Package ‘ROI’

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**Title** R Optimization Infrastructure

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is a sophisticated framework for handling optimization problems in R.

Additional information can be found on the 'ROI' homepage <https://roi.r-forge.r-project.org/>.

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as.L_term

Canonicalize the Linear Term

Description

Canonicalize the linear term of a linear constraint. Objects from the following classes can be canonicalized: "NULL", "numeric", "matrix", "simple_triplet_matrix" and "list".

Usage

as.L_term(x, ...)

Arguments

x an R object.
...

further arguments passed to or from other methods.

Details

In the case of lists "as.Q_term" is applied to every element of the list, for NULL one can supply the optional arguments "nrow" and "ncol" which will create a "simple_triplet_zero_matrix" with the specified dimension.

Value

an object of class "simple_triplet_matrix"

---

as.Q_term

Canonicalize the Quadratic Term

Description

Canonicalize the quadratic term of a quadratic constraint. Objects from the following classes can be canonicalized: "NULL", "numeric", "matrix", "simple_triplet_matrix" and "list".
Usage

```
as.Q_term(x, ...)
## S3 method for class 'list'
as.Q_term(x, ...)
## S3 method for class 'numeric'
as.Q_term(x, ...)
## S3 method for class 'matrix'
as.Q_term(x, ...)
## S3 method for class 'simple_triplet_matrix'
as.Q_term(x, ...)
## S3 method for class `
`NULL`
`as.Q_term(x, ...)
```

Arguments

- `x`: an R object.
- `...`: further arguments

Details

In the case of lists "as.Q_term" is applied to every element of the list, for NULL one can supply the optional arguments "nrow" and "ncol" which will create a "simple_triplet_zero_matrix" with the specified dimension.

Value

an object of class "simple_triplet_matrix"

Description

**ROI** distinguishes between 2 different types of bounds:

- No Bounds `N0_bound`
- Variable Bounds `V_bound` (inherits from "bound")

Usage

```
## S3 method for class 'bound'
c(...)

is.bound(x)
```
bounds (Set/Get)

Arguments

x          object to be tested
...         arguments (inheriting from bound) to be combined

Details

ROI provides the method \texttt{V\_bound} as constructor for variable bounds. \texttt{NO\_bound} is not explicitly implemented but represented by \texttt{NULL}.

---

**bounds (Set/Get)**

**Bounds - Accessor and Mutator Functions**

Description

The bounds of a given optimization problem (OP) can be accessed or mutated via the method 'bounds'.

Usage

\begin{verbatim}
bounds(x)

## S3 method for class 'OP'
bounds(x)

bounds(x) <- value
\end{verbatim}

Arguments

x              an object of type 'OP' used to select the method.
value          an object derived from 'bound' ('V\_bound') or NULL.

Value

the extracted bounds object on get and the altered 'OP' object on set.

Examples

\begin{verbatim}
## Not run:
lp_obj <- L\_objective(c(1, 2))
lp_con <- L\_constraint(c(1, 1), dir="==", rhs=2)
lp_bound <- V\_bound(ui=1:2, ub=c(3, 3))
lp <- OP(objective=lp_obj, constraints=lp_con, bounds=lp_bound, maximum=FALSE)
bounds(lp)
x <- ROI\_solve(lp)
x$objval
x$solution
bounds(lp) <- V\_bound(ui=1:2, ub=c(1, 1))
y <- ROI\_solve(lp)
\end{verbatim}
### Description

**ROI** distinguishes between 5 different types of constraint:

- No Constraint `NO_constraint` (inherits from "constraint")
- Linear Constraint `L_constraint` (inherits from "constraint")
- Quadratic Constraint `Q_constraint` (inherits from "constraint")
- Conic Constraint `C_constraint` (inherits from "constraint")
- Function Constraint `F_constraint` (inherits from "constraint")

### Usage

```r
## S3 method for class 'constraint'
c(..., recursive = FALSE)

as.constraint(x)

is.constraint(x)

## S3 method for class 'constraint'
dim(x)
```

### Arguments

- **recursive**: a logical, giving if the arguments should be combined recursively.
- **x**: an object to be coerced or tested.
- **...**: objects to be combined.
Description

The utility functions eq, leq and geq replicate the signs "==", ">=" and "<=" n times.

Usage

eq(n)
leq(n)
geq(n)

Arguments

n an integer giving the number of times the sign should be repeated.

Examples

eq(3)
leq(2)
geq(4)

Constraints (Set/Get)

Description

The constraints of a given optimization problem (OP) can be accessed or mutated via the method 'constraints'.

Usage

constraints(x)

## S3 method for class 'OP'
constraints(x)

constraints(x) <- value

Arguments

x an object used to select the method.
value an R object.
Value

the extracted constraints object.

Author(s)

Stefan Theussl

Examples

```r
## minimize: x + 2 y
## subject to: x + y >= 1
## x, y >= 0
x <- OP(1:2)
constraints(x) <- L_constraint(c(1, 1), ">=", 1)
constraints(x)
```

### Description

Conic constraints are often written in the form

\[ Lx + s = rhs \]

where \( L \) is a \( m \times n \) (sparse) matrix and \( s \in K \) are the slack variables restricted to some cone \( K \) which is typically the product of simpler cones \( K = \prod K_i \). The right hand side \( rhs \) is a vector of length \( m \).

### Usage

```r
C_constraint(L, cones, rhs, names = NULL)
as.C_constraint(x, ...)
is.C_constraint(x)
```

```r
## S3 method for class 'C_constraint'
length(x)
```

```r
## S3 method for class 'C_constraint'
variable.names(object, ...)
```

```r
## S3 method for class 'C_constraint'
terms(x, ...)
```
Arguments

- `L`: a numeric vector of length `n` (a single constraint) or a matrix of dimension `m × n`, where `n` is the number of objective variables and `m` is the number of constraints. Matrices can be of class "simple_triplet_matrix" to allow a sparse representation of constraints.
- `cones`: an object of class "cone" created by the combination of `K_zero`, `K_lin`, `K_soc`, `K_psd`, `K_expp`, `K_expd`, `K_powp` or `K_powd`.
- `rhs`: a numeric vector giving the right hand side of the constraints.
- `names`: an optional character vector giving the names of `x` (column names of `L`).
- `x`: an R object.
- `...`: further arguments passed to or from other methods (currently ignored).
- `object`: an R object.

