary Algorithm based on decomposition - MOEA/D.
Value

List object of class `moeadoutput` containing:

- information on the final population \((x)\), its objective values \((y)\) and constraint information list \((v)\) (see `evaluate_population()` for details);
- Archive population list containing its corresponding \(x\), \(y\) and \(v\) fields (only if `update$UseArchive` = TRUE).
- Estimates of the \textit{ideal} and \textit{nadir} points, calculated for the final population;
- Number of function evaluations, iterations, and total execution time;
- Random seed employed in the run, for reproducibility

Problem Description

The `problem` parameter consists of a list with all necessary definitions for the multiobjective optimization problem to be solved. `problem` must contain at least the following fields:

- `problem$name`: name of the problem instance function, that is, a routine that calculates \(Y = f(X)\);
- `problem$xmin`: vector of lower bounds of each variable
- `problemxmax`: vector of upper bounds of each variable
- `problem$m`: integer indicating the number of objectives

Besides these fields, `problem` should contain any other relevant inputs for the routine listed in `$name`. `problem` may also contain the (optional) field `problem$constraints`, which is a list object containing information about the problem constraints. If present, this list must have the following fields:

- `problem$constraints$name` - (required) name of the function that calculates the constraint values (see below for details)
- `problem$constraints$epsilon` - (optional) a small non-negative value indicating the tolerance to be considered for equality constraints. Defaults to zero.

Besides these fields, `problem$constraint` should contain any other relevant inputs for the routine listed in `problem$constraint$name`.

Detailed instructions for defining the routines for calculating the objective and constraint functions are provided in the vignette \textit{Defining Problems in the MOEADr Package}. Check that documentation for details.

Decomposition Methods

The `decomp` parameter is a list that defines the method to be used for the generation of the weight vectors. `decomp` must have at least the `$name` parameter. Currently available methods can be verified using `get_decomposition_methods()`. Check `generate_weights()` and the information provided by `get_decomposition_methods()` for more details.
Neighborhood Strategies

The neighbors parameter is a list that defines the method for defining the neighborhood relations among subproblems. neighbors must have at least three parameters:

- **neighbors$name**, name of the strategy used to define the neighborhoods. Currently available methods are: - $name = "lambda": uses the distances between weight vectors. The calculation is performed only once for the entire run, since the weight vectors are assumed static. - $name = "x": uses the distances between the incumbent solutions associated with each subproblem. In this case the calculation is performed at each iteration, since incumbent solutions may change.
- **neighbors$t**: defines the neighborhood size. This parameter must receive a value smaller than the number of subproblems defined for the MOEA/D.
- **neighbors$delta_p**: parameter that defines the probability of sampling from the neighborhood when performing variation.

Check `define_neighborhood()` for more details.

Variation Operators

The variation parameter consists of a list vector, in which each sublist defines a variation operator to be used as part of the variation block. Each sublist must have at least a field $name, containing the name of the i-th variation operator to be applied. Use `get_variation_operators()` to generate a list of available operators, and consult the vignette Variation Stack in the MOEA/Dr Package for more details.

Scalar Aggregation Functions

The aggfun parameter is a list that defines the scalar aggregation function to be used. aggfun must have at least the $name parameter. Currently available methods can be verified using `get_scalarization_methods()`. Check `scalarize_values()` and the information provided by `get_scalarization_methods()` for more details.

Update Methods

The update parameter is a list that defines the population update strategy to be used. update must have at least the $name parameter. Currently available methods can be verified using `get_update_methods()`. Check `update_population()` and the information provided by `get_update_methods()` for more details.

Another (optional) field of the update parameter is update$UseArchive, which is a binary flag defining whether the algorithm should keep an external solution archive (TRUE) or not (FALSE). Since it adds to the computational burden and memory requirements of the algorithm, the use of an archive population is recommended only in the case of constrained problems with constraint handling method that can occasionally accept unfeasible solutions, leading to the potential loss of feasible efficient solutions for certain subproblems (e.g., `constraint_vbr()` with type = "sr" or "vt").
Constraint Handling Methods

The constraint parameter is a list that defines the constraint-handling technique to be used. constraint must have at least the $name parameter. Currently available methods can be verified using \texttt{get_constraint_methods()}. Check \texttt{update_population()} and the information provided by \texttt{get_constraint_methods()} for more details.

Objective Scaling

Objective scaling refers to the re-scaling of the objective values at each iteration, which is generally considered to prevent problems arising from differently-scaled objective functions. scaling is a list that must have at least the $name parameter. Currently available options are $name = "none", which does not perform any scaling, and $name = "simple", which performs a simple linear scaling of the objectives to the interval [0, 1].

Stop Criteria

The \texttt{stopcrit} parameter consists of a list vector, in which each sublist defines a termination criterion to be used for the MOEA/D. Each sublist must have at least a field $name, containing the name of the i-th criterion to be verified. The iterative cycle of the MOEA/D is terminated whenever any criterion is met. Use \texttt{get_stop_criteria()} to generate a list of available criteria, and check the information provided by that function for more details.

Echoing Options

The \texttt{showpars} parameter is a list that defines the echoing options of the MOEA/D. \texttt{showpars} must contain two fields:

- \texttt{showpars$show.iters}, defining the type of echoing output. \texttt{show.iters} can be set as "none", "numbers", or "dots".
- \texttt{showpars$show.every}, defining the period of echoing (in iterations). \texttt{show.every} must be a positive integer.

