Package 'CVXR'

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Type Package

Title Disciplined Convex Optimization

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VignetteBuilder knitr

URL https://cvxr.rbind.io, https://www.cvxgrp.org/CVXR/

BugReports https://github.com/cvxgrp/CVXR/issues

Description An object-oriented modeling language for disciplined convex programming (DCP) as described in Fu, Narasimhan, and Boyd (2020, <doi:10.18637/jss.v094.i14>). It allows the user to formulate convex optimization problems in a natural way following mathematical convention and DCP rules. The system analyzes the problem, verifies its convexity, converts it into a canonical form, and hands it off to an appropriate solver to obtain the solution. Interfaces to solvers on CRAN and elsewhere are provided, both commercial and open source.

Additional_repositories https://bnaras.github.io/drat

Depends R (>= 3.4.0)

Imports methods, R6, Matrix, Rcpp (>= 0.12.12), bit64, gmp, Rmpfr, ECOSolveR (>= 0.5.3), scs (>= 1.3), stats, osqp

Suggests knitr, rmarkdown, testthat, nnls, slam, covr

LinkingTo Rcpp, RcppEigen

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LazyData true

Collate 'CVXR.R' 'data.R' 'globals.R' 'generics.R' 'interface.R' 'canonical.R' 'expressions.R' 'constant.R' 'variable.R' 'lin_ops.R' 'atoms.R' 'affine.R' 'problem.R' 'constraints.R' 'elementwise.R' 'coeff_extractor.R' 'reductions.R' 'reduction_solvers.R' 'complex2real.R' 'conic_solvers.R' 'eliminate_pwl.R' 'dcp2cone.R' 'dgp2dcp.R' 'qp2quad_form.R' 'qp_solvers.R' 'utilities.R' 'solver_utilities.R' 'transforms.R' 'exports.R' 'rcppUtils.R' 'R6List.R'

'ProblemData-R6.R' 'LinOp-R6.R' 'LinOpVector-R6.R' 'RcppExports.R' 'CVXcanon-R6.R' 'Deque.R' 'canonInterface.R'

RoxygenNote 7.1.1

Encoding UTF-8

Enhances Rcplex, gurobi, rcbc, cccp, Rmosek, Rglpk

NeedsCompilation yes

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R topics documented:

`CVXR-package` *CVXR: Disciplined Convex Optimization in R*

Description

CVXR is an R package that provides an object-oriented modeling language for convex optimization, similar to CVX, CVXPY, YALMIP, and Convex.jl. This domain specific language (DSL) allows the user to formulate convex optimization problems in a natural mathematical syntax rather than the restrictive standard form required by most solvers. The user specifies an objective and set of constraints by combining constants, variables, and parameters using a library of functions with known mathematical properties. CVXR then applies signed disciplined convex programming (DCP) to verify the problem's convexity. Once verified, the problem is converted into standard conic form using graph implementations and passed to a cone solver such as ECOS or SCS.

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`*,Expression,Expression-method` *Elementwise multiplication operator*

Description

Elementwise multiplication operator

Usage

```
## S4 method for signature 'Expression,Expression'
e1 * e2

## S4 method for signature 'Expression,ConstVal'
e1 * e2

## S4 method for signature 'ConstVal,Expression'
e1 * e2
```

Arguments

`e1, e2`	The Expression objects or numeric constants to multiply elementwise.

+,Expression,missing-method
The AddExpression class.

Description

This class represents the sum of any number of expressions.

Usage

```
## S4 method for signature 'Expression,missing'
e1 + e2

## S4 method for signature 'Expression,Expression'
e1 + e2

## S4 method for signature 'Expression,ConstVal'
e1 + e2

## S4 method for signature 'ConstVal,Expression'
e1 + e2

## S4 method for signature 'AddExpression'
dim_from_args(object)

## S4 method for signature 'AddExpression'
name(x)

## S4 method for signature 'AddExpression'
to_numeric(object, values)

## S4 method for signature 'AddExpression'
is_atom_log_log_convex(object)

## S4 method for signature 'AddExpression'
is_atom_log_log_concave(object)

## S4 method for signature 'AddExpression'
is_symmetric(object)

## S4 method for signature 'AddExpression'
is_hermitian(object)

## S4 method for signature 'AddExpression'
copy(object, args = NULL, id_objects = list())

## S4 method for signature 'AddExpression'
```

```
graph_implementation(object, arg_objs, dim, data = NA_real_)
```

Arguments

e1, e2	The Expression objects or numeric constants to add.
x, object	An AddExpression object.
values	A list of arguments to the atom.
args	An optional list of arguments to reconstruct the atom. Default is to use current args of the atom.
id_objects	Currently unused.
arg_objs	A list of linear expressions for each argument.
dim	A vector representing the dimensions of the resulting expression.
data	A list of additional data required by the atom.

Methods (by generic)

- `dim_from_args`: The dimensions of the expression.
- `name`: The string form of the expression.
- `to_numeric`: Sum all the values.
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log convex?
- `is_symmetric`: Is the atom symmetric?
- `is_hermitian`: Is the atom hermitian?
- `copy`: Returns a shallow copy of the AddExpression atom
- `graph_implementation`: The graph implementation of the expression.

Slots

`arg_groups` A `list` of Expressions and numeric data.frame, matrix, or vector objects.

`-,Expression,missing-method`

The NegExpression class.

Description

This class represents the negation of an affine expression.

Usage

```
## S4 method for signature 'Expression,missing'
e1 - e2

## S4 method for signature 'Expression,Expression'
e1 - e2

## S4 method for signature 'Expression,ConstVal'
e1 - e2

## S4 method for signature 'ConstVal,Expression'
e1 - e2

## S4 method for signature 'NegExpression'
dim_from_args(object)

## S4 method for signature 'NegExpression'
sign_from_args(object)

## S4 method for signature 'NegExpression'
is_incr(object, idx)

## S4 method for signature 'NegExpression'
is_decr(object, idx)

## S4 method for signature 'NegExpression'
is_symmetric(object)

## S4 method for signature 'NegExpression'
is_hermitian(object)

## S4 method for signature 'NegExpression'
graph_implementation(object, arg_objs, dim, data = NA_real_)
```

Arguments

`e1, e2`	The Expression objects or numeric constants to subtract.
`object`	A NegExpression object.
`idx`	An index into the atom.
`arg_objs`	A list of linear expressions for each argument.
`dim`	A vector representing the dimensions of the resulting expression.
`data`	A list of additional data required by the atom.

Methods (by generic)

- `dim_from_args`: The (row, col) dimensions of the expression.
- `sign_from_args`: The (is positive, is negative) sign of the expression.

- `is_incr`: The expression is not weakly increasing in any argument.
- `is_decr`: The expression is weakly decreasing in every argument.
- `is_symmetric`: Is the expression symmetric?
- `is_hermitian`: Is the expression Hermitian?
- `graph_implementation`: The graph implementation of the expression.

`.build_matrix_0` *Get the* `sparse` *flag field for the LinOp object*

Description

Get the `sparse` flag field for the LinOp object

Usage

```
.build_matrix_0(xp, v)
```

Arguments

`xp`	the LinOpVector Object XPtr
`v`	the `id_to_col` named int vector in R with integer names

Value

a XPtr to ProblemData Object

`.build_matrix_1` *Get the* `sparse` *flag field for the LinOp object*

Description

Get the `sparse` flag field for the LinOp object

Usage

```
.build_matrix_1(xp, v1, v2)
```

Arguments

`xp`	the LinOpVector Object XPtr
`v1`	the `id_to_col` named int vector in R with integer names
`v2`	the `constr_offsets` vector of offsets (an int vector in R)

Value

a XPtr to ProblemData Object

`.decomp_quad` *Compute a Matrix Decomposition.*

Description

Compute sgn, scale, M such that $P = sgn * scale * dot(M, t(M))$.

Usage

```
.decomp_quad(P, cond = NA, rcond = NA)
```

Arguments

`P`	A real symmetric positive or negative (semi)definite input matrix
`cond`	Cutoff for small eigenvalues. Singular values smaller than rcond * largest_eigenvalue are considered negligible.
`rcond`	Cutoff for small eigenvalues. Singular values smaller than rcond * largest_eigenvalue are considered negligible.

Value

A list consisting of induced matrix 2-norm of P and a rectangular matrix such that P = scale * (dot(M1, t(M1)) - dot(M2, t(M2)))

`.LinOpVector__new` *Create a new LinOpVector object.*

Description

Create a new LinOpVector object.

Usage

```
.LinOpVector__new()
```

Value

an external ptr (Rcpp::XPtr) to a LinOp object instance.