Value

an object of class "C_constraint" which inherits from "constraint".

Examples

```r
## minimize: x1 + x2 + x3
## subject to:
## x1 == sqrt(2)
## ||(x2, x3)|| <= x1
x <- OP(objective = c(1, 1, 1),
        constraints = C_constraint(L = rbind(rbind(c(1, 0, 0),
                                                diag(x=-1, 3)),
                                cones = c(K_zero(1), K_soc(3)),
                                rhs = c(sqrt(2), rep(0, 3))),
        types = rep("C", 3),
        bounds = V_bound(li = 1:3, lb = rep(-Inf, 3)), maximum = FALSE)
```

equal

Compare two Objects

Description

The utility function `equal` can be used to compare two ROI objects and is mainly used for testing purposes.

Usage

```r
equal(x, y, ...)
```

## S3 method for class "NULL"
equal(x, y, ...)

Arguments

x   an R object to be compared with object y.
y   an R object to be compared with object x.
... optional arguments to equal.

Value

TRUE if x and y are equal FALSE otherwise.

Examples

## compare numeric values
equal(1e-4, 1e-5, tol=1e-3)
## L_constraint
lc1 <- L_constraint(diag(1), dir=c("="), rhs=1)
lc2 <- L_constraint(diag(2), dir=c("=","<="), rhs=1:2)
equal(lc1, lc1)
equal(lc1, lc2)
Function (or generally speaking nonlinear) constraints are typically of the form

\[ f(x) \leq b \]

where \( f() \) is a well-defined R function taking the objective variables \( x \) (typically a numeric vector) as arguments. \( b \) is called the right hand side of the constraints.

### Usage

\[
F\_constraint(F, \text{dir}, rhs, J = \text{NULL}, \text{names} = \text{NULL})
\]

```
## S3 method for class 'F\_constraint'
variable\_names(object, ...)

is.F\_constraint(x)

as.F\_constraint(x, ...)

## S3 method for class '\text{\`NULL\}'
as.F\_constraint(x, ...)

## S3 method for class 'NO\_constraint'
as.F\_constraint(x, ...)

## S3 method for class 'constraint'
as.F\_constraint(x, ...)

## S3 method for class 'F\_constraint'
terms(x, ...)
```

### Arguments

- **F**: a function or a list of functions of length \( m \). Each function takes \( n \) parameters as input and must return a scalar. Thus, \( n \) is the number of objective variables and \( m \) is the number of constraints.
- **dir**: a character vector with the directions of the constraints. Each element must be one of "\<=", "\>=" or "\==".
- **rhs**: a numeric vector with the right hand side of the constraints.
- **J**: an optional function holding the Jacobian of \( F \).
- **names**: an optional character vector giving the names of \( x \).
- **object**: an R object.
- **x**: object to be tested.
- **...**: further arguments passed to or from other methods (currently ignored).
**Value**

an object of class "F_constraint" which inherits from "constraint".

**Author(s)**

Stefan Theussl

---

**F_objective**

*General (Nonlinear) Objective Function*

---

**Description**

General objective function \( f(x) \) to be optimized.

**Usage**

```r
F_objective(F, n, G = NULL, H = NULL, names = NULL)
## S3 method for class
'/quotesingle.Var
F_objective
'/quotesingle.Var
terms(x, ...)
as.F_objective(x)
## S3 method for class 'F_objective'
variable.names(object, ...)
```

**Arguments**

- **F** : an R "function" taking a numeric vector \( x \) of length \( n \) as argument.
- **n** : the number of objective variables.
- **G** : an R "function" returning the gradient at \( x \).
- **H** : an optional function holding the Hessian of \( F \).
- **names** : an optional character vector giving the names of \( x \).
- **x** : an R object.
- **...** : further arguments passed to or from other methods.
- **object** : an R object.

**Value**

an object of class "F_objective" which inherits from "objective".

**Author(s)**

Stefan Theussl
Extract Gradient information

Description

Extract the gradient from its argument (typically a ROI object of class "objective").

Usage

\[ G(x, \ldots) \]

Arguments

- \( x \): an object used to select the method.
- \( \ldots \): further arguments passed down to the \texttt{grad()} function for calculating gradients (only for "F_objective").

Details

By default ROI uses the "grad" function from the \texttt{numDeriv} package to derive the gradient information. An alternative function can be provided via \texttt{ROI_options}. For example \texttt{ROI_options("gradient", myGrad)} would tell ROI to use the function "myGrad" for the gradient calculation. The only requirement to the function "myGrad" is that it has the argument "func" which takes a function with a scalar real result.

Value

a "function".

Examples

```r
## Not run:
f <- function(x) {
  return(100 * (x[2] - x[1]^2)^2 + (1 - x[1])^2)
}
x <- OP(objective = F_objective(f, n=2L),
        bounds = V_bound(li=1:2, ui=1:2, lb=c(-3, -3), ub=c(3, 3)))
G(objective(x))(c(0, 0)) ## gradient numerically approximated by numDeriv

f.gradient <- function(x) {
}
x <- OP(objective = F_objective(f, n=2L, G=f.gradient),
        bounds = V_bound(li=1:2, ui=1:2, lb=c(-3, -3), ub=c(3, 3)))
G(objective(x))(c(0, 0)) ## gradient calculated by f.gradient

## End(Not run)
```
is.default_bound  

**Check for default bounds**

**Description**

tests if the given object is a variable bound which represents default values only (i.e., all lower bounds are 0 and all upper bounds as Inf).

**Usage**

```r
is.default_bound(x)
```

**Arguments**

- `x`  
  object to be tested

**Value**

a logical of length one indicating whether default bounds are given

---

**J**  

**Extract Jacobian Information**

**Description**

Derive the Jacobian for a given constraint.