References


Examples

```r
## Prepare a test problem composed of minimization of the (shifted)
## sphere and Rastrigin functions

sphere <- function(x) {sum((x + seq_along(x) * 0.1) ^ 2)}
rastringin <- function(x) {
  x.shift <- x - seq_along(x) * 0.1
  sum((x.shift) ^ 2 - 10 * cos(2 * pi * x.shift) + 10)
}
problem.sr <- function(X) {
  t(apply(X, MARGIN = 1, FUN = function(X){c(sphere(X), rastringin(X))))}
```
## Set the input parameters for the moead() routine
## This reproduces the Original MOEA/D of Zhang and Li (2007)
## (with a few changes in the computational budget, to make it run faster)

```r
problem <- list(name = "problem sr",
               xmin = rep(-1, 30),
               xmax = rep(1, 30),
               m = 2)
decom <- list(name = "SLD", H = 49) # <-- H = 99 in the original
neighbors <- list(name = "lambda",
                   T = 20,
                   delta.p = 1)
aggfun <- list(name = "wt")
variation <- list(name = "sbx",
                  etax = 20, pc = 1),
              list(name = "polymut",
                  etam = 20, pm = 0.1),
              list(name = "truncate")
update <- list(name = "standard", UseArchive = FALSE)
scaling <- list(name = "none")
constraint <- list(name = "none")
stopcrit <- list(name = "maxiter",
                 maxiter = 50)) # <-- maxiter = 200 in the original
showpars <- list(show.iters = "dots",
                 showevery = 10)
seed <- 42
```

## Run MOEA/D

```r
out1 <- moead(preset = NULL,
              problem, decomp, aggfun, neighbors, variation, update,
              constraint, scaling, stopcrit, showpars, seed)
```

## Examine the output:

```r
summary(out1)
```

## Alternatively, the standard MOEA/D could also be set up using the
## preset_moea() function. The code below runs the original MOEA/D with
## exactly the same configurations as in Zhang and Li (2007).

## Not run:

```r
out2 <- moead(preset = preset_moea("original"),
              problem = problem,
              showpars = showpars,
              seed = 42)
```

## Examine the output:

```r
summary(out2)
plot(out2, suppress.pause = TRUE)
```

## End(Not run)

# Rerun with MOEA/D-DE configuration and AWT scalarization

```r
out3 <- moead(preset = preset_moea("moea.de"),
              problem = problem,
              aggfun = list(name = "awt"),
```
order_neighborhood

Description

Calculates the ordering of competing solutions for each subproblem in the MOEA/D, based on their scalarized performance and violation values.

Usage

order_neighborhood(bigZ, B, V, Vt, constraint)

Arguments

- bigZ: Matrix of scalarized performance values by neighborhood, generated by `scalarize_values()`
- B: Neighborhood matrix, generated by `define_neighborhood()`
- V: List object containing information about the constraint violations of the candidate solutions, generated by `evaluate_population()`
- Vt: List object containing information about the constraint violations of the incumbent solutions, generated by `evaluate_population()`
- constraint: list containing the parameters defining the constraint handling method. See Section Constraint Handling of the `moead()` documentation for details.

Details

This routine receives a matrix of scalarized performance values (returned by `scalarize_values()`), a neighborhood matrix, and the list of violation values for the candidate and incumbent populations. It calculates the preference order of the candidates for each neighborhood based on the performance values and constraint handling method.

The list of available constraint handling methods can be generated using `get_constraint_methods()`.

Value

$[N \times (T+1)]$ matrix of preference indexes. Each row contains the T indexes of the candidate solutions in the neighborhood of a given subproblem, plus a value (column T+1) for the incumbent solution of that subproblem, in an order defined by the constraint handling method specified in `moead.env$constraint`.

```r
stopcrit = list(name = "maxiter", 
                maxiter = 50),
seed = seed)
plot(out3, suppress.pause = TRUE)
```
perform_variation  
*Run variation operators*

**Description**

Sequentially apply variation operators for the MOEADr package

**Usage**

```r
perform_variation(variation, X, iter, ...)
```

**Arguments**

- `variation`: List vector containing the variation operators to be used. See `moead()` for details.
- `X`: Population matrix of the MOEA/D (each row is a candidate solution).
- `iter`: Iterations counter of the `moead()` function.
- `...`: Other parameters to be passed down to the individual variation operators (see documentation of the specific `variation_.xyz()` functions for details).

**Details**

This routine performs the variation block for the MOEA/D. The list of available variation operators can be generated using `get_variation_operators()`.

If the `localsearch` operator is included, it is executed whenever its conditions (period of occurrence or probability of occurrence) are verified. See `variation_localsearch()` for details.

**Value**

List object containing a modified population matrix `X`, a local search argument list `ls.arg`, and the number of function evaluations used by the variation operators, `var.nfe`.

---

**plot.moeadoutput**

**Description**

S3 method for plotting `moeadoutput` objects (the output of `moead()`).