.LinOpVector__push_back *Perform a push back operation on the `args` field of LinOp*

Description

Perform a push back operation on the `args` field of LinOp

Usage

```
.LinOpVector__push_back(xp, yp)
```

Arguments

`xp`	the LinOpVector Object XPtr
`yp`	the LinOp Object XPtr to push

.LinOp_at_index *Return the LinOp element at index i (0-based)*

Description

Return the LinOp element at index i (0-based)

Usage

```
.LinOp_at_index(lvec, i)
```

Arguments

`lvec`	the LinOpVector Object XPtr
`i`	the index

.LinOp__args_push_back *Perform a push back operation on the* `args` *field of LinOp*

Description

Perform a push back operation on the `args` field of LinOp

Usage

```
.LinOp__args_push_back(xp, yp)
```

Arguments

`xp`	the LinOp Object XPtr
`yp`	the LinOp Object XPtr to push

.LinOp__get_dense_data *Get the field* `dense_data` *for the LinOp object*

Description

Get the field `dense_data` for the LinOp object

Usage

```
.LinOp__get_dense_data(xp)
```

Arguments

`xp`	the LinOp Object XPtr

Value

a MatrixXd object

`.LinOp__get_id` *Get the id field of the LinOp Object*

Description

Get the id field of the LinOp Object

Usage

```
.LinOp__get_id(xp)
```

Arguments

`xp`	the LinOp Object XPtr

Value

the value of the id field of the LinOp Object

`.LinOp__get_size` *Get the field `size` for the LinOp object*

Description

Get the field `size` for the LinOp object

Usage

```
.LinOp__get_size(xp)
```

Arguments

`xp`	the LinOp Object XPtr

Value

an integer vector

.LinOp__get_slice *Get the slice field of the LinOp Object*

Description

Get the slice field of the LinOp Object

Usage

```
.LinOp__get_slice(xp)
```

Arguments

xp	the LinOp Object XPtr

Value

the value of the slice field of the LinOp Object

.LinOp__get_sparse *Get the `sparse` flag field for the LinOp object*

Description

Get the `sparse` flag field for the LinOp object

Usage

```
.LinOp__get_sparse(xp)
```

Arguments

xp	the LinOp Object XPtr

Value

TRUE or FALSE

.LinOp__get_sparse_data

Get the field named `sparse_data` from the LinOp object

Description

Get the field named `sparse_data` from the LinOp object

Usage

```
.LinOp__get_sparse_data(xp)
```

Arguments

`xp`	the LinOp Object XPtr

Value

a dgCMatrix-class object

.LinOp__get_type

Get the field named `type` for the LinOp object

Description

Get the field named `type` for the LinOp object

Usage

```
.LinOp__get_type(xp)
```

Arguments

`xp`	the LinOp Object XPtr

Value

an integer value for type

`.LinOp__new` *Create a new LinOp object.*

Description

Create a new LinOp object.

Usage

```
.LinOp__new()
```

Value

an external ptr (Rcpp::XPtr) to a LinOp object instance.

`.LinOp__set_dense_data` *Set the field* `dense_data` *of the LinOp object*

Description

Set the field `dense_data` of the LinOp object

Usage

```
.LinOp__set_dense_data(xp, denseMat)
```

Arguments

`xp`	the LinOp Object XPtr
`denseMat`	a standard matrix object in R

`.LinOp__set_size` *Set the field* `size` *of the LinOp object*

Description

Set the field `size` of the LinOp object

Usage

```
.LinOp__set_size(xp, value)
```

Arguments

`xp`	the LinOp Object XPtr
`value`	an integer vector object in R

`.LinOp__set_slice` *Set the slice field of the LinOp Object*

Description

Set the slice field of the LinOp Object

Usage

```
.LinOp__set_slice(xp, value)
```

Arguments

`xp`	the LinOp Object XPtr
`value`	a list of integer vectors, e.g. `list(1:10,2L,11:15)`

Value

the value of the slice field of the LinOp Object

`.LinOp__set_sparse` *Set the flag* `sparse` *of the LinOp object*

Description

Set the flag `sparse` of the LinOp object

Usage

```
.LinOp__set_sparse(xp, sparseSEXP)
```

Arguments

`xp`	the LinOp Object XPtr
`sparseSEXP`	an R boolean

.LinOp__set_sparse_data

Set the field named `sparse_data` of the LinOp object

Description

Set the field named `sparse_data` of the LinOp object

Usage

```
.LinOp__set_sparse_data(xp, sparseMat)
```

Arguments

`xp`	the LinOp Object XPtr
`sparseMat`	a dgCMatrix-class object

.LinOp__set_type

Set the field named `type` for the LinOp object

Description

Set the field named `type` for the LinOp object

Usage

```
.LinOp__set_type(xp, typeValue)
```

Arguments

`xp`	the LinOp Object XPtr
`typeValue`	an integer value

`.LinOp__size_push_back`
Perform a push back operation on the `size` field of LinOp

Description

Perform a push back operation on the `size` field of LinOp

Usage

```
.LinOp__size_push_back(xp, intVal)
```

Arguments

`xp`	the LinOp Object XPtr
`intVal`	the integer value to push back

`.LinOp__slice_push_back`
Perform a push back operation on the `slice` field of LinOp

Description

Perform a push back operation on the `slice` field of LinOp

Usage

```
.LinOp__slice_push_back(xp, intVec)
```

Arguments

`xp`	the LinOp Object XPtr
`intVec`	an integer vector to push back

`.ProblemData__get_const_to_row` *Get the const_to_row field of the ProblemData Object*

Description

Get the const_to_row field of the ProblemData Object

Usage

```
.ProblemData__get_const_to_row(xp)
```

Arguments

`xp`	the ProblemData Object XPtr

Value

the const_to_row field as a named integer vector where the names are integers converted to characters

`.ProblemData__get_const_vec` *Get the const_vec field from the ProblemData Object*

Description

Get the const_vec field from the ProblemData Object

Usage

```
.ProblemData__get_const_vec(xp)
```

Arguments

`xp`	the ProblemData Object XPtr

Value

a numeric vector of the field const_vec from the ProblemData Object

.ProblemData__get_I *Get the I field of the ProblemData Object*

Description

Get the I field of the ProblemData Object

Usage

```
.ProblemData__get_I(xp)
```

Arguments

xp	the ProblemData Object XPtr

Value

an integer vector of the field I from the ProblemData Object

.ProblemData__get_id_to_col *Get the id_to_col field of the ProblemData Object*

Description

Get the id_to_col field of the ProblemData Object

Usage

```
.ProblemData__get_id_to_col(xp)
```

Arguments

xp	the ProblemData Object XPtr

Value

the id_to_col field as a named integer vector where the names are integers converted to characters

`.ProblemData__get_J` *Get the J field of the ProblemData Object*

Description

Get the J field of the ProblemData Object

Usage

```
.ProblemData__get_J(xp)
```

Arguments

`xp`	the ProblemData Object XPtr

Value

an integer vector of the field J from the ProblemData Object

`.ProblemData__get_V` *Get the V field of the ProblemData Object*

Description

Get the V field of the ProblemData Object

Usage

```
.ProblemData__get_V(xp)
```

Arguments

`xp`	the ProblemData Object XPtr

Value

a numeric vector of doubles (the field V) from the ProblemData Object

`.ProblemData__new` *Create a new ProblemData object.*

Description

Create a new ProblemData object.

Usage

```
.ProblemData__new()
```

Value

an external ptr (Rcpp::XPtr) to a ProblemData object instance.

`.ProblemData__set_const_to_row` *Set the const_to_row map of the ProblemData Object*

Description

Set the const_to_row map of the ProblemData Object

Usage

```
.ProblemData__set_const_to_row(xp, iv)
```

Arguments

`xp`	the ProblemData Object XPtr
`iv`	a named integer vector with names being integers converted to characters

.ProblemData__set_const_vec *Set the const_vec field in the ProblemData Object*

Description

Set the const_vec field in the ProblemData Object

Usage

```
.ProblemData__set_const_vec(xp, cvp)
```

Arguments

xp	the ProblemData Object XPtr
cvp	a numeric vector of values for const_vec field of the ProblemData object

.ProblemData__set_I *Set the I field in the ProblemData Object*

Description

Set the I field in the ProblemData Object

Usage

```
.ProblemData__set_I(xp, ip)
```

Arguments

xp	the ProblemData Object XPtr
ip	an integer vector of values for field I of the ProblemData object

.ProblemData__set_id_to_col *Set the id_to_col field of the ProblemData Object*

Description

Set the id_to_col field of the ProblemData Object

Usage

```
.ProblemData__set_id_to_col(xp, iv)
```

Arguments

`xp`	the ProblemData Object XPtr
`iv`	a named integer vector with names being integers converted to characters

.ProblemData__set_J *Set the J field in the ProblemData Object*

Description

Set the J field in the ProblemData Object

Usage

```
.ProblemData__set_J(xp, jp)
```

Arguments

`xp`	the ProblemData Object XPtr
`jp`	an integer vector of the values for field J of the ProblemData object

.ProblemData__set_V *Set the V field in the ProblemData Object*

Description

Set the V field in the ProblemData Object

Usage

```
.ProblemData__set_V(xp, vp)
```

Arguments

xp	the ProblemData Object XPtr
vp	a numeric vector of values for field V

.p_norm *Internal method for calculating the p-norm*

Description

Internal method for calculating the p-norm

Usage

```
.p_norm(x, p)
```

Arguments

x	A matrix
p	A number grater than or equal to 1, or equal to positive infinity

Value

Returns the specified norm of matrix x

`/,Expression,Expression-method`
The DivExpression class.