**Usage**

```r
J(x, ...)
```

### S3 method for class 'L_constraint'

```r
J(x, ...)
```

### S3 method for class 'Q_constraint'

```r
J(x, ...)
```

**Arguments**

- `x`  
  a `L_constraint`, `Q_constraint` or `F_constraint`

- `...`  
  further arguments

**Value**

a list of functions
Examples

L <- matrix(c(3, 4, 2, 2, 1, 3, 2, 1), nrow=3, byrow=TRUE)
lc <- L_constraint(L = L, dir = c("="), rhs = c(60, 40, 80))
J(lc)

---

**K_zero**

---

**Cone Constructors**

Description

Constructor functions for the different cone types. Currently ROI supports eight different types of cones.

- **Zero cone**
  \[ \mathcal{K}_{\text{zero}} = \{0\} \]

- **Nonnegative (linear) cone**
  \[ \mathcal{K}_{\text{lin}} = \{ x | x \geq 0 \} \]

- **Second-order cone**
  \[ \mathcal{K}_{\text{soc}} = \{(t, x) | \|x\|_2 \leq t, x \in \mathbb{R}^n, t \in \mathbb{R}\} \]

- **Positive semidefinite cone**
  \[ \mathcal{K}_{\text{psd}} = \{ X | \min(eig(X)) \geq 0, X = X^T, X \in \mathbb{R}^{n \times n}\} \]

- **Exponential cone**
  \[ \mathcal{K}_{\text{expp}} = \{(x, y, z) | ye^x \leq z, y > 0\} \]

- **Dual exponential cone**
  \[ \mathcal{K}_{\text{expd}} = \{(u, v, w) | -we^v \leq ew, u < 0\} \]

- **Power cone**
  \[ \mathcal{K}_{\text{powp}} = \{(x, y, z) | x^\alpha * y^{(1-\alpha)} \geq |z|, x \geq 0, y \geq 0\} \]

- **Dual power cone**
  \[ \mathcal{K}_{\text{powd}} = \{(u, v, w) | \left(\frac{u}{\alpha}\right)^\alpha * \left(\frac{v}{(1-\alpha)}\right)^{(1-\alpha)} \geq |w|, u \geq 0, v \geq 0\} \]
Usage

K_zero(size)
K_lin(size)
K_soc(sizes)
K_psd(sizes)
K_expp(size)
K_expd(size)
K_powp(alpha)
K_powd(alpha)

Arguments

size   a integer giving the size of the cone, if the dimension of the cones is fixed (i.e. zero, lin, expp, expd) the number of cones is sufficient to define the dimension of the product cone.

sizes  a integer giving the sizes of the cones, if the dimension of the cones is not fixed (i.e. soc, psd) we have to define the sizes of each single cone.

alpha  a numeric vector giving the alphas for the (dual) power cone.

Examples

K_zero(3) ## 3 equality constraints
K_lin(3)  ## 3 constraints where the slack variable s lies in the linear cone

Description

Linear constraints are typically of the form

\[ Lx \leq rhs \]

where \( L \) is a \( m \times n \) (sparse) matrix of coefficients to the objective variables \( x \) and the right hand side \( rhs \) is a vector of length \( m \).
L_objective

Description

A linear objective function is typically of the form

$$c^T x$$

where $c$ is a (sparse) vector of coefficients to the $n$ objective variables $x$. 
maximum (Set/Get)

Usage

L_objective(L, names = NULL)

## S3 method for class 'L_objective'
terms(x, ...)
as.L_objective(x)

## S3 method for class 'L_objective'
variable.names(object, ...)

Arguments

L
          a numeric vector of length \( n \) or an object of class "simple_triplet_matrix"
          (or coercible to such) with dimension \( 1 \times n \), where \( n \) is the number of objective
          variables. Names will be preserved and used e.g., in the print method.

names
          an optional character vector giving the names of \( x \) (column names of \( L \)).

x
          an R object.

... further arguments passed to or from other methods

object an R object.

Value

an object of class "L_objective" which inherits from "Q_objective" and "objective".

Author(s)

Stefan Theussl

maximum (Set/Get) Maximum - Accessor and Mutator Functions

Description

The maximum of a given optimization problem (OP) can be accessed or mutated via the method
'maximum'. If 'maximum' is set to TRUE the OP is maximized, if 'maximum' is set to FALSE the OP
is minimized.

Usage

maximum(x)

maximum(x) <- value
Arguments

- **x**: an object used to select the method.
- **value**: an R object.

Value

a logical giving the direction.

Examples

```r
## maximize: x + y
## subject to: x + y <= 2
## x, y >= 0
x <- OP(objective = c(1, 1),
        constraints = L_constraint(L = c(1, 1), dir = "<=",
                                  rhs = 2),
        maximum = FALSE)
maximum(x) <- TRUE
maximum(x)
```

Description

This function was contributed by Diethelm Wuertz.

Usage

```r
nlminb2(
  start,
  objective,
  eqFun = NULL,
  leqFun = NULL,
  lower = -Inf,
  upper = Inf,
  gradient = NULL,
  hessian = NULL,
  control = list()
)
```

Arguments

- **start**: numeric vector of start values.
- **objective**: the function to be minimized $f(x)$.
- **eqFun**: functions specifying equal constraints of the form $h_i(x) = 0$. Default: NULL (no equal constraints).
functions specifying less equal constraints of the form $g_i(x) \leq 0$. Default: NULL (no less equal constraints).

lower a numeric representing lower variable bounds. Repeated as needed. Default: -Inf.

upper a numeric representing upper variable bounds. Repeated as needed. Default: Inf.

gradient gradient of $f(x)$. Default: NULL (no gradient information).

hessian hessian of $f(x)$. Default: NULL (no hessian provided).

control a list of control parameters. See `nlminb()` for details. The parameter "scale" is set here in contrast to `nlminb()`.

Value

list()

Author(s)

Diethelm Wuertz

Examples

## Equal constraint function
```r
eval_g0_eq <- function( x, params = c(1,1,-1)) {
  return( params[1]*x^2 + params[2]*x + params[3] )
}
eval_f0 <- function( x, ... ) {
  return( 1)
}
```

Description

In case the constraints slot in the problem object is NULL the return value of a call of constraints() will return an object of class "NO_constraint" which inherits from "L_constraint".