**Usage**

```r
# S3 method for class 'moeadoutput'
plot(x, ..., useArchive = FALSE, feasible.only = TRUE,
     viol.threshold = 1e-06, nondominated.only = TRUE, plot.weights = FALSE,
     which.objectives = NULL, suppress.pause = FALSE, color.by.obj = 1)
```
Arguments

- **x**: list object of class `moeadoutput` (generated by `moead()`)
- **...**: other parameters to be passed down to specific plotting functions (currently unused)
- **useArchive**: logical flag to use information from x$Archive. Only used if x$Archive is not NULL.
- **feasible.only**: logical flag to use only feasible points in the plots.
- **viol.threshold**: threshold of tolerated constraint violation, used to determine feasibility if feasible.only == TRUE.
- **nondominated.only**: logical flag to use only nondominated points in the plots.
- **plot.weights**: logical flag to plot the weight vectors for 2 and 3-objective problems.
- **which.objectives**: integer vector of which objectives to plot. Defaults to NULL (use all objectives)
- **suppress.pause**: logical flag to prevent pause messages from being show after every image. Defaults to FALSE (show pause messages)
- **color.by.obj**: integer, determines which objective is used as the basis for coloring the parallel coordinates plot.

Examples

```r
problem.1 <- list(name = "example_problem",
                   xmin = rep(-1,30),
                   xmax = rep(1,30),
                   m = 2)
out <- moead(preset = preset_moead("original2"),
             problem = problem.1,
             stopcrit = list(list(name = "maxiter",
                                  maxiter = 100)),
             showpars = list(show.ites = "dots",
                             showevery = 10))
plot(out, suppress.pause = TRUE)
```

Description

Generate a preset configuration for moead().

Usage

```r
preset_moead(name = NULL)
```
Arguments

name  name of the preset to be generated. Use preset_moead() to obtain the list of available options.

Details

This function returns a list of configuration presets taken from the literature to be used with the moead() function in package MOEAdr.

Use these configurations as a starting point. We strongly recommend that you play around with the particular configurations (see example).

Value

List object containing the preset, to be used as an input to moead(): or, if name == NULL (the default), returns a logical flag invisibly.

Examples

```r
# Generate list of available presets
preset_moead(name = NULL)

## Not run:
library(smoof) # < Install package smoof if needed
ZDT1 <- make_vectorized_smoof(prob.name = "ZDT1",
   dimensions = 30)
   problem <- list(name = "ZDT1",
   xmin = rep(0, 30),
   xmax = rep(1, 30),
   m = 2)

# Get preset configuration for original MOEA/D
configuration <- preset_moead("original")

# Modify whatever you fancy:
stopcrit <- list(maxiter = 50)
showpars <- list(show.iters = "dots", show.every = 10)
seed <- 42

output <- moead(problem = problem,
   preset = configuration,
   showpars = showpars,
   stopcrit = stopcrit,
   seed = seed)

## End(Not run)```
**print_progress**

*Print progress of MOEA/D*

**Description**

Echoes progress of MOEA/D to the terminal for the MOEADr package

**Usage**

```
print_progress(iter.times, showpars)
```

**Arguments**

- `iter.times`: vector of iteration times of the `moead()` routine.
- `showpars`: list object containing parameters that control the printed output of `moead()`. Parameter `showpars` can have the following key-value pairs:
  - `show.iters`: type of output ("dots", "numbers", or "none"). If not present in `showpars`, it defaults to "numbers";
  - `show.every`: positive integer that determines how frequently the routine echoes something to the terminal. If not present in `showpars`, it defaults to 10.

---

**scalarization_awt**

*Adjusted Weighted Tchebycheff Scalarization*

**Description**

Perform Adjusted Weighted Tchebycheff Scalarization for the MOEADr package.

**Usage**

```
scalarization_awt(Y, W, minP, eps = 1e-16, ...)
```

**Arguments**

- `Y`: matrix of objective function values
- `W`: matrix of weights.
- `minP`: numeric vector containing estimated ideal point
- `eps`: tolerance value for avoiding divisions by zero.
- `...`: other parameters (included for compatibility with generic call)

**Details**

This routine calculates the scalarized performance values for the MOEA/D using the Adjusted Weighted Tchebycheff method.
scalarization_ipbi

Value
Vector of scalarized performance values.

References

Examples
```
w <- generate_weights(decomp = list(name = "sld", H = 19), m = 2)
Y <- matrix(runif(40), ncol = 2)
minP <- apply(Y, 2, min)
Z <- scalarization_awt(Y, w, minP)
```

---

scalarization_ipbi  
*Inverted Penalty-based Boundary Intersection Scalarization*

Description
Perform inverted PBI Scalarization for the MOEADr package.

Usage
```
scalarization_ipbi(Y, W, maxP, aggfun, eps = 1e-16, ...)
```

Arguments
- **Y**: matrix of objective function values
- **W**: matrix of weights.
- **maxP**: numeric vector containing estimated ideal point
- **aggfun**: list containing parameters for the aggregation function. Must contain the non-negative numeric constant aggfun$theta.
- **eps**: tolerance value for avoiding divisions by zero.
- **...**: other parameters (included for compatibility with generic call)

Details
This routine calculates the scalarized performance values for the MOEA/D using the inverted PBI method.
Value

Vector of scalarized performance values.

References


Examples