Description

This class represents one expression divided by another expression.

Usage

```
## S4 method for signature 'Expression,Expression'
e1 / e2

## S4 method for signature 'Expression,ConstVal'
e1 / e2

## S4 method for signature 'ConstVal,Expression'
e1 / e2

## S4 method for signature 'DivExpression'
to_numeric(object, values)

## S4 method for signature 'DivExpression'
is_quadratic(object)

## S4 method for signature 'DivExpression'
is_qpwa(object)

## S4 method for signature 'DivExpression'
dim_from_args(object)

## S4 method for signature 'DivExpression'
is_atom_convex(object)

## S4 method for signature 'DivExpression'
is_atom_concave(object)

## S4 method for signature 'DivExpression'
is_atom_log_log_convex(object)

## S4 method for signature 'DivExpression'
is_atom_log_log_concave(object)

## S4 method for signature 'DivExpression'
is_incr(object, idx)

## S4 method for signature 'DivExpression'
```

```
is_decr(object, idx)

## S4 method for signature 'DivExpression'
graph_implementation(object, arg_objs, dim, data = NA_real_)
```

Arguments

e1, e2	The Expression objects or numeric constants to divide. The denominator, e2, must be a scalar constant.
object	A DivExpression object.
values	A list of arguments to the atom.
idx	An index into the atom.
arg_objs	A list of linear expressions for each argument.
dim	A vector representing the dimensions of the resulting expression.
data	A list of additional data required by the atom.

Methods (by generic)

- `to_numeric`: Matrix division by a scalar.
- `is_quadratic`: Is the left-hand expression quadratic and the right-hand expression constant?
- `is_qpwa`: Is the expression quadratic of piecewise affine?
- `dim_from_args`: The (row, col) dimensions of the left-hand expression.
- `is_atom_convex`: Division is convex (affine) in its arguments only if the denominator is constant.
- `is_atom_concave`: Division is concave (affine) in its arguments only if the denominator is constant.
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `is_incr`: Is the right-hand expression positive?
- `is_decr`: Is the right-hand expression negative?
- `graph_implementation`: The graph implementation of the expression.

`<=,Expression,Expression-method`
The IneqConstraint class

Description

The IneqConstraint class

Usage

```
## S4 method for signature 'Expression,Expression'
e1 <= e2

## S4 method for signature 'Expression,ConstVal'
e1 <= e2

## S4 method for signature 'ConstVal,Expression'
e1 <= e2

## S4 method for signature 'Expression,Expression'
e1 < e2

## S4 method for signature 'Expression,ConstVal'
e1 < e2

## S4 method for signature 'ConstVal,Expression'
e1 < e2

## S4 method for signature 'Expression,Expression'
e1 >= e2

## S4 method for signature 'Expression,ConstVal'
e1 >= e2

## S4 method for signature 'ConstVal,Expression'
e1 >= e2

## S4 method for signature 'Expression,Expression'
e1 > e2

## S4 method for signature 'Expression,ConstVal'
e1 > e2

## S4 method for signature 'ConstVal,Expression'
e1 > e2

## S4 method for signature 'IneqConstraint'
name(x)

## S4 method for signature 'IneqConstraint'
dim(x)

## S4 method for signature 'IneqConstraint'
size(object)

## S4 method for signature 'IneqConstraint'
expr(object)
```

```
## S4 method for signature 'IneqConstraint'
is_dcp(object)

## S4 method for signature 'IneqConstraint'
is_dgp(object)

## S4 method for signature 'IneqConstraint'
residual(object)
```

Arguments

e1, e2	The Expression objects or numeric constants to compare.
x, object	A IneqConstraint object.

Methods (by generic)

- name: The string representation of the constraint.
- dim: The dimensions of the constrained expression.
- size: The size of the constrained expression.
- expr: The expression to constrain.
- is_dcp: A non-positive constraint is DCP if its argument is convex.
- is_dgp: Is the constraint DGP?
- residual: The residual of the constraint.

==,Expression,Expression-method
The EqConstraint class

Description

The EqConstraint class

Usage

```
## S4 method for signature 'Expression,Expression'
e1 == e2

## S4 method for signature 'Expression,ConstVal'
e1 == e2

## S4 method for signature 'ConstVal,Expression'
e1 == e2

## S4 method for signature 'EqConstraint'
```

```
name(x)

## S4 method for signature 'EqConstraint'
dim(x)

## S4 method for signature 'EqConstraint'
size(object)

## S4 method for signature 'EqConstraint'
expr(object)

## S4 method for signature 'EqConstraint'
is_dcp(object)

## S4 method for signature 'EqConstraint'
is_dgp(object)

## S4 method for signature 'EqConstraint'
residual(object)
```

Arguments

`e1, e2`	The Expression objects or numeric constants to compare.
`x, object`	A EqConstraint object.

Methods (by generic)

- `name`: The string representation of the constraint.
- `dim`: The dimensions of the constrained expression.
- `size`: The size of the constrained expression.
- `expr`: The expression to constrain.
- `is_dcp`: Is the constraint DCP?
- `is_dgp`: Is the constraint DGP?
- `residual`: The residual of the constraint..

`abs,Expression-method` *Absolute Value*

Description

The elementwise absolute value.

Usage

```
## S4 method for signature 'Expression'
abs(x)
```

Arguments

x An Expression.

Value

An Expression representing the absolute value of the input.

Examples

```
A <- Variable(2,2)
prob <- Problem(Minimize(sum(abs(A))), list(A <= -2))
result <- solve(prob)
result$value
result$getValue(A)
```

Abs-class *The Abs class.*

Description

This class represents the elementwise absolute value.

Usage

```
Abs(x)

## S4 method for signature 'Abs'
to_numeric(object, values)

## S4 method for signature 'Abs'
allow_complex(object)

## S4 method for signature 'Abs'
sign_from_args(object)

## S4 method for signature 'Abs'
is_atom_convex(object)

## S4 method for signature 'Abs'
is_atom_concave(object)

## S4 method for signature 'Abs'
is_incr(object, idx)

## S4 method for signature 'Abs'
is_decr(object, idx)

## S4 method for signature 'Abs'
is_pwl(object)
```

Arguments

`x`	An Expression object.
`object`	An Abs object.
`values`	A list of arguments to the atom.
`idx`	An index into the atom.

Methods (by generic)

- `to_numeric`: The elementwise absolute value of the input.
- `allow_complex`: Does the atom handle complex numbers?
- `sign_from_args`: The atom is positive.
- `is_atom_convex`: The atom is convex.
- `is_atom_concave`: The atom is not concave.
- `is_incr`: A logical value indicating whether the atom is weakly increasing.
- `is_decr`: A logical value indicating whether the atom is weakly decreasing.
- `is_pwl`: Is `x` piecewise linear?

Slots

`x` An Expression object.

`accepts` *Reduction Acceptance*

Description

Determine whether the reduction accepts a problem.

Usage

```
accepts(object, problem)
```

Arguments

`object`	A Reduction object.
`problem`	A Problem to check.

Value

A logical value indicating whether the reduction can be applied.

AffAtom-class *The AffAtom class.*

Description

This virtual class represents an affine atomic expression.

Usage

```
## S4 method for signature 'AffAtom'
allow_complex(object)

## S4 method for signature 'AffAtom'
sign_from_args(object)

## S4 method for signature 'AffAtom'
is_imag(object)

## S4 method for signature 'AffAtom'
is_complex(object)

## S4 method for signature 'AffAtom'
is_atom_convex(object)

## S4 method for signature 'AffAtom'
is_atom_concave(object)

## S4 method for signature 'AffAtom'
is_incr(object, idx)

## S4 method for signature 'AffAtom'
is_decr(object, idx)

## S4 method for signature 'AffAtom'
is_quadratic(object)

## S4 method for signature 'AffAtom'
is_qpwa(object)

## S4 method for signature 'AffAtom'
is_pwl(object)

## S4 method for signature 'AffAtom'
is_psd(object)

## S4 method for signature 'AffAtom'
is_nsd(object)
```

```
## S4 method for signature 'AffAtom'
.grad(object, values)
```

Arguments

`object`	An AffAtom object.
`idx`	An index into the atom.
`values`	A list of numeric values for the arguments

Methods (by generic)

- `allow_complex`: Does the atom handle complex numbers?
- `sign_from_args`: The sign of the atom.
- `is_imag`: Is the atom imaginary?
- `is_complex`: Is the atom complex valued?
- `is_atom_convex`: The atom is convex.
- `is_atom_concave`: The atom is concave.
- `is_incr`: The atom is weakly increasing in every argument.
- `is_decr`: The atom is not weakly decreasing in any argument.
- `is_quadratic`: Is every argument quadratic?
- `is_qpwa`: Is every argument quadratic of piecewise affine?
- `is_pwl`: Is every argument piecewise linear?
- `is_psd`: Is the atom a positive semidefinite matrix?
- `is_nsd`: Is the atom a negative semidefinite matrix?
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable

---

`are_args_affine` *Are the arguments affine?*

Description

Are the arguments affine?