Usage

```r
NO_constraint(n_obj)

as.NO_constraint(x, ...)

is.NO_constraint(x)
```
**objective (Set/Get)**

**Arguments**

- `n_obj` a numeric vector of length 1 representing the number of objective variables.
- `x` an R object.
- `...` further arguments passed to or from other methods (currently ignored).

**Value**

- an object of class "NO_constraint" which inherits from "L_constraint" and "constraint".

**Author(s)**

Stefan Theussl

---

**objective (Set/Get) **  
*Objective - Accessor and Mutator Functions*

**Description**

The **objective** of a given optimization problem (OP) can be accessed or mutated via the method 'objective'.

**Usage**

- `objective(x)`
- `objective(x) <- value`
- `as.objective(x)`

**Arguments**

- `x` an object used to select the method.
- `value` an R object.

**Value**

- a function inheriting from "objective".

**Author(s)**

Stefan Theussl

**Examples**

- `x <- OP()`
- `objective(x) <- 1:3`
**Description**

Optimization problem constructor

**Usage**

```
OP(objective, constraints, types, bounds, maximum = FALSE)
as.OP(x)
```

**Arguments**

- **objective**: an object inheriting from class "objective".
- **constraints**: an object inheriting from class "constraints".
- **types**: a character vector giving the types of the objective variables, with "C", "I", and "B" corresponding to continuous, integer, and binary, respectively, or NULL (default), taken as all-continuous. Recycled as needed.
- **bounds**: NULL (default) or a list with elements `upper` and `lower` containing the indices and corresponding bounds of the objective variables. The default for each variable is a bound between 0 and Inf.
- **maximum**: a logical giving the direction of the optimization. TRUE means that the objective is to maximize the objective function, FALSE (default) means to minimize it.
- **x**: an R object.

**Value**

an object of class "OP".

**Author(s)**

Stefan Theussl

**References**

Examples

```r
## Simple linear program.
## maximize: 2 x_1 + 4 x_2 + 3 x_3
## subject to: 3 x_1 + 4 x_2 + 2 x_3 <= 60
## 2 x_1 + x_2 + x_3 <= 40
## x_1 + 3 x_2 + 2 x_3 <= 80
## x_1, x_2, x_3 are non-negative real numbers

LP <- OP( c(2, 4, 3),
          L_constraint(L = matrix(c(3, 2, 1, 4, 1, 3, 2, 2), nrow = 3),
                      dir = c("<=", "<=", "<="),
                      rhs = c(60, 40, 80)),
          max = TRUE )

LP
```

```r
## Simple quadratic program.
## minimize: - 5 x_2 + 1/2 (x_1^2 + x_2^2 + x_3^2)
## subject to: -4 x_1 - 3 x_2 >= -8
## 2 x_1 + x_2 >= 2
## - 2 x_2 + x_3 >= 0

QP <- OP( Q_objective (Q = diag(1, 3), L = c(0, -5, 0)),
          L_constraint(L = matrix(c(-4,-3,0,2,1,0,0,-2,1),
                                  ncol = 3, byrow = TRUE),
                      dir = rep(">=", 3),
                      rhs = c(-8,2,0)) )

QP
```

**OP_signature**

*Optimization Problem Signature*

**Description**

Takes an object of class "OP" (optimization problem) and returns the signature of the optimization problem.

**Usage**

```r
OP_signature(x)
```

**Arguments**

- `x` an object of class "OP"

**Value**

A `data.frame` giving the signature of the optimization problem.
Description

Quadratic constraints are typically of the form

\[ \frac{1}{2} x^\top Q_i x + L_i x \leq rhs_i \]

where \( Q_i \) is the \( i \)th of \( m \) (sparse) matrices (all of dimension \( n \times n \)) giving the coefficients of the quadratic part of the equation. The \( m \times n \) (sparse) matrix \( L \) holds the coefficients of the linear part of the equation and \( L_i \) refers to the \( i \)th row. The right hand side of the constraints is represented by the vector \( rhs \).

Usage

\[
\text{Q Constraint}(Q, L, \text{dir}, \text{rhs}, \text{names} = \text{NULL})
\]

## S3 method for class 'Q Constraint'

\[
\text{variable.names(object, ...)}
\]

\[
\text{as.Q Constraint(x)}
\]

\[
\text{is.Q Constraint(x)}
\]

## S3 method for class 'Q Constraint'

\[
\text{length(x)}
\]

## S3 method for class 'Q Constraint'

\[
\text{terms(x, ...)}
\]

Arguments

- \( Q \): a list of (sparse) matrices representing the quadratic part of each constraint.
- \( L \): a numeric vector of length \( n \) (a single constraint) or a matrix of dimension \( m \times n \), where \( n \) is the number of objective variables and \( m \) is the number of constraints. Matrices can be of class "simple_triplet_matrix" to allow a sparse representation of constraints.
- \( \text{dir} \): a character vector with the directions of the constraints. Each element must be one of "<", "=" or ">
- \( \text{rhs} \): a numeric vector with the right hand side of the constraints.
- \( \text{names} \): an optional character vector giving the names of \( x \) (row/column names of \( Q \), column names of \( A \)).
- \( \text{object} \): an R object.
- \( \ldots \): further arguments passed to or from other methods (currently ignored).
- \( x \): an R object.
**Q_objective**

**Value**

an object of class "Q_constraint" which inherits from "constraint".

**Author(s)**

Stefan Theussl

---

**Q_objective**

**Quadratic Objective Function**

**Description**

A quadratic objective function is typically of the form

\[
\frac{1}{2}x^\top Q x + c^\top x
\]

where \( Q \) is a (sparse) matrix defining the quadratic part of the function and \( c \) is a (sparse) vector of coefficients to the \( n \) defining the linear part.