```r
W <- generate_weights(decomp = list(name = "sld", H = 19), m = 2)
Y <- matrix(runif(40), ncol = 2)
minP <- apply(Y, 2, min)
aggfun <- aggfun <- list(name = "ipbi", theta = 5)
Z <- scalarization_ipbi(Y, W, minP, aggfun)
```

Description

Perform PBI Scalarization for the MOEADr package.

Usage

```r
scalarization_pbi(Y, W, minP, aggfun, eps = 1e-16, ...)
```

Arguments

- `Y` matrix of objective function values
- `W` matrix of weights.
- `minP` numeric vector containing estimated ideal point
- `aggfun` list containing parameters for the aggregation function. Must contain the non-negative numeric constant `aggfun$theta`.
- `eps` tolerance value for avoiding divisions by zero.
- `...` other parameters (included for compatibility with generic call)

Details

This routine calculates the scalarized performance values for the MOEA/D using the PBI method.
**Value**

Vector of scalarized performance values.

**References**

Q. Zhang and H. Li, "MOEA/D: A Multiobjective Evolutionary Algorithm


**Examples**

```r
W <- generate_weights(decomp = list(name = "sld", H = 19), m = 2)
Y <- matrix(runif(48), ncol = 2)
minP <- apply(Y, 2, min)
aggfun <- aggfun <- list(name = "pbi", theta = 5)
Z <- scalarization_pbi(Y, W, minP, aggfun)
```

---

**scalarization_ws**  
*Weighted Sum Scalarization*

**Description**

Perform Weighted Sum Scalarization for the MOEADr package.

**Usage**

`scalarization_ws(Y, W, minP, eps = 1e-16, ...)`

**Arguments**

- **Y**
  - matrix of objective function values
- **W**
  - matrix of weights.
- **minP**
  - numeric vector containing estimated ideal point
- **eps**
  - tolerance value for avoiding divisions by zero.
- **...**
  - other parameters (included for compatibility with generic call)

**Details**

This routine calculates the scalarized performance values for the MOEA/D using the Weighted Sum method.

**Value**

vector of scalarized performance values.
References

Q. Zhang and H. Li, "MOEA/D: A Multiobjective Evolutionary Algorithm
H. Li, Q. Zhang, "Multiobjective Optimization Problems With Complicated Pareto Sets, MOEA/D

Examples

```r
W <- generate_weights(decomp = list(name = "sld", H = 19), m = 2)
Y <- matrix(rrunif(40), ncol = 2)
minP <- apply(Y, 2, min)
Z <- scalarization_ws(Y, W, minP)
```

---

**scalarization_wt**  
**Weighted Tchebycheff Scalarization**

**Description**

Perform Weighted Tchebycheff Scalarization for the MOEA/D package.

**Usage**

`scalarization_wt(Y, W, minP, eps = 1e-16, ...)`

**Arguments**

- `Y`: matrix of objective function values
- `W`: matrix of weights.
- `minP`: numeric vector containing estimated ideal point
- `eps`: tolerance value for avoiding divisions by zero.
- `...`: other parameters (included for compatibility with generic call)

**Details**

This routine calculates the scalarized performance values for the MOEA/D using the Weighted
Tchebycheff method.

**Value**

Vector of scalarized performance values.

**References**

Q. Zhang and H. Li, "MOEA/D: A Multiobjective Evolutionary Algorithm
H. Li, Q. Zhang, "Multiobjective Optimization Problems With Complicated Pareto Sets, MOEA/D
Examples

```r
W <- generate_weights(decomp = list(name = "sld", H = 19), m = 2)
Y <- matrix(runif(40), ncol = 2)
minP <- apply(Y, 2, min)
Z <- scalarization_wt(Y, W, minP)
```

---

`scalarize_values` *Scalarize values for MOEA/D*

**Description**

Perform scalarization for the MOEA/D package.

**Usage**