Usage

```
are_args_affine(constraints)
```

Arguments

`constraints`	A Constraint object.

Value

All the affine arguments in given constraints.

Atom-class *The Atom class.*

Description

This virtual class represents atomic expressions in CVXR.

Usage

```
## S4 method for signature 'Atom'
name(x)

## S4 method for signature 'Atom'
validate_args(object)

## S4 method for signature 'Atom'
dim(x)

## S4 method for signature 'Atom'
nrow(x)

## S4 method for signature 'Atom'
ncol(x)

## S4 method for signature 'Atom'
allow_complex(object)

## S4 method for signature 'Atom'
is_nonneg(object)

## S4 method for signature 'Atom'
is_nonpos(object)

## S4 method for signature 'Atom'
is_imag(object)

## S4 method for signature 'Atom'
is_complex(object)

## S4 method for signature 'Atom'
is_convex(object)

## S4 method for signature 'Atom'
is_concave(object)

## S4 method for signature 'Atom'
is_log_log_convex(object)
```

```
## S4 method for signature 'Atom'
is_log_log_concave(object)

## S4 method for signature 'Atom'
canonicalize(object)

## S4 method for signature 'Atom'
graph_implementation(object, arg_objs, dim, data = NA_real_)

## S4 method for signature 'Atom'
value_impl(object)

## S4 method for signature 'Atom'
value(object)

## S4 method for signature 'Atom'
grad(object)

## S4 method for signature 'Atom'
domain(object)

## S4 method for signature 'Atom'
atoms(object)
```

Arguments

x, object	An Atom object.
arg_objs	A list of linear expressions for each argument.
dim	A vector with two elements representing the dimensions of the resulting expression.
data	A list of additional data required by the atom.

Methods (by generic)

- name: Returns the string representtation of the function call
- validate_args: Raises an error if the arguments are invalid.
- dim: The c(row,col) dimensions of the atom.
- nrow: The number of rows in the atom.
- ncol: The number of columns in the atom.
- allow_complex: Does the atom handle complex numbers?
- is_nonneg: A logical value indicating whether the atom is nonnegative.
- is_nonpos: A logical value indicating whether the atom is nonpositive.
- is_imag: A logical value indicating whether the atom is imaginary.
- is_complex: A logical value indicating whether the atom is complex valued.

- is_convex: A logical value indicating whether the atom is convex.
- is_concave: A logical value indicating whether the atom is concave.
- is_log_log_convex: A logical value indicating whether the atom is log-log convex.
- is_log_log_concave: A logical value indicating whether the atom is log-log concave.
- canonicalize: Represent the atom as an affine objective and conic constraints.
- graph_implementation: The graph implementation of the atom.
- value_impl: Returns the value of each of the componets in an Atom. Returns an empty matrix if it's an empty atom
- value: Returns the value of the atom.
- grad: The (sub/super)-gradient of the atom with respect to each variable.
- domain: A list of constraints describing the closure of the region where the expression is finite.
- atoms: Returns a list of the atom types present amongst this atom's arguments

---

AxisAtom-class *The AxisAtom class.*

Description

This virtual class represents atomic expressions that can be applied along an axis in CVXR.

Usage

```
## S4 method for signature 'AxisAtom'
dim_from_args(object)

## S4 method for signature 'AxisAtom'
get_data(object)

## S4 method for signature 'AxisAtom'
validate_args(object)

## S4 method for signature 'AxisAtom'
.axis_grad(object, values)

## S4 method for signature 'AxisAtom'
.column_grad(object, value)
```

Arguments

object	An Atom object.
values	A list of numeric values for the arguments
value	A numeric value

Methods (by generic)

- `dim_from_args`: The dimensions of the atom determined from its arguments.
- `get_data`: A list containing `axis` and `keepdims`.
- `validate_args`: Check that the new dimensions have the same number of entries as the old.
- `.axis_grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable
- `.column_grad`: Gives the (sub/super)gradient of the atom w.r.t. each column variable

Slots

`expr` A numeric element, data.frame, matrix, vector, or Expression.

`axis` (Optional) The dimension across which to apply the function: `1` indicates rows, `2` indicates columns, and `NA` indicates rows and columns. The default is `NA`.

`keepdims` (Optional) Should dimensions be maintained when applying the atom along an axis? If `FALSE`, result will be collapsed into an $nx1$ column vector. The default is `FALSE`.

`BinaryOperator-class` *The BinaryOperator class.*

Description

This base class represents expressions involving binary operators.

Usage

```
## S4 method for signature 'BinaryOperator'
name(x)

## S4 method for signature 'BinaryOperator'
to_numeric(object, values)

## S4 method for signature 'BinaryOperator'
sign_from_args(object)

## S4 method for signature 'BinaryOperator'
is_imag(object)

## S4 method for signature 'BinaryOperator'
is_complex(object)
```

Arguments

`x, object`	A BinaryOperator object.
`values`	A list of arguments to the atom.

Methods (by generic)

- `name`: Returns the name of the BinaryOperator object.
- `to_numeric`: Apply the binary operator to the values.
- `sign_from_args`: Default to rule for multiplication.
- `is_imag`: Is the expression imaginary?
- `is_complex`: Is the expression complex valued?

Slots

`lh_exp` The Expression on the left-hand side of the operator.

`rh_exp` The Expression on the right-hand side of the operator.

`op_name` A `character` string indicating the binary operation.

---

bmat *Block Matrix*

Description

Constructs a block matrix from a list of lists. Each internal list is stacked horizontally, and the internal lists are stacked vertically.

Usage

```
bmat(block_lists)
```

Arguments

`block_lists`	A list of lists containing Expression objects, matrices, or vectors, which represent the blocks of the block matrix.

Value

An Expression representing the block matrix.

Examples

```
x <- Variable()
expr <- bmat(list(list(matrix(1, nrow = 3, ncol = 1), matrix(2, nrow = 3, ncol = 2)),
                 list(matrix(3, nrow = 1, ncol = 2), x)
              ))
prob <- Problem(Minimize(sum_entries(expr)), list(x >= 0))
result <- solve(prob)
result$value
```

CallbackParam-class *The CallbackParam class.*

Description

This class represents a parameter whose value is obtained by evaluating a function.

Usage

```
CallbackParam(callback, dim = NULL, ...)

## S4 method for signature 'CallbackParam'
value(object)
```

Arguments

callback	A callback function that generates the parameter value.
dim	The dimensions of the parameter.
...	Additional attribute arguments. See Leaf for details.
object	A CallbackParam object.

Slots

`callback` A callback function that generates the parameter value.

`dim` The dimensions of the parameter.

Examples

```
x <- Variable(2)
fun <- function() { value(x) }
y <- CallbackParam(fun, dim(x), nonneg = TRUE)
get_data(y)
```

Canonical-class *The Canonical class.*

Description

This virtual class represents a canonical expression.

Usage

```
## S4 method for signature 'Canonical'
expr(object)

## S4 method for signature 'Canonical'
id(object)

## S4 method for signature 'Canonical'
canonical_form(object)

## S4 method for signature 'Canonical'
variables(object)

## S4 method for signature 'Canonical'
parameters(object)

## S4 method for signature 'Canonical'
constants(object)

## S4 method for signature 'Canonical'
atoms(object)

## S4 method for signature 'Canonical'
get_data(object)
```

Arguments

`object`	A Canonical object.

Methods (by generic)

- `expr`: The expression associated with the input.
- `id`: The unique ID of the canonical expression.
- `canonical_form`: The graph implementation of the input.
- `variables`: List of Variable objects in the expression.
- `parameters`: List of Parameter objects in the expression.
- `constants`: List of Constant objects in the expression.
- `atoms`: List of Atom objects in the expression.
- `get_data`: Information needed to reconstruct the expression aside from its arguments.

Canonicalization-class
The Canonicalization class.

Description

This class represents a canonicalization reduction.

Usage

```
## S4 method for signature 'Canonicalization,Problem'
perform(object, problem)

## S4 method for signature 'Canonicalization,Solution,InverseData'
invert(object, solution, inverse_data)

## S4 method for signature 'Canonicalization'
canonicalize_tree(object, expr)

## S4 method for signature 'Canonicalization'
canonicalize_expr(object, expr, args)
```

Arguments

`object`	A Canonicalization object.
`problem`	A Problem object.
`solution`	A Solution to a problem that generated the inverse data.
`inverse_data`	An InverseData object that contains the data encoding the original problem.
`expr`	An Expression object.
`args`	List of arguments to canonicalize the expression.

Methods (by generic)

- `perform`: Recursively canonicalize the objective and every constraint.
- `invert`: Performs the reduction on a problem and returns an equivalent problem.
- `canonicalize_tree`: Recursively canonicalize an Expression.
- `canonicalize_expr`: Canonicalize an expression, w.r.t. canonicalized arguments.

`canonicalize` *Canonicalize*

Description

Computes the graph implementation of a canonical expression.