**Usage**

```R
Q_objective(Q, L = NULL, names = NULL)
```

## S3 method for class 'Q_objective'

```R
terms(x, ...)
as.Q_objective(x)
```

## S3 method for class 'Q_objective'

```R
variable.names(object, ...)
```

**Arguments**

- **Q**
  - a \( n \times n \) matrix with numeric entries representing the quadratic part of objective function. Sparse matrices of class "simple_triplet_matrix" can be supplied.
- **L**
  - a numeric vector of length \( n \), where \( n \) is the number of objective variables.
- **names**
  - an optional character vector giving the names of \( x \) (row/column names of \( Q \), column names of \( L \)).
- **x**
  - an R object.
- **...**
  - further arguments passed to or from other methods
- **object**
  - an R object.

**Value**

an object of class "Q_objective" which inherits from "objective".
**Author(s)**

Stefan Theussl

---

**rbind.constraint**  
**Combine Constraints**

**Description**

Take a sequence of constraints (ROI objects) arguments and combine by rows, i.e., putting several constraints together.

**Usage**

```r
## S3 method for class 'constraint'
rbind(..., use.names = FALSE, recursive = FALSE)
```

**Arguments**

- `...` constraints objects to be concatenated.
- `use.names` a logical if FALSE the names of the constraints are ignored when combining them, if TRUE the constraints are combined based on their variable.names.
- `recursive` a logical, if TRUE, rbind.

**Details**

The output type is determined from the highest type of the components in the hierarchy 
"L_constraint" < "Q_constraint" < "F_constraint" and 
"L_constraint" < "C_constraint".

**Value**

an object of a class depending on the input which also inherits from "constraint". See Details.

**Author(s)**

Stefan Theussl
**ROI_applicable_solvers**

*Obtain Applicable Solvers*

**Description**

ROI_applicable_solvers takes as argument an optimization problem (object of class 'OP') and returns a vector giving the applicable solver. The set of applicable solver is restricted on the available solvers, which means if solver "A" and "B" would be applicable but a ROI.plugin is only installed for solver "A" only solver "A" would be listed as applicable solver.

**Usage**

ROI_applicable_solvers(op)

**Arguments**

- **op**
  
an ROI-object of type 'OP'.

**Value**

An character vector giving the applicable solver, for a certain optimization problem.

---

**ROI_available_solvers**

*Available Solvers*

**Description**

ROI_available_solvers returns a data.frame of details corresponding to solvers currently available at one or more repositories. The current list of packages is downloaded over the Internet.

**Usage**

ROI_available_solvers(x = NULL, method = getOption("download.file.method"))

**Arguments**

- **x**
  
an object used to select a method. It can be either an object of class "OP" or an object of class "ROI_signature" or NULL.

- **method**
  
a character string giving the method to be used for downloading files. For more information see download.file.
Details

To get an overview about the available solvers ROI_available_solvers() can be used. If a signature or an object of class "OP" is provided ROI will only return the solvers applicable the optimization problem. Note since NLP solver are also applicable for LP and QP they will also be listed.

Value

a data.frame with one row per package and repository.

Examples

```r
## Not run:
ROI_available_solvers()
op <- OP(1:2)
ROI_available_solvers(op)
ROI_available_solvers(OP_signature(op))
## End(Not run)
```

<table>
<thead>
<tr>
<th>ROI_options</th>
<th>ROI Options</th>
</tr>
</thead>
</table>

Description

Allow the user to set and examine a variety of ROI options like the default solver or the function used to compute the gradients.

Usage

ROI_options(option, value)

Arguments

- option: any options can be defined, using 'key, value' pairs. If 'value' is missing the current set value is returned for the given 'option'. If both are missing, all set options are returned.
- value: the corresponding value to set for the given option.
ROI_plugin_add_status_code_to_db

Add Status Code to the Status Database

Description

Add a status code to the status database.

Usage

ROI_plugin_add_status_code_to_db(solver, code, symbol, message, roi_code = 1L)

Arguments

- **solver**: a character string giving the name of the solver.
- **code**: an integer giving the status code of the solver.
- **symbol**: a character string giving the status symbol.
- **message**: a character string used as status message.
- **roi_code**: an integer giving the ROI status code, 1L for failure and 0L for success.

See Also

Other plugin functions: ROI_plugin_build_equality_constraints(), ROI_plugin_build_inequality_constraints(), ROI_plugin_canonicalize_solution(), ROI_plugin_get_solver_name(), ROI_plugin_make_signature(), ROI_plugin_register_solver_control(), ROI_plugin_register_solver_method(), ROI_plugin_solution_prim(), ROI_registered_solver_control()

Examples

```r
## Not run:
solver <- "ecos"
ROI_plugin_add_status_code_to_db(solver, 0L, "ECOS_OPTIMAL", "Optimal solution found.", 0L)
ROI_plugin_add_status_code_to_db(solver,-7L, "ECOS_FATAL", "Unknown problem in solver.", 1L)
solver <- "glpk"
ROI_plugin_add_status_code_to_db(solver, 5L, "GLP_OPT", "Solution is optimal.", 0L)
ROI_plugin_add_status_code_to_db(solver, 1L, "GLP_UNDEF", "Solution is undefined.", 1L)
## End(Not run)
```
ROI_plugin_build_equality_constraints

Build Functional Equality Constraints

Description

There exist different forms of functional equality constraints, this function transforms the form used in ROI into the forms commonly used by R optimization solvers.

Usage

ROI_plugin_build_equality_constraints(x, type = c("eq_zero", "eq_rhs"))

Arguments

- **x**: an object of type "OP".
- **type**: an character giving the type of the function to be returned, possible values are "eq_zero" or "eq_rhs". For more information see Details.

Details

There are two types of equality constraints commonly used in R

1. eq_zero: \( h(x) = 0 \)
2. eq_rhs: \( h(x) = rhs \).

Value

Returns one function, which combines all the functional constraints.

Note

This function only intended for plugin authors.

See Also

Other plugin functions: ROI_plugin_add_status_code_to_db(), ROI_plugin_build_inequality_constraints(), ROI_plugin_canonicalize_solution(), ROI_plugin_get_solver_name(), ROI_plugin_make_signature(), ROI_plugin_register_solver_control(), ROI_plugin_register_solver_method(), ROI_plugin_solution_prim(), ROI_registered_solver_control()
ROI_plugin_build_inequality_constraints

*Build Functional Inequality Constraints*

**Description**

There exist different forms of functional inequality constraints, this function transforms the form used in **ROI** into the forms commonly used by R optimization solvers.