```r
scalarize_values(normYs, W, B, aggfun)
```

**Arguments**

- `normYs`: List generated by `scale_objectives()`, containing two matrices of scaled objective values (`normYs$Y` and `normYs$Yt`) and two vectors, containing the current estimates of the ideal (`normYs$minP`) and nadir (`normYs$maxP`) points. See `scale_objectives()` for details.
- `W`: matrix of weights, generated by `generate_weights()`.
- `B`: neighborhood matrix, generated by `define_neighborhood()`.
- `aggfun`: List containing the aggregation function parameters. See Section Scalar Aggregation Functions of the `moead()` documentation for details.

**Details**

This routine calculates the scalarized performance values for the MOEA/D.

The list of available scalarization methods can be generated using `get_scalarization_methods()`

**Value**

*\[(T+1) \times N\] matrix of scalarized performance values. Each column contains the T scalarized performances of the candidate solutions in the neighborhood of a given subproblem, plus the scalarized performance value for the incumbent solution for that subproblem.*
scale_objectives  Scaling of the objective function values

Description
Performs scaling of the objective function values for the MOEADr package

Usage
scale_objectives(Y, Yt, scaling, eps = 1e-16, ...)

Arguments
Y  matrix of objective function values for the incumbent solutions
Yt  matrix of objective function values for the candidate solutions
scaling  list containing the scaling parameters (see moead() for details).
eps  tolerance value for avoiding divisions by zero.
...  other parameters (included for compatibility with generic call)

Details
This routine scales the matrices of objective function values for the current (Yt) and candidate (Y) solutions. The following methods are currently available:

• scaling$name = "none": no scaling
• scaling$name = "simple": simple linear scaling between estimated ideal and nadir points, calculated from the available points in Y and Yt at each iteration.

Value
List object containing scaled objective function value matrices Y and Yt, as well as estimates of the "ideal" point minP and "nadir" point maxP.

stop_maxeval  Stop criterion: maximum number of evaluations

Description
Verifies stop criterion "maximum number of evaluations" for the MOEADr package. For internal use only, not to be called directly by the user.

Usage
stop_maxeval(stopcrit, nfe, ...)
**stop_maxiter**

**Arguments**

- **stopcrit**: list containing the parameters defining the stop handling method. See Section Constraint Handling of the `moead()` documentation for details.
- **nfe**: evaluations counter of `moead()`.
- **...**: other parameters (included for compatibility with generic call)

**Details**

When this stop criterion is used, one element of the `stopcrit` parameter (see `moead()`) must have the following structure:

- `stopcrit$name = "maxeval"
- `stopcrit$maxeval`, containing a positive integer representing the desired maximum number of evaluations.

**Value**

boolean value: **TRUE** if this criterion has been met, **FALSE** otherwise.

---

<table>
<thead>
<tr>
<th>stop_maxiter</th>
<th>Stop criterion: maximum number of iterations</th>
</tr>
</thead>
</table>

**Description**

Verifies stop criterion "maximum number of iterations" for the MOEADr package. For internal use only, not to be called directly by the user.

**Usage**

`stop_maxiter(stopcrit, iter, ...)`

**Arguments**

- **stopcrit**: list containing the parameters defining the stop handling method. See Section Constraint Handling of the `moead()` documentation for details.
- **iter**: iterations counter of `moead()`.
- **...**: other parameters (included for compatibility with generic call)

**Details**

When this stop criterion is used, one element of the `stopcrit` parameter (see `moead()`) must have the following structure:

- `stopcrit$name = "maxiter"
- `stopcrit$maxiter`, containing a positive integer representing the desired maximum number of iterations.
Value

boolean value: TRUE if this criterion has been met, FALSE otherwise.

Description

Verifies stop criterion "run time limit" for the MOEADr package. For internal use only, not to be called directly by the user.

Usage

\texttt{stop\_maxtime(stopcrit, iter\.times, ...)}

Arguments

\begin{itemize}
\item \texttt{stopcrit} list containing the parameters defining the stop handling method. See Section Constraint Handling of the \texttt{moead()} documentation for details.
\item \texttt{iter\.times} vector containing the times spent by each iteration of the \texttt{moead()} routine, up to the current one.
\item \ldots other parameters (included for compatibility with generic call)
\end{itemize}

Details

When this stop criterion is used, one element of the \texttt{stopcrit} parameter (see \texttt{moead()}) must have the following structure:

\begin{itemize}
\item \texttt{stopcrit$name = "maxtime"}
\item \texttt{stopcrit$maxtime}, containing a positive integer representing the desired time limit (in seconds).
\end{itemize}

Value

boolean value: TRUE if this criterion has been met, FALSE otherwise.

Warning

This function uses \texttt{Sys\.time()} for verifying the total run time, i.e., it counts wall-clock time, not CPU time.
Description

S3 method for summarizing \texttt{moeadoutput} objects (the output of \texttt{moead()}).

Usage

```r
## S3 method for class 'moeadoutput'
summary(object, ..., useArchive = FALSE,
         viol.threshold = 1e-06, ndigits = 3, ref.point = NULL,
         ref.front = NULL)
```

Arguments

- \texttt{object} list object of class \texttt{moeadoutput} (generated by \texttt{moead()})
- \texttt{...} other parameters to be passed down to specific summary functions (currently unused)
- \texttt{useArchive} logical flag to use information from \texttt{object$archive}. Only used if \texttt{object$archive} is not \texttt{NULL}.
- \texttt{viol.threshold} threshold of tolerated constraint violation, used to determine feasibility of points in \texttt{object}.
- \texttt{ndigits} number of decimal places to use for the ideal and nadir estimates
- \texttt{ref.point} reference point for calculating the dominated hypervolume (only if package \texttt{emoa} is available). If \texttt{NULL} the estimated nadir point is used instead.
- \texttt{ref.front} \( N \times Nobj \) matrix containing a sample of the true Pareto-optimal front, for calculating IGD.

Examples