Usage

```
canonicalize(object)

canonical_form(object)
```

Arguments

`object`	A Canonical object.

Value

A list of `list(affine expression,list(constraints))`.

`CBC_CONIC-class` *An interface to the CBC solver*

Description

An interface to the CBC solver

Usage

```
CBC_CONIC()

## S4 method for signature 'CBC_CONIC'
mip_capable(solver)

## S4 method for signature 'CBC_CONIC'
status_map(solver, status)

## S4 method for signature 'CBC_CONIC'
status_map_mip(solver, status)

## S4 method for signature 'CBC_CONIC'
status_map_lp(solver, status)

## S4 method for signature 'CBC_CONIC'
name(x)
```

```
## S4 method for signature 'CBC_CONIC'
import_solver(solver)

## S4 method for signature 'CBC_CONIC,Problem'
accepts(object, problem)

## S4 method for signature 'CBC_CONIC,Problem'
perform(object, problem)

## S4 method for signature 'CBC_CONIC,list,list'
invert(object, solution, inverse_data)

## S4 method for signature 'CBC_CONIC'
solve_via_data(
  object,
  data,
  warm_start,
  verbose,
  feastol,
  reltol,
  abstol,
  num_iter,
  solver_opts,
  solver_cache
)
```

Arguments

`solver, object, x`	A CBC_CONIC object.
`status`	A status code returned by the solver.
`problem`	A Problem object.
`solution`	The raw solution returned by the solver.
`inverse_data`	A list containing data necessary for the inversion.
`data`	Data generated via an apply call.
`warm_start`	A boolean of whether to warm start the solver.
`verbose`	A boolean of whether to enable solver verbosity.
`feastol`	The feasible tolerance.
`reltol`	The relative tolerance.
`abstol`	The absolute tolerance.
`num_iter`	The maximum number of iterations.
`solver_opts`	A list of Solver specific options
`solver_cache`	Cache for the solver.

Methods (by generic)

- `mip_capable`: Can the solver handle mixed-integer programs?
- `status_map`: Converts status returned by the CBC solver to its respective CVXPY status.
- `status_map_mip`: Converts status returned by the CBC solver to its respective CVXPY status for mixed integer problems.
- `status_map_lp`: Converts status returned by the CBC solver to its respective CVXPY status for linear problems.
- `name`: Returns the name of the solver
- `import_solver`: Imports the solver
- `accepts`: Can CBC_CONIC solve the problem?
- `perform`: Returns a new problem and data for inverting the new solution.
- `invert`: Returns the solution to the original problem given the inverse_data.
- `solve_via_data`: Solve a problem represented by data returned from apply.

`cdiac` *Global Monthly and Annual Temperature Anomalies (degrees C), 1850-2015 (Relative to the 1961-1990 Mean) (May 2016)*

Description

Global Monthly and Annual Temperature Anomalies (degrees C), 1850-2015 (Relative to the 1961-1990 Mean) (May 2016)

Usage

```
cdiac
```

Format

A data frame with 166 rows and 14 variables:

year Year
jan Anomaly for month of January
feb Anomaly for month of February
mar Anomaly for month of March
apr Anomaly for month of April
may Anomaly for month of May
jun Anomaly for month of June
jul Anomaly for month of July
aug Anomaly for month of August
sep Anomaly for month of September
oct Anomaly for month of October
nov Anomaly for month of November
dec Anomaly for month of December
annual Annual anomaly for the year

Source

https://ess-dive.lbl.gov/

References

https://ess-dive.lbl.gov/

Chain-class *The Chain class.*

Description

This class represents a reduction that replaces symbolic parameters with their constraint values.

Usage

```
## S4 method for signature 'Chain'
as.character(x)

## S4 method for signature 'Chain,Problem'
accepts(object, problem)

## S4 method for signature 'Chain,Problem'
perform(object, problem)

## S4 method for signature 'Chain,SolutionORList,list'
invert(object, solution, inverse_data)
```

Arguments

x, object	A Chain object.
problem	A Problem object to check.
solution	A Solution or list.
inverse_data	A list that contains the data encoding the original problem.

Methods (by generic)

- `accepts`: A problem is accepted if the sequence of reductions is valid. In particular, the i-th reduction must accept the output of the i-1th reduction, with the first reduction (self.reductions[0]) in the sequence taking as input the supplied problem.
- `perform`: Applies the chain to a problem and returns an equivalent problem.
- `invert`: Performs the reduction on a problem and returns an equivalent problem.

complex-atoms *Complex Numbers*

Description

Basic atoms that support complex arithmetic.

Usage

```
## S4 method for signature 'Expression'
Re(z)

## S4 method for signature 'Expression'
Im(z)

## S4 method for signature 'Expression'
Conj(z)
```

Arguments

z	An Expression object.

Value

An Expression object that represents the real, imaginary, or complex conjugate.

complex-methods *Complex Properties*

Description

Determine if an expression is real, imaginary, or complex.

Usage

```
is_real(object)

is_imag(object)

is_complex(object)
```

Arguments

object	An Expression object.

Value

A logical value.

`Complex2Real-class` *Lifts complex numbers to a real representation.*

Description

This reduction takes in a complex problem and returns an equivalent real problem.

Usage

```
## S4 method for signature 'Complex2Real,Problem'
accepts(object, problem)

## S4 method for signature 'Complex2Real,Problem'
perform(object, problem)

## S4 method for signature 'Complex2Real,Solution,InverseData'
invert(object, solution, inverse_data)
```

Arguments

`object`	A Complex2Real object.
`problem`	A Problem object.
`solution`	A Solution object to invert.
`inverse_data`	A InverseData object containing data necessary for the inversion.

Methods (by generic)

- `accepts`: Checks whether or not the problem involves any complex numbers.
- `perform`: Converts a Complex problem into a Real one.
- `invert`: Returns a solution to the original problem given the inverse data.

`Complex2Real.abs_canon`
Complex canonicalizer for the absolute value atom

Description

Complex canonicalizer for the absolute value atom

Usage

```
Complex2Real.abs_canon(expr, real_args, imag_args, real2imag)
```

Arguments

`expr`	An Expression object
`real_args`	A list of Constraint objects for the real part of the expression
`imag_args`	A list of Constraint objects for the imaginary part of the expression
`real2imag`	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.

Value

A canonicalization of the absolute value atom of a complex expression, where the returned variables are its real and imaginary components parsed out.

`Complex2Real.add` *Helper function to sum arguments.*

Description

Helper function to sum arguments.

Usage

```
Complex2Real.add(lh_arg, rh_arg, neg = FALSE)
```

Arguments

`lh_arg`	The arguments for the left-hand side
`rh_arg`	The arguments for the right-hand side
`neg`	Whether to negate the right hand side

`Complex2Real.at_least_2D` *Upcast 0D and 1D to 2D.*

Description

Upcast 0D and 1D to 2D.

Usage

```
Complex2Real.at_least_2D(expr)
```

Arguments

`expr`	An Expression object

Value

An expression of dimension at least 2.

`Complex2Real.binary_canon`
Complex canonicalizer for the binary atom

Description

Complex canonicalizer for the binary atom

Usage

```
Complex2Real.binary_canon(expr, real_args, imag_args, real2imag)
```

Arguments

`expr`	An Expression object
`real_args`	A list of Constraint objects for the real part of the expression
`imag_args`	A list of Constraint objects for the imaginary part of the expression
`real2imag`	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.

Value

A canonicalization of a binary atom, where the returned variables are the real component and the imaginary component.

`Complex2Real.canonicalize_expr`
Canonicalizes a Complex Expression

Description

Canonicalizes a Complex Expression

Usage

```
Complex2Real.canonicalize_expr(expr, real_args, imag_args, real2imag, leaf_map)
```

Arguments

`expr`	An Expression object.
`real_args`	A list of Constraint objects for the real part of the expression.
`imag_args`	A list of Constraint objects for the imaginary part of the expression.
`real2imag`	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.
`leaf_map`	A map that consists of a tree representation of the overall expression

Value

A list of the parsed out real and imaginary components of the expression at hand.

`Complex2Real.canonicalize_tree`

Recursively Canonicalizes a Complex Expression.

Description

Recursively Canonicalizes a Complex Expression.

Usage

```
Complex2Real.canonicalize_tree(expr, real2imag, leaf_map)
```

Arguments

`expr`	An Expression object.
`real2imag`	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.
`leaf_map`	A map that consists of a tree representation of the expression.

Value

A list of the parsed out real and imaginary components of the expression that was constructed by performing the canonicalization of each leaf in the tree.

Complex2Real.conj_canon

Complex canonicalizer for the conjugate atom

Description

Complex canonicalizer for the conjugate atom

Usage

```
Complex2Real.conj_canon(expr, real_args, imag_args, real2imag)
```

Arguments

expr	An Expression object
real_args	A list of Constraint objects for the real part of the expression
imag_args	A list of Constraint objects for the imaginary part of the expression
real2imag	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.

Value

A canonicalization of a conjugate atom, where the returned variables are the real components and negative of the imaginary component.