**Usage**

```r
ROI_plugin_build_inequality_constraints(x, type = c("leq_zero", "geq_zero"))
```

**Arguments**

- `x` an object of type "OP".
- `type` an character giving the type of the function to be returned, possible values are "leq\_zero" and "geq\_zero". For more information see Details.

**Details**

There are three types of inequality constraints commonly used in R

1. **leq\_zero**: $h(x) \leq 0$
2. **geq\_zero**: $h(x) \geq 0$
3. **leq\_geq\_rhs**: $lhs \geq h(x) \leq rhs$.

**Value**

Returns one function, which combines all the functional constraints.

**Note**

This function only intended for plugin authors.

**See Also**

Other plugin functions: `ROI_plugin_add_status_code_to_db()`, `ROI_plugin_build_equality_constraints()`, `ROI_plugin_canonicalize_solution()`, `ROI_plugin_get_solver_name()`, `ROI_plugin_make_signature()`, `ROI_plugin_register_solver_control()`, `ROI_plugin_register_solver_method()`, `ROI_plugin_solution_prim()`, `ROI_registered_solver_control()`
ROI_plugincanonicalize_solution

Canonicalize Solution

Description

Transform the solution to a standardized form.

Usage

ROI_plugin_canonicalize_solution(
  solution,
  optimum,
  status,
  solver,
  message = NULL,
  ...
)

Arguments

solution a numeric or integer vector giving the solution of the optimization problem.

optimum a numeric giving the optimal value.

status an integer giving the status code (exit flag).

solver a character string giving the name of the solver.

message an optional \texttt{R} object giving the original solver message.

... further arguments to be stored in the solution object.

Value

an object of class "OP_solution".

See Also

Other plugin functions: ROI_plugin_add_status_code_to_db(), ROI_plugin_build_equality_constraints(), ROI_plugin_build_inequality_constraints(), ROI_plugin_get_solver_name(), ROI_plugin_make_signature(), ROI_plugin_register_solver_control(), ROI_plugin_register_solver_method(), ROI_plugin_solution_prim(), ROI_registered_solver_control()
ROI_plugin_get_solver_name

Get Solver Name

Description
Get the name of the solver plugin.

Usage
ROI_plugin_get_solver_name(pkgname)

Arguments
pkgname  a string giving the package name.

Value
Returns the name of the solver as character.

See Also
Other plugin functions: ROI_plugin_add_status_code_to_db(), ROI_plugin_build_equality_constraints(), ROI_plugin_build_inequality_constraints(), ROI_plugin_canonicalize_solution(), ROI_plugin_make_signature(), ROI_plugin_register_solver_control(), ROI_plugin_register_solver_method(), ROI_plugin_solution_prim(), ROI_registered_solver_control()

ROI_plugin_make_signature

Make Signatures

Description
Create a solver signature, the solver signatures are used to indicate which problem types can be solved by a given solver.

Usage
ROI_plugin_make_signature(...)  

Arguments
...  signature definitions

Value
an object of class "ROI_signature" (inherting from data.frame) with the supported signatures.
See Also

Other plugin functions: \texttt{ROI_plugin_add_status_code_to_db()}, \texttt{ROI_plugin_build_equality_constraints()}, \texttt{ROI_plugin_build_inequality_constraints()}, \texttt{ROI_plugin_canonicalize_solution()}, \texttt{ROI_plugin_get_solver_name()}, \texttt{ROI_plugin_register_solver_control()}, \texttt{ROI_plugin_register_solver_method()}, \texttt{ROI_plugin_solution_prim()}, \texttt{ROI_registered_solver_control()}

Examples

\begin{verbatim}
## ROI_make_LP_signatures
lp_signature <- ROI_plugin_make_signature( objective = "L",
                         constraints = "L",
                         types = c("C"),
                         bounds = c("X", "V"),
                         cones = c("X"),
                         maximum = c(TRUE, FALSE) )
\end{verbatim}
ROI_plugin_register_reformulation

Value

NULL on success

See Also

Other input output: ROI_read(), ROI_registered_reader(), ROI_registered_writer(), ROI_write()

---------------------------------------------

ROI_plugin_register_reformulation
Register Reformulation Method

Description

Register a new reformulation method to be used with ROI_reformulate.

Usage

ROI_plugin_register_reformulation(
  from,
  to,
  method_name,
  method,
  description = "",
  cite = "",
  author = ""
)

Arguments

from a data.frame with the supported signatures.
to a data.frame with the supported signatures.
method_name a character string giving the name of the method.
method a function registered as solver method.
description a optional character string giving a description of what the reformulation does.
cite a optional character string indicating a reference, such as the name of a book.
author a optional character string giving the name of the author.

Value

TRUE on success

See Also

Other reformulate functions: ROI_reformulate(), ROI_registered_reformulations()
ROI_plugin_register_solver_control

Register Solver Controls

Description

Register a new solver control argument.

Usage

ROI_plugin_register_solver_control(solver, args, roi_control = "X")

Arguments

- solver: a character string giving the solver name.
- args: a character vector specifying with the supported signatures.
- roi_control: a character vector specifying the corresponding ROI control argument.

Value

TRUE on success

See Also

Other plugin functions: ROI_plugin_add_status_code_to_db(), ROI_plugin_build_equality_constraints(), ROI_plugin_build_inequality_constraints(), ROI_plugin_canonicalize_solution(), ROI_plugin_get_solver_name(), ROI_plugin_make_signature(), ROI_plugin_register_solver_method(), ROI_plugin_solution_prim(), ROI_registered_solver_control()

ROI_plugin_register_solver_method

Register Solver Method

Description

Register a new solver method.

Usage

ROI_plugin_register_solver_method(signatures, solver, method, plugin = solver)
ROI_plugin_solution_prim

Arguments

- **signatures**: a data.frame with the supported signatures.
- **solver**: a character string giving the solver name.
- **method**: a function registered as solver method.
- **plugin**: a character string giving the plugin name.