```r
problem.1 <- list(name = "example_problem",
                 xmin = rep(-1,30),
                 xmax = rep(1,30),
                 m = 2)
out <- moead(preset = preset_moead("original2"),
            problem = problem.1,
            stopcrit = list(list(name = "maxiter",
                                 maxiter = 100)),
            showpars = list(show.iters = "dots",
                            showevery = 10))
summary(out)
```
unitary_constraints

Description
Calculates the constraint values and violations when only unitary constraints (i.e., the sum of all variables equals one) are present.

Usage
unitary_constraints(X, epsilon = 0, ...)

Arguments
- X: Population matrix of the MOEA/D (each row is a candidate solution). If NULL the function searches for X in the calling environment.
- epsilon: small non-negative value indicating the tolerance to be considered for the equality constraint. Defaults to zero.
- ...: other parameters (unused, included for compatibility with generic call)

Details
This routine calculates the constraint values and violations for a population matrix in the MOEA/D. Each row of the matrix is considered as a candidate solution. This routine expects the candidate solutions to be standardized, i.e., that the variable limits given in problem$xmin and problemxmax are mapped to 0 and 1, respectively.

Value
List objective containing a matrix of constraint values Cmatrix, a matrix of individual constraint violations Vmatrix, and a vector of total constraint violations v.

update_population

Description
Selection and population update procedures for the MOEA/D

Usage
update_population(update, ...)

**Arguments**

update  List containing the population update parameters. See Section Update Strategies of the moead() documentation for details.

... other parameters to be passed down to the specific updt_xyz() routines.

**Details**

This update routine is intended to be used internally by the main moead() function, and should not be called directly by the user. The list of available update methods can be generated using get_update_methods().

**Value**

List object containing the updated values of the population matrix X, objective function matrix Y, and constraint values list V, as well as an updated Archive list containing its corresponding components X, Y and V.

---

**updt_best**  
**Best Neighborhood Replacement Update for MOEA/D**

**Description**

Population update using the best neighborhood replacement method for the MOEADr package.

**Usage**

updt_best(update, X, Xt, Y, Yt, V, Vt, normYs, W, BP, constraint, aggfun, ...)

**Arguments**

update  List containing the population update parameters. See Section Update Strategies of the moead() documentation for details. update must have the following key-value pairs:

- update$Tr$: positive integer, neighborhood size for the update operation
- update$nr$: positive integer, maximum number of copies of a given candidate solution.

X  Matrix of candidate solutions

Xt  Matrix of incumbent solutions

Y  Matrix of objective function values of X

Yt  Matrix of objective function values of Xt

V  List object containing information about the constraint violations of the candidate solutions, generated by evaluate_population()

Vt  List object containing information about the constraint violations of the incumbent solutions, generated by evaluate_population()
normYs List generated by `scale_objectives()`, containing two matrices of scaled objective values (normYs$Y and normYs$Yt) and two vectors, containing the current estimates of the ideal (normYs$minP) and nadir (normYs$maxP) points. See `scale_objectives()` for details.

W matrix of weights, generated by `generate_weights()`.

BP Neighborhood list, generated by `define_neighborhood()`.

constraint list containing the parameters defining the constraint handling method. See Section Constraint Handling of the `moead()` documentation for details.

aggfun List containing the aggregation function parameters. See Section Scalar Aggregation Functions of the `moead()` documentation for details.

... other parameters (included for compatibility with generic call)

Details

The Best Neighborhood Replacement method consists of three steps:

- For each subproblem \( i \), the best candidate solution \( x_j \) from the entire population is determined.
- The neighborhood of subproblem \( i \) is replaced by the neighborhood of subproblem \( j \). The size of this neighborhood is given by a parameter \( Tr \).
- The Restricted replacement (see `updt_restricted()`) is then applied using this new neighborhood.

This update routine is intended to be used internally by the main `moead()` function, and should not be called directly by the user.

Value

List object containing the update population matrix \( (X) \), and its corresponding matrix of objective function values \( (Y) \) and constraint value list \( (V) \).

Description

Population update using the restricted neighborhood replacement method for the MOEADr package.

Usage

`updt_restricted(update, X, Xt, Y, Yt, V, Vt, sel.index, B, ...)`)
Arguments

- **update**: List containing the population update parameters. See Section Update Strategies of the `moead()` documentation for details. *update* must contain a field `update$nr`, a positive integer that determines the maximum number of copies of each candidate solution.

- **X**: Matrix of candidate solutions
- **Xt**: Matrix of incumbent solutions
- **Y**: Matrix of objective function values of *X*
- **Yt**: Matrix of objective function values of *Xt*
- **V**: List object containing information about the constraint violations of the candidate solutions, generated by `evaluate_population()`
- **Vt**: List object containing information about the constraint violations of the incumbent solutions, generated by `evaluate_population()`
- **sel.indx**: matrix of selection indices, generated by `order_neighborhood()`
- **B**: Neighborhood matrix, generated by `define_neighborhood()`.
- **...**: other parameters (included for compatibility with generic call)

Details

The restricted neighborhood replacement method behaves like the "standard" replacement method, except that each individual can only be selected up to `nr` times. After this limit has been reached, the next best individual in the same neighborhood is selected.

This update routine is intended to be used internally by the main `moead()` function, and should not be called directly by the user.

Value

List object containing the update population matrix (*X*), and its corresponding matrix of objective function values (*Y*) and constraint value list (*V*).

---

**updt_standard**

*Standard Neighborhood Replacement Update for MOEA/D*

Description