Complex2Real.constant_canon

Complex canonicalizer for the constant atom

Description

Complex canonicalizer for the constant atom

Usage

```
Complex2Real.constant_canon(expr, real_args, imag_args, real2imag)
```

Arguments

expr	An Expression object
real_args	A list of Constraint objects for the real part of the expression
imag_args	A list of Constraint objects for the imaginary part of the expression
real2imag	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.

Value

A canonicalization of a constant atom, where the returned variables are the real component and the imaginary component in the Constant atom.

Complex2Real.hermitian_canon
Complex canonicalizer for the hermitian atom

Description

Complex canonicalizer for the hermitian atom

Usage

```
Complex2Real.hermitian_canon(expr, real_args, imag_args, real2imag)
```

Arguments

expr	An Expression object
real_args	A list of Constraint objects for the real part of the expression
imag_args	A list of Constraint objects for the imaginary part of the expression
real2imag	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.

Value

A canonicalization of a hermitian matrix atom, where the returned variables are the real component and the imaginary component.

Complex2Real.imag_canon
Complex canonicalizer for the imaginary atom

Description

Complex canonicalizer for the imaginary atom

Usage

```
Complex2Real.imag_canon(expr, real_args, imag_args, real2imag)
```

Arguments

expr	An Expression object
real_args	A list of Constraint objects for the real part of the expression
imag_args	A list of Constraint objects for the imaginary part of the expression
real2imag	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.

Value

A canonicalization of an imaginary atom, where the returned variables are the imaginary component and NULL for the real component.

Complex2Real.join   *Helper function to combine arguments.*

Description

Helper function to combine arguments.

Usage

```
Complex2Real.join(expr, lh_arg, rh_arg)
```

Arguments

expr	An Expression object
lh_arg	The arguments for the left-hand side
rh_arg	The arguments for the right-hand side

Value

A joined expression of both left and right expressions

Complex2Real.lambda_sum_largest_canon

Complex canonicalizer for the largest sum atom

Description

Complex canonicalizer for the largest sum atom

Usage

```
Complex2Real.lambda_sum_largest_canon(expr, real_args, imag_args, real2imag)
```

Arguments

expr	An Expression object
real_args	A list of Constraint objects for the real part of the expression
imag_args	A list of Constraint objects for the imaginary part of the expression
real2imag	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.

Value

A canonicalization of the largest sum atom, where the returned variables are the real component and the imaginary component.

Complex2Real.matrix_frac_canon

Complex canonicalizer for the matrix fraction atom

Description

Complex canonicalizer for the matrix fraction atom

Usage

```
Complex2Real.matrix_frac_canon(expr, real_args, imag_args, real2imag)
```

Arguments

expr	An Expression object
real_args	A list of Constraint objects for the real part of the expression
imag_args	A list of Constraint objects for the imaginary part of the expression
real2imag	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.

Value

A canonicalization of a matrix atom, where the returned variables are converted to real variables.

Complex2Real.nonpos_canon

Complex canonicalizer for the non-positive atom

Description

Complex canonicalizer for the non-positive atom

Usage

```
Complex2Real.nonpos_canon(expr, real_args, imag_args, real2imag)
```

Arguments

expr	An Expression object
real_args	A list of Constraint objects for the real part of the expression
imag_args	A list of Constraint objects for the imaginary part of the expression
real2imag	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.

Value

A canonicalization of a non positive atom, where the returned variables are the real component and the imaginary component.

Complex2Real.norm_nuc_canon

Complex canonicalizer for the nuclear norm atom

Description

Complex canonicalizer for the nuclear norm atom

Usage

```
Complex2Real.norm_nuc_canon(expr, real_args, imag_args, real2imag)
```

Arguments

expr	An Expression object
real_args	A list of Constraint objects for the real part of the expression
imag_args	A list of Constraint objects for the imaginary part of the expression
real2imag	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.

Value

A canonicalization of a nuclear norm matrix atom, where the returned variables are the real component and the imaginary component.

Complex2Real.param_canon

Complex canonicalizer for the parameter matrix atom

Description

Complex canonicalizer for the parameter matrix atom

Usage

```
Complex2Real.param_canon(expr, real_args, imag_args, real2imag)
```

Arguments

expr	An Expression object
real_args	A list of Constraint objects for the real part of the expression
imag_args	A list of Constraint objects for the imaginary part of the expression
real2imag	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.

Value

A canonicalization of a parameter matrix atom, where the returned variables are the real component and the imaginary component.

Complex2Real.pnorm_canon
Complex canonicalizer for the p norm atom

Description

Complex canonicalizer for the p norm atom

Usage

```
Complex2Real.pnorm_canon(expr, real_args, imag_args, real2imag)
```

Arguments

expr	An Expression object
real_args	A list of Constraint objects for the real part of the expression
imag_args	A list of Constraint objects for the imaginary part of the expression
real2imag	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.

Value

A canonicalization of a pnorm atom, where the returned variables are the real component and the NULL imaginary component.

Complex2Real.psd_canon
Complex canonicalizer for the positive semidefinite atom

Description

Complex canonicalizer for the positive semidefinite atom

Usage

```
Complex2Real.psd_canon(expr, real_args, imag_args, real2imag)
```

Arguments

expr	An Expression object
real_args	A list of Constraint objects for the real part of the expression
imag_args	A list of Constraint objects for the imaginary part of the expression
real2imag	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.

Value

A canonicalization of a positive semidefinite atom, where the returned variables are the real component and the NULL imaginary component.

`Complex2Real.quad_canon` *Complex canonicalizer for the quadratic atom*

Description

Complex canonicalizer for the quadratic atom

Usage

```
Complex2Real.quad_canon(expr, real_args, imag_args, real2imag)
```

Arguments

`expr`	An Expression object
`real_args`	A list of Constraint objects for the real part of the expression
`imag_args`	A list of Constraint objects for the imaginary part of the expression
`real2imag`	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.

Value

A canonicalization of a quadratic atom, where the returned variables are the real component and the imaginary component as NULL.

`Complex2Real.quad_over_lin_canon` *Complex canonicalizer for the quadratic over linear term atom*

Description

Complex canonicalizer for the quadratic over linear term atom

Usage

```
Complex2Real.quad_over_lin_canon(expr, real_args, imag_args, real2imag)
```

Arguments

`expr`	An Expression object
`real_args`	A list of Constraint objects for the real part of the expression
`imag_args`	A list of Constraint objects for the imaginary part of the expression
`real2imag`	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.

Value

A canonicalization of a quadratic over a linear term atom, where the returned variables are the real component and the imaginary component.

`Complex2Real.real_canon` *Complex canonicalizer for the real atom*

Description

Complex canonicalizer for the real atom

Usage

```
Complex2Real.real_canon(expr, real_args, imag_args, real2imag)
```

Arguments

`expr`	An Expression object
`real_args`	A list of Constraint objects for the real part of the expression
`imag_args`	A list of Constraint objects for the imaginary part of the expression
`real2imag`	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.

Value

A canonicalization of a real atom, where the returned variables are the real component and NULL for the imaginary component.

Complex2Real.separable_canon
Complex canonicalizer for the separable atom

Description

Complex canonicalizer for the separable atom

Usage

```
Complex2Real.separable_canon(expr, real_args, imag_args, real2imag)
```

Arguments

expr	An Expression object
real_args	A list of Constraint objects for the real part of the expression
imag_args	A list of Constraint objects for the imaginary part of the expression
real2imag	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.

Value

A canonicalization of a separable atom, where the returned variables are its real and imaginary components parsed out.

Complex2Real.soc_canon
Complex canonicalizer for the SOC atom

Description

Complex canonicalizer for the SOC atom

Usage

```
Complex2Real.soc_canon(expr, real_args, imag_args, real2imag)
```

Arguments

expr	An Expression object
real_args	A list of Constraint objects for the real part of the expression
imag_args	A list of Constraint objects for the imaginary part of the expression
real2imag	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.

Value

A canonicalization of a SOC atom, where the returned variables are the real component and the NULL imaginary component.

`Complex2Real.variable_canon`

Complex canonicalizer for the variable atom

Description

Complex canonicalizer for the variable atom

Usage

```
Complex2Real.variable_canon(expr, real_args, imag_args, real2imag)
```

Arguments

`expr`	An Expression object
`real_args`	A list of Constraint objects for the real part of the expression
`imag_args`	A list of Constraint objects for the imaginary part of the expression
`real2imag`	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.

Value

A canonicalization of a variable atom, where the returned variables are the real component and the NULL imaginary component.

`Complex2Real.zero_canon`

Complex canonicalizer for the zero atom

Description

Complex canonicalizer for the zero atom

Usage

```
Complex2Real.zero_canon(expr, real_args, imag_args, real2imag)
```

Arguments

`expr`	An Expression object
`real_args`	A list of Constraint objects for the real part of the expression
`imag_args`	A list of Constraint objects for the imaginary part of the expression
`real2imag`	A list mapping the ID of the real part of a complex expression to the ID of its imaginary part.

Value

A canonicalization of a zero atom, where the returned variables are the real component and the imaginary component.