Value

TRUE on success

See Also

Other plugin functions: ROI_plugin_add_status_code_to_db(), ROI_plugin_build_equality_constraints(), ROI_plugin_build_inequality_constraints(), ROI_plugin_canonicalize_solution(), ROI_plugin_get_solver_name(), ROI_plugin_make_signature(), ROI_plugin_register_solver_control(), ROI_plugin_solution_prim(), ROI_registered_solver_control()

ROI_plugin_solution_prim

Extract solution from the solver.

Description

Generic getter functions used by the function solution. These functions can be used to write a solver specific getter function.

Usage

```r
ROI_plugin_solution_prim(x, force = FALSE)
```

```r
## S3 method for class 'OP_solution'
ROI_plugin_solution_prim(x, force = FALSE)
```

```r
## S3 method for class 'OP_solution_set'
ROI_plugin_solution_prim(x, force = FALSE)
```

ROI_plugin_solution_dual(x)

ROI_plugin_solution_aux(x)

ROI_plugin_solution_psd(x)

ROI_plugin_solution_msg(x)

ROI_plugin_solution_status_code(x)
ROI_plugin_solution_status(x)

ROI_plugin_solution_objval(x, force = FALSE)

Arguments

x
an R object inheriting from solution or solutions.

force
a logical to control the return value in the case that the status code is equal to 1 (i.e. something went wrong). By default force is FALSE and a solution is only provided if the status code is equal to 0 (i.e. success). If force is TRUE ROI ignores the status code and also returns solutions where the solver signaled an issue.

Value

the corresponding solution/s.

See Also

Other plugin functions: ROI_plugin_add_status_code_to_db(), ROI_plugin_build_equality_constraints(), ROI_plugin_build_inequality_constraints(), ROI_plugin_canonicalize_solution(), ROI_plugin_get_solver_name(), ROI_plugin_make_signature(), ROI_plugin_register_solver_control(), ROI_plugin_register_solver_method(), ROI_registered_solver_control()
See Also

Other input output: ROI_plugin_register_reader_writer, ROI_registered_reader, ROI_registered_writer, ROI_write

---

ROI_reformulate

Reformulate an Optimization Problem

Description

Register a new reformulation method.

Usage

ROI_reformulate(x, to, method = NULL)

Arguments

x
an object of class 'OP' giving the optimization problem.

to
a data.frame with the supported signatures.

method
a character string giving the name of the method.

Details

Currently ROI provides two reformulation methods.

1. bqp_to_lp transforms binary quadratic problems to linear mixed integer problems.
2. qp_to_socp transforms quadratic problems with linear constraints to second-order cone problems.

Value

the reformulated optimization problem.

See Also

Other reformulate functions: ROI_plugin_register_reformulation, ROI_registered_reformulations

Examples

## Example from
## Boros, Endre, and Peter L. Hammer. "Pseudo-boolean optimization."

## minimize: 3 x y + y z - x - 4 y - z + 6

Q <- rbind(c(0, 3, 0),
           c(3, 0, 1),
           c(0, 1, 0))
\begin{verbatim}
L <- c(-1, -4, -1)
x <- OP(objective = Q_objective(Q = Q, L = L), types = rep("B", 3))

## reformulate into a mixed integer linear problem
milp <- ROI_reformulate(x, "lp")

## reformulate into a second-order cone problem
socp <- ROI_reformulate(x, "socp")
\end{verbatim}

---

**ROI_registered_reader**  
*List Registered Reader*

**Description**

Retrieve meta information about the registered reader

**Usage**

ROI_registered_reader(type = NULL)

**Arguments**

- `type` an optional character giving the type of the file (e.g. "mps_free", "mps_fixed", "lp_cp1ex", "lp_lpsolve", ...).

**Value**

- `x` a data.frame containing information about the registered readers.

**See Also**

Other input output: ROI_plugin_register_reader_writer, ROI_read(), ROI_registered_writer(), ROI_write()

**Examples**

ROI_registered_reader()
ROI_registered_reader("mps_fixed")
ROI_registered_reformulations

Registered Reformulations

Description
Retrieve meta information about the registered reformulations.

Usage
ROI_registered_reformulations()

Value
a data.frame giving some information about the registered reformulation methods.

See Also
Other reformulate functions: ROI_plugin_register_reformulation(), ROI_reformulate()

Examples
ROI_registered_reformulations()

ROI_registered_solvers
 Solver Tools

Description
Retrieve the names of installed or registered solvers.

Usage
ROI_registered_solvers(...)  
ROI_installed_solvers(...)  

Arguments
...  
arguments passed on to installed.packages.

Details
Whereas ROI_installed_solvers() may lists the names of installed solvers that do not necessarily work, ROI_registered_solvers() lists all solvers that can be used to solve optimization problems.
ROI_registered_writer

**Description**

Write an optimization problem to file.

**Usage**

ROI_registered_writer(signature = NULL)

**Author(s)**

Stefan Theussl
ROI_require_solver

Arguments

signature an optimization problem of class "OP".

See Also

Other input output: ROI_plugin_register_reader_writer, ROI_read(), ROI_registered_reader(), ROI_write()

Examples

ROI_registered_writer()
op <- OP(1:2)
ROI_registered_writer(OP_signature(op))

ROI_require_solver Require Solver

Description

Loads the specified solver and registers it in an internal data base. A request to load an already loaded solver has no effect.

Usage

ROI_require_solver(solver, warn = 0)

Arguments

solver a character string giving the solver name.

warn an integer giving if the warn level. For warn = -1 the warning is ignored. For warn = 0 the warning is stored and printed later. For warn = 1 the warning is printed immediately. For warn = 2 the warning is turned into an error. Default is warn = 0.

Value

Returns TRUE on success otherwise FALSE.
**ROI_solve**

**Solve an Optimization Problem**

**Description**

Solve a given optimization problem. This function uses the given solver (or searches for an appropriate solver) to solve the supplied optimization problem.