Population update using the standard neighborhood replacement method for the MOEADr package.

Usage

`updt_standard(X, Xt, Y, Yt, V, Vt, sel.indx, B, ...)`
variation_binrec

Arguments

- X: Matrix of candidate solutions
- Xt: Matrix of incumbent solutions
- Y: Matrix of objective function values of X
- Yt: Matrix of objective function values of Xt
- V: List object containing information about the constraint violations of the candidate solutions, generated by evaluate_population()
- Vt: List object containing information about the constraint violations of the incumbent solutions, generated by evaluate_population()
- sel.indx: matrix of selection indices, generated by order_neighborhood()
- B: Neighborhood matrix, generated by define_neighborhood().
- ...: other parameters (included for compatibility with generic call)

Details

This routine executes the standard neighborhood replacement operation to update the population matrix of the MOEA/D. This update routine is intended to be used internally by the main moead() function, and should not be called directly by the user.

Value

List object containing the update population matrix (X), and its corresponding matrix of objective function values (Y) and constraint value list (V).

---

variation_binrec  Binomial Recombination

Description

Binomial recombination implementation for the MOEA/D.

Usage

variation_binrec(X, Xt, rho, ...)

Arguments

- X: Population matrix
- Xt: Original population matrix
- rho: mutation probability
- ...: other parameters (included for compatibility with generic call)
Details

This variation operator only works if at least one other variation operator is performed prior to its execution, otherwise it becomes an identity operator (returns an unchanged matrix X).

Value

Matrix X’ containing the recombined population

References


variation_diffmut  Differential Mutation

Description

Differential Mutation implementation for the MOEA/D

Usage

variation_diffmut(X, P, B, Phi = NULL, basis = "rand", ...)

Arguments

X  Population matrix
P  Matrix of selection probabilities (generated by define_neighborhood())
B  Matrix of neighborhoods (generated by define_neighborhood())
Phi  Mutation parameter. Either a scalar numeric constant, or NULL for randomly chosen between 0 and 1 (independently sampled for each operation).
basis  how to select the basis vector. Currently supported methods are:
  • basis = "rand", for using a randomly sampled vector from the population;
  • basis = "mean", for using the mean point of the neighborhood;
  • basis = "wgi", for using the the weighted mean point of the neighborhood.
...
other parameters to be passed down to specific options of basis vector generation (e.g., Y, Yt, W, scaling and aggfun, required when basis = "wgi").

Details

This function generalizes many variations of the Differential Mutation operator with general form:

\[ u = x_{basis} + \Phi (x_a - x_b) \]

Where u is the new candidate vector, \( \Phi \neq 0 \) is a real number, and \( x_{basis}, x_a \) and \( x_b \) are distinct vectors.

This routine is intended to be used internally by perform_variation(), and should not be called directly by the user.
Value

Matrix $X'$ containing the mutated population

References


Local search Operators

Description

Local search operators for the MOEA/D

Usage

variation_localsearch(...)

Arguments

... arguments to be passed down to the specific ls_xyz() functions. A list of available local search methods can be generated by get_localsearch_methods(). Consult the documentation of the specific functions for details.

Details

This routine calls the local search operator for the MOEADr package, as part of the call to perform_variation(). This operator requires its entry in the variation stack (see Section Variation Operators of moead()) to contain the following fields:

- name = "localsearch"
- type (see get_localsearch_methods() for details)
- gamma.ls (optional): probability of application of local search to a given subproblem at any given iteration (numeric between 0 and 1)
- tau.ls (optional): period of application of local search to each subproblem (positive integer)
- trunc.x (optional): logical flag for truncating the results of the local search operator to the limits defined by problem$xmin, problemxmax (logical). Defaults to TRUE.

Whenever local search is triggered for a given subproblem, it cancels all other variation operators for that subproblem and is executed directly on the incumbent solution.

This routine is intended to be used internally by perform_variation(), and should not be called directly by the user.
Value

Either a matrix Xls containing the modified points (points that did not undergo local search are indicated as NA in this output matrix), or a list object containing the Xls matrix and an integer nfe, informing how many additional function evaluations were performed by the local search operator. The specific output is defined by the ls_xyz() method used.

---

| variation_none | Identity operator |

Description

Identity operator (no variation performed)

Usage

variation_none(X, ...)

Arguments

<table>
<thead>
<tr>
<th>X</th>
<th>Population matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>...</td>
<td>other parameters (included for compatibility with generic call)</td>
</tr>
</tbody>
</table>

Details

Performs the identity operator (no variation). This routine is included to simplify the use of automated tuning / design tools such as Iterated Racing.

Value

Input matrix X

---

| variation_polymut | Polynomial mutation |

Description

Polynomial mutation implementation for the MOEA/D

Usage

variation_polymut(X, etam, pm, eps = 1e-06, ...)


variation_sbx

Arguments

- \( x \)  
  Population matrix
- \( \eta_m \)  
  mutation constant
- \( p_m \)  
  variable-wise probability of mutation
- \( \epsilon_s \)  
  small constant used to prevent divisions by zero
- ...  
  other parameters (included for compatibility with generic call)

Details

This R implementation of the Polynomial Mutation reproduces the C code implementation available in the R package `emoa` 0.5-0, by Olaf Mersmann. The differences between the present version and the original one are:

- The operator is performed on the variables scaled to the \([0, 1]\) interval, which simplifies the calculations.
- Calculations are vectorized over variables, which also simplifies the implementation.

Value

Matrix \( X' \) containing the mutated population

References


Olaf Mersmann (2012). emoa: Evolutionary Multiobjective Optimization Algorithms. R package version 0.5-0.

http://CRAN.R-project.org/package=emoa

---

| variation_sbx | Simulated binary crossover |

Description

SBX implementation for the MOEA/D

Usage