`cone-methods` *Second-Order Cone Methods*

Description

The number of elementwise cones or a list of the sizes of the elementwise cones.

Usage

```
num_cones(object)

cone_sizes(object)
```

Arguments

`object`	An SOCAxis object.

Value

The number of cones, or the size of a cone.

`ConeDims-class` *Summary of cone dimensions present in constraints.*

Description

Constraints must be formatted as dictionary that maps from constraint type to a list of constraints of that type.

Details

Attributes ———- zero : int The dimension of the zero cone. nonpos : int The dimension of the non-positive cone. exp : int The dimension of the exponential cone. soc : list of int A list of the second-order cone dimensions. psd : list of int A list of the positive semidefinite cone dimensions, where the dimension of the PSD cone of k by k matrices is k.

ConeMatrixStuffing-class — *Construct Matrices for Linear Cone Problems*

Description

Linear cone problems are assumed to have a linear objective and cone constraints, which may have zero or more arguments, all of which must be affine.

Usage

```
## S4 method for signature 'ConeMatrixStuffing,Problem'
accepts(object, problem)

## S4 method for signature 'ConeMatrixStuffing,Problem,CoeffExtractor'
stuffed_objective(object, problem, extractor)
```

Arguments

`object`	A ConeMatrixStuffing object.
`problem`	A Problem object.
`extractor`	Used to extract the affine coefficients of the objective.

Details

minimize c^Tx subject to cone_constr1(A_1*x + b_1, ...) ... cone_constrK(A_K*x + b_K, ...)

Methods (by generic)

- `accepts`: Is the solver accepted?
- `stuffed_objective`: Returns a list of the stuffed matrices

ConicSolver-class — *The ConicSolver class.*

Description

Conic solver class with reduction semantics.

Usage

```
## S4 method for signature 'ConicSolver,Problem'
accepts(object, problem)

## S4 method for signature 'ConicSolver'
reduction_format_constr(object, problem, constr, exp_cone_order)

## S4 method for signature 'ConicSolver'
group_coeff_offset(object, problem, constraints, exp_cone_order)

## S4 method for signature 'ConicSolver,Solution,InverseData'
invert(object, solution, inverse_data)
```

Arguments

`object`	A ConicSolver object.
`problem`	A Problem object.
`constr`	A Constraint to format.
`exp_cone_order`	A list indicating how the exponential cone arguments are ordered.
`constraints`	A list of Constraint objects.
`solution`	A Solution object to invert.
`inverse_data`	A InverseData object containing data necessary for the inversion.

Methods (by generic)

- `accepts`: Can the problem be solved with a conic solver?
- `reduction_format_constr`: Return a list representing a cone program whose problem data tensors will yield the coefficient "A" and offset "b" for the respective constraints: Linear Equations: A Linear inequalities: A Second order cone: A Exponential cone: A Semidefinite cone: A
- `group_coeff_offset`: Combine the constraints into a single matrix, offset.
- `invert`: Returns the solution to the original problem given the inverse_data.

`ConicSolver.get_coeff_offset`

Return the coefficient and offset in $Ax + b$.

Description

Return the coefficient and offset in $Ax + b$.

Usage

```
ConicSolver.get_coeff_offset(expr)
```

Arguments

expr	An Expression object.

Value

The coefficient and offset in $Ax + b$.

`ConicSolver.get_spacing_matrix`
Returns a sparse matrix that spaces out an expression.

Description

Returns a sparse matrix that spaces out an expression.

Usage

```
ConicSolver.get_spacing_matrix(dim, spacing, offset)
```

Arguments

dim	A vector outlining the dimensions of the matrix.
spacing	An int of the number of rows between the start of each non-zero block.
offset	An int of the number of zeros at the beginning of the matrix.

Value

A sparse matrix that spaces out an expression

`Conjugate-class` *The Conjugate class.*

Description

This class represents the complex conjugate of an expression.

Usage

```
Conjugate(expr)

## S4 method for signature 'Conjugate'
to_numeric(object, values)

## S4 method for signature 'Conjugate'
dim_from_args(object)

## S4 method for signature 'Conjugate'
is_incr(object, idx)

## S4 method for signature 'Conjugate'
is_decr(object, idx)

## S4 method for signature 'Conjugate'
is_symmetric(object)

## S4 method for signature 'Conjugate'
is_hermitian(object)
```

Arguments

`expr`	An Expression or R numeric data.
`object`	A Conjugate object.
`values`	A list of arguments to the atom.
`idx`	An index into the atom.

Methods (by generic)

- `to_numeric`: Elementwise complex conjugate of the constant.
- `dim_from_args`: The (row, col) dimensions of the expression.
- `is_incr`: Is the composition weakly increasing in argument idx?
- `is_decr`: Is the composition weakly decreasing in argument idx?
- `is_symmetric`: Is the expression symmetric?
- `is_hermitian`: Is the expression hermitian?

Slots

`expr` An Expression or R numeric data.

Constant-class *The Constant class.*

Description

This class represents a constant.

Coerce an R object or expression into the Constant class.

Usage

```
Constant(value)

## S4 method for signature 'Constant'
show(object)

## S4 method for signature 'Constant'
name(x)

## S4 method for signature 'Constant'
constants(object)

## S4 method for signature 'Constant'
value(object)

## S4 method for signature 'Constant'
is_pos(object)

## S4 method for signature 'Constant'
grad(object)

## S4 method for signature 'Constant'
dim(x)

## S4 method for signature 'Constant'
canonicalize(object)

## S4 method for signature 'Constant'
is_nonneg(object)

## S4 method for signature 'Constant'
is_nonpos(object)

## S4 method for signature 'Constant'
is_imag(object)

## S4 method for signature 'Constant'
is_complex(object)
```

```
## S4 method for signature 'Constant'
is_symmetric(object)

## S4 method for signature 'Constant'
is_hermitian(object)

## S4 method for signature 'Constant'
is_psd(object)

## S4 method for signature 'Constant'
is_nsd(object)

as.Constant(expr)
```

Arguments

value	A numeric element, vector, matrix, or data.frame. Vectors are automatically cast into a matrix column.
x, object	A Constant object.
expr	An Expression, numeric element, vector, matrix, or data.frame.

Value

A Constant representing the input as a constant.

Methods (by generic)

- name: The name of the constant.
- constants: Returns itself as a constant.
- value: The value of the constant.
- is_pos: A logical value indicating whether all elements of the constant are positive.
- grad: An empty list since the gradient of a constant is zero.
- dim: The c(row,col) dimensions of the constant.
- canonicalize: The canonical form of the constant.
- is_nonneg: A logical value indicating whether all elements of the constant are non-negative.
- is_nonpos: A logical value indicating whether all elements of the constant are non-positive.
- is_imag: A logical value indicating whether the constant is imaginary.
- is_complex: A logical value indicating whether the constant is complex-valued.
- is_symmetric: A logical value indicating whether the constant is symmetric.
- is_hermitian: A logical value indicating whether the constant is a Hermitian matrix.
- is_psd: A logical value indicating whether the constant is a positive semidefinite matrix.
- is_nsd: A logical value indicating whether the constant is a negative semidefinite matrix.

Slots

value A numeric element, vector, matrix, or data.frame. Vectors are automatically cast into a matrix column.

sparse (Internal) A logical value indicating whether the value is a sparse matrix.

is_pos (Internal) A logical value indicating whether all elements are non-negative.

is_neg (Internal) A logical value indicating whether all elements are non-positive.

Examples

```
x <- Constant(5)
y <- Constant(diag(3))
get_data(y)
value(y)
is_nonneg(y)
size(y)
as.Constant(y)
```

ConstantSolver-class *The ConstantSolver class.*

Description

The ConstantSolver class.

Usage

```
## S4 method for signature 'ConstantSolver'
mip_capable(solver)

## S4 method for signature 'ConstantSolver,Problem'
accepts(object, problem)

## S4 method for signature 'ConstantSolver,Problem'
perform(object, problem)

## S4 method for signature 'ConstantSolver,Solution,list'
invert(object, solution, inverse_data)

## S4 method for signature 'ConstantSolver'
name(x)

## S4 method for signature 'ConstantSolver'
import_solver(solver)

## S4 method for signature 'ConstantSolver'
is_installed(solver)
```

```
## S4 method for signature 'ConstantSolver'
solve_via_data(
  object,
  data,
  warm_start,
  verbose,
  feastol,
  reltol,
  abstol,
  num_iter,
  solver_opts,
  solver_cache
)

## S4 method for signature 'ConstantSolver,ANY'
reduction_solve(object, problem, warm_start, verbose, solver_opts)
```

Arguments

solver, object, x	A ConstantSolver object.
problem	A Problem object.
solution	A Solution object to invert.
inverse_data	A list containing data necessary for the inversion.
data	Data for the solver.
warm_start	A boolean of whether to warm start the solver.
verbose	A boolean of whether to enable solver verbosity.
feastol	The feasible tolerance.
reltol	The relative tolerance.
abstol	The absolute tolerance.
num_iter	The maximum number of iterations.
solver_opts	A list of Solver specific options
solver_cache	Cache for the solver.