**Usage**

```r
ROI_solve(x, solver, control = list(), ...)
```

**Arguments**

- **x**: an optimization problem of class "OP".
- **solver**: a character vector specifying the solver to use. If missing, then the default solver returned by `ROI_options` is used.
- **control**: a list with additional control parameters for the solver. This is solver specific so please consult the corresponding documentation.
- **...**: a list of control parameters (overruling those specified in `control`).

**Value**

a list containing the solution and a message from the solver.

- **solution**: the vector of optimal coefficients
- **objval**: the value of the objective function at the optimum
- **status**: a list giving the status code and message from the solver. The status code is 0 on success (no error occurred) 1 otherwise.
- **message**: a list giving the original message provided by the solver.

**Author(s)**

Stefan Theussl

**References**

Examples

### Rosenbrock Banana Function
### -----------------------------------------
### objective
f <- function(x) {
  return( 100 * (x[2] - x[1] * x[1])^2 + (1 - x[1])^2 )
}
### gradient
g <- function(x) {
}
### bounds
b <- V_bound(li = 1:2, ui = 1:2, lb = c(-3, -3), ub = c(3, 3))
op <- OP( objective = F_objective(f, n = 2L, G = g),
         bounds = b )
res <- ROI_solve( op, solver = "nlminb", control = list(start = c( -1.2, 1 )) )
solution( res )

### Portfolio optimization - minimum variance
### -----------------------------------------
### get monthly returns of 30 US stocks
data( US30 )
r <- na.omit( US30 )
### objective function to minimize
obj <- Q_objective( 2*cov(r) )
### full investment constraint
full_invest <- L_constraint( rep(1, ncol(US30)), "==", 1 )
### create optimization problem / long-only
op <- OP( objective = obj, constraints = full_invest )
### solve the problem - only works if a QP solver is registered
### Not run:
res <- ROI_solve( op )
res
sol <- solution( res )
names( sol ) <- colnames( US30 )
round( sol[ which(sol > 1/10^6) ], 3 )

## End(Not run)

ROI_solver_signature  Obtain Solver Signature

Description

Obtain the signature of a registered solver.

Usage

ROI_solver_signature(solver)
ROI_write

Arguments

solver a character string giving the name of the solver.

Value

the solver signature if the specified solver is registered NULL otherwise.

Examples

ROI_solver_signature("nlminb")

ROI_write Write Optimization Problems

Description

Write an optimization problem to file.

Usage

ROI_write(x, file, type, solver = NULL, ...)

Arguments

x an optimization problem of class "OP".
file a character giving the name of the file the optimization problem is to be written.
type a character giving the type of the file (e.g. "freemps", "mps_fixed", "lp_cplex", "lp_lpsolve", ...).
solver an optional character giving the name of the plugin (e.g. "lpsolve").
... further arguments passed on to the write method.

See Also

Other input output: ROI_plugin_register_reader_writer, ROI_read(), ROI_registered_reader(), ROI_registered_writer()
Description

The solution can be accessed via the method 'solution'.

Usage

solution(x, type = c("primal", "dual", "aux", "psd", "msg", "objval", "status", "status_code"), force = FALSE, ...)

Arguments

x an object of type 'OP_solution' or 'OP_solution_set'.
type a character giving the name of the solution to be extracted.
force a logical to control the return value in the case that the status code is equal to 1 (i.e. something went wrong). By default force is FALSE and a solution is only provided if the status code is equal to 0 (i.e. success). If force is TRUE ROI ignores the status code and also returns solutions where the solver signaled an issue.
...
... further arguments passed to or from other methods.

Value

the extracted solution.

types (Set/Get) Types - Accessor and Mutator Functions

Description

The types of a given optimization problem (OP) can be accessed or mutated via the method 'types'.

Usage

types(x)

types(x) <- value
Arguments

- **x**: an object used to select the method.
- **value**: an R object.

Value

a character vector.

Author(s)

Stefan Theussl

Examples

```r
## minimize: x + 2 y
## subject to: x + y >= 1
## x, y >= 0  x, y are integer
x <- OP(objective = 1:2, constraints = L_constraint(c(1, 1), ">=", 1))
types(x) <- c("I", "I")
types(x)
```

Description

This dataset contains the historical monthly returns of 30 of the largest US stocks from 1999-01-29 to 2013-12-31. This data is dividend adjusted based on the CRSP methodology.

Format

A matrix with 30 columns (representing stocks) and 180 rows (months).

Details

The selected stocks reflect the DJ 30 Industrial Average Index members as of 2013-09-20 (downloaded from https://www.quandl.com which was acquired by https://data.nasdaq.com/).

The data source is Quandl. Data flagged as "WIKI" in their database is public domain.

Source

https://data.nasdaq.com/
**vech**

*Half-Vectorization*

---

**Description**

The utility function `vech` performs a half-vectorization on the given matrices.

**Usage**

`vech(...)`

**Arguments**

`...`  
one or more matrices to be half-vectorized.

**Value**

a matrix

---

**V_bound**

*Objective Variable Bounds*

---

**Description**

Constructs a variable bounds object.

**Usage**

`V_bound(li, ui, lb, ub, nobj, ld = 0, ud = Inf, names = NULL)`

`as.V_bound(x)`

`is.V_bound(x)`

**Arguments**

`li`  
an integer vector specifying the indices of non-standard (i.e., values ≠ 0) lower bounds.

`ui`  
an integer vector specifying the indices of non-standard (i.e., values ≠ Inf) upper bounds.

`lb`  
a numeric vector with lower bounds.

`ub`  
a numeric vector with upper bounds.

`nobj`  
an integer representing the number of objective variables

`ld`  
a numeric giving lower default bound.

`ud`  
a numeric giving upper default bound.

`names`  
a character vector giving the names of the bounds.

`x`  
object to be coerced or tested.
Details

This function returns a sparse representation of objective variable bounds.

Value

An S3 object of class "V_bound" containing lower and upper bounds of the objective variables.

Examples

V_bound(li=1:3, lb=rep.int(-Inf, 3))
V_bound(li=c(1, 5, 10), ui=13, lb=rep.int(-Inf, 3), ub=100, nobj=20)
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