```r
variation_sbx(X, P, etax, pc = 1, eps = 1e-06, ...)
```
variation_truncate

Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>Population matrix</td>
</tr>
<tr>
<td>P</td>
<td>Matrix of probabilities of selection for variation (created by define_neighborhood()).</td>
</tr>
<tr>
<td>etax</td>
<td>spread constant</td>
</tr>
<tr>
<td>pc</td>
<td>variable-wise probability of recombination</td>
</tr>
<tr>
<td>eps</td>
<td>smallest difference considered for recombination</td>
</tr>
<tr>
<td>...</td>
<td>other parameters (included for compatibility with generic call)</td>
</tr>
</tbody>
</table>

Details

This R implementation of the Simulated Binary Crossover reproduces the C code implementation available in the R package emoa 0.5-0, by Olaf Mersmann. The differences between the present version and the original one are:

- The operator is performed on the variables scaled to the $[0, 1]$ interval, which simplifies the calculations.
- Calculations are vectorized over variables, which also simplifies the implementation.

Value

Matrix $X'$ containing the recombined population

References


Olaf Mersmann (2012). emoa: Evolutionary Multiobjective Optimization Algorithms. R package version 0.5-0. 
http://CRAN.R-project.org/package=emoa

Description

Truncation variation operator

Usage

variation_truncate(X, ...)

Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>Population matrix</td>
</tr>
<tr>
<td>...</td>
<td>other parameters (included for compatibility with generic call)</td>
</tr>
</tbody>
</table>
Variation_truncate

Details

Truncate the solution matrix X to the $[0, 1]$ interval.

Value

Truncated matrix $X'$. 
Index

box_constraints, 3

calcIGD, 4
check_stop_criteria, 4
constraint_none, 5
constraint_penalty, 5
constraint_vbr, 6
constraint_vbr(), 26
create_population, 8
decomposition_msl, 9
decomposition_sld, 10
decomposition_sld(), 9
decomposition_uniform, 11
define_neighborhood, 12
define_neighborhood(), 6, 21, 22, 26, 29

evaluate_population, 13
evaluate_population(), 6, 21, 22, 25, 29, 44, 46, 47
evaluate_population(), 6, 21, 22, 25, 29, 44, 46, 47

example_problem, 14

find_non_dominated_points, 14

generate_weights, 15
generate_weights(), 21, 22, 25, 38, 45
generate_weights(), 21, 22, 25, 38, 45
get_constraint_methods, 16
get_constraint_methods(), 27, 29
get_constraint_methods(), 27, 29
get_decomposition_methods, 16
get_decomposition_methods(), 25
get_decomposition_methods(), 25
get_local_search_methods, 17
get_local_search_methods, 17
get_local_search_methods(), 49
get_local_search_methods(), 49
get_scalarization_methods, 18
get_scalarization_methods, 18
get_scalarization_methods(), 26
get_scalarization_methods(), 26
generate_weights(), 21, 22, 25, 38, 45
generate_weights(), 21, 22, 25, 38, 45
get_stop_criteria, 18
get_stop_criteria(), 27
get_stop_criteria(), 27
get_stop_criteria(), 27
get_update_methods, 19
get_update_methods, 19
get_update_methods(), 26, 44
get_update_methods(), 26, 44
get_variation_operators, 20
get_variation_operators, 20
get_variation_operators, 20
get_variation_operators(), 26, 30
get_variation_operators(), 26, 30
get_variation_operators(), 26, 30
get_variation_operators(), 26, 30

ls_dvl, 20
ls_tpa, 22
make_vectorized_smoof, 23
moead, 24
moead(), 4, 8, 10, 11, 13–15, 21, 22, 29–33, 38–42, 44–47, 49
moead(), 4, 8, 10, 11, 13–15, 21, 22, 29–33, 38–42, 44–47, 49

order_neighborhood, 29
order_neighborhood(), 6, 7, 46, 47

perform_variation, 30
perform_variation(), 48, 49
plot.moeadoutput, 30
preset_moead, 31
preset_moead(), 24
print_progress, 33
print_progress, 33
print_progress(), 24
print_progress(), 24

scalarization_awt, 33
scalarization_ipbi, 34
scalarization_ipbi, 34
scalarization_pbi, 35
scalarization_ws, 36
scalarization_ws, 36
scalarization_wt, 37
scalarization_wt, 37
scalarize_values, 38
scalarize_values, 38
scalarize_values(), 6, 26, 29
scale_objectives, 39
scale_objectives, 39
scale_objectives(), 38, 45
scale_objectives(), 38, 45
stop_maxeval, 39
stop_maxiter, 40
stop_maxtime, 41
summary.moeadoutput, 42
summary.moeadoutput, 42

unitary_constraints, 43
update_population, 43
update_population, 43
update_population(), 26, 27
update_population(), 26, 27
update_population(), 26, 27
update_population(), 26, 27
updt_best, 44
updt_best, 44
updt_restricted, 45
updt_restricted, 45
updt_restricted, 45
updt_restricted(), 45
updt_restricted(), 45
updt_restricted(), 45
updt_standard, 46
updt_standard, 46
updt_standard, 46
INDEX

variation_binrec, 47
variation_diffmut, 48
variation_local_search, 49
variation_local_search(), 21, 22, 30
variation_none, 50
variation_polymut, 50
variation_sbx, 51
variation_truncate, 52