Methods (by generic)

- `mip_capable`: Can the solver handle mixed-integer programs?
- `accepts`: Is the solver capable of solving the problem?
- `perform`: Returns a list of the ConstantSolver, Problem, and an empty list.
- `invert`: Returns the solution.
- `name`: Returns the name of the solver.
- `import_solver`: Imports the solver.
- `is_installed`: Is the solver installed?

- `solve_via_data`: Solve a problem represented by data returned from apply.
- `reduction_solve`: Solve the problem and return a Solution object.

`Constraint-class` *The Constraint class.*

Description

This virtual class represents a mathematical constraint.

Usage

```
## S4 method for signature 'Constraint'
as.character(x)

## S4 method for signature 'Constraint'
dim(x)

## S4 method for signature 'Constraint'
size(object)

## S4 method for signature 'Constraint'
is_real(object)

## S4 method for signature 'Constraint'
is_imag(object)

## S4 method for signature 'Constraint'
is_complex(object)

## S4 method for signature 'Constraint'
is_dcp(object)

## S4 method for signature 'Constraint'
is_dgp(object)

## S4 method for signature 'Constraint'
residual(object)

## S4 method for signature 'Constraint'
violation(object)

## S4 method for signature 'Constraint'
constr_value(object, tolerance = 1e-08)

## S4 method for signature 'Constraint'
get_data(object)
```

```
## S4 method for signature 'Constraint'
dual_value(object)

## S4 replacement method for signature 'Constraint'
dual_value(object) <- value

## S4 method for signature 'ZeroConstraint'
size(object)
```

Arguments

`x, object`	A Constraint object.
`tolerance`	The tolerance for checking if the constraint is violated.
`value`	A numeric scalar, vector, or matrix.

Methods (by generic)

- `dim`: The dimensions of the constrained expression.
- `size`: The size of the constrained expression.
- `is_real`: Is the constraint real?
- `is_imag`: Is the constraint imaginary?
- `is_complex`: Is the constraint complex?
- `is_dcp`: Is the constraint DCP?
- `is_dgp`: Is the constraint DGP?
- `residual`: The residual of a constraint
- `violation`: The violation of a constraint.
- `constr_value`: The value of a constraint.
- `get_data`: Information needed to reconstruct the object aside from the args.
- `dual_value`: The dual values of a constraint.
- `dual_value<-`: Replaces the dual values of a constraint..
- `size`: The size of the constrained expression.

`construct_intermediate_chain,Problem,list-method`

Builds a chain that rewrites a problem into an intermediate representation suitable for numeric reductions.

Description

Builds a chain that rewrites a problem into an intermediate representation suitable for numeric reductions.

Usage

```
## S4 method for signature 'Problem,list'
construct_intermediate_chain(problem, candidates, gp = FALSE)
```

Arguments

problem	The problem for which to build a chain.
candidates	A list of candidate solvers.
gp	A logical value indicating whether the problem is a geometric program.

Value

A Chain object that can be used to convert the problem to an intermediate form.

---

construct_solving_chain

Build a reduction chain from a problem to an installed solver.

Description

Build a reduction chain from a problem to an installed solver.

Usage

```
construct_solving_chain(problem, candidates)
```

Arguments

problem	The problem for which to build a chain.
candidates	A list of candidate solvers.

Value

A SolvingChain that can be used to solve the problem.

constr_value — *Is Constraint Violated?*

Description

Checks whether the constraint violation is less than a tolerance.

Usage

```
constr_value(object, tolerance = 1e-08)
```

Arguments

`object`	A Constraint object.
`tolerance`	A numeric scalar representing the absolute tolerance to impose on the violation.

Value

A logical value indicating whether the violation is less than the `tolerance`. Raises an error if the residual is `NA`.

conv — *Discrete Convolution*

Description

The 1-D discrete convolution of two vectors.

Usage

```
conv(lh_exp, rh_exp)
```

Arguments

`lh_exp`	An Expression or vector representing the left-hand value.
`rh_exp`	An Expression or vector representing the right-hand value.

Value

An Expression representing the convolution of the input.

Examples

```
set.seed(129)
x <- Variable(5)
h <- matrix(stats::rnorm(2), nrow = 2, ncol = 1)
prob <- Problem(Minimize(sum(conv(h, x))))
result <- solve(prob)
result$value
result$getValue(x)
```

Conv-class *The Conv class.*

Description

This class represents the 1-D discrete convolution of two vectors.

Usage

```
Conv(lh_exp, rh_exp)

## S4 method for signature 'Conv'
to_numeric(object, values)

## S4 method for signature 'Conv'
validate_args(object)

## S4 method for signature 'Conv'
dim_from_args(object)

## S4 method for signature 'Conv'
sign_from_args(object)

## S4 method for signature 'Conv'
is_incr(object, idx)

## S4 method for signature 'Conv'
is_decr(object, idx)

## S4 method for signature 'Conv'
graph_implementation(object, arg_objs, dim, data = NA_real_)
```

Arguments

lh_exp	An Expression or R numeric data representing the left-hand vector.
rh_exp	An Expression or R numeric data representing the right-hand vector.
object	A Conv object.
values	A list of arguments to the atom.

idx	An index into the atom.
arg_objs	A list of linear expressions for each argument.
dim	A vector representing the dimensions of the resulting expression.
data	A list of additional data required by the atom.

Methods (by generic)

- `to_numeric`: The convolution of the two values.
- `validate_args`: Check both arguments are vectors and the first is a constant.
- `dim_from_args`: The dimensions of the atom.
- `sign_from_args`: The sign of the atom.
- `is_incr`: Is the left-hand expression positive?
- `is_decr`: Is the left-hand expression negative?
- `graph_implementation`: The graph implementation of the atom.

Slots

`lh_exp` An Expression or R numeric data representing the left-hand vector.

`rh_exp` An Expression or R numeric data representing the right-hand vector.

CPLEX_CONIC-class *An interface for the CPLEX solver*

Description

An interface for the CPLEX solver

Usage

```
CPLEX_CONIC()

CPLEX_CONIC()

## S4 method for signature 'CPLEX_CONIC'
mip_capable(solver)

## S4 method for signature 'CPLEX_CONIC'
name(x)

## S4 method for signature 'CPLEX_CONIC'
import_solver(solver)

## S4 method for signature 'CPLEX_CONIC,Problem'
accepts(object, problem)
```

```
## S4 method for signature 'CPLEX_CONIC'
status_map(solver, status)

## S4 method for signature 'CPLEX_CONIC,Problem'
perform(object, problem)

## S4 method for signature 'CPLEX_CONIC,list,list'
invert(object, solution, inverse_data)

## S4 method for signature 'CPLEX_CONIC'
solve_via_data(
  object,
  data,
  warm_start,
  verbose,
  feastol,
  reltol,
  abstol,
  num_iter,
  solver_opts,
  solver_cache
)
```

Arguments

`solver, object, x`	A CPLEX_CONIC object.
`problem`	A Problem object.
`status`	A status code returned by the solver.
`solution`	The raw solution returned by the solver.
`inverse_data`	A list containing data necessary for the inversion.
`data`	Data generated via an apply call.
`warm_start`	A boolean of whether to warm start the solver.
`verbose`	A boolean of whether to enable solver verbosity.
`feastol`	The feasible tolerance on the primal and dual residual.
`reltol`	The relative tolerance on the duality gap.
`abstol`	The absolute tolerance on the duality gap.
`num_iter`	The maximum number of iterations.
`solver_opts`	A list of Solver specific options
`solver_cache`	Cache for the solver.

Methods (by generic)

- `mip_capable`: Can the solver handle mixed-integer programs?

- name: Returns the name of the solver.
- import_solver: Imports the solver.
- accepts: Can CPLEX solve the problem?
- status_map: Converts status returned by the CPLEX solver to its respective CVXPY status.
- perform: Returns a new problem and data for inverting the new solution.
- invert: Returns the solution to the original problem given the inverse_data.
- solve_via_data: Solve a problem represented by data returned from apply.

CPLEX_QP-class *An interface for the CPLEX solver.*

Description

An interface for the CPLEX solver.

Usage

```
CPLEX_QP()

## S4 method for signature 'CPLEX_QP'
mip_capable(solver)

## S4 method for signature 'CPLEX_QP'
status_map(solver, status)

## S4 method for signature 'CPLEX_QP'
name(x)

## S4 method for signature 'CPLEX_QP'
import_solver(solver)

## S4 method for signature 'CPLEX_QP,list,InverseData'
invert(object, solution, inverse_data)

## S4 method for signature 'CPLEX_QP'
solve_via_data(
  object,
  data,
  warm_start,
  verbose,
  feastol,
  reltol,
  abstol,
  num_iter,
  solver_opts,
  solver_cache
)
```

Arguments

`status`	A status code returned by the solver.
`x, object, solver`	A CPLEX_QP object.
`solution`	The raw solution returned by the solver.
`inverse_data`	A InverseData object containing data necessary for the inversion.
`data`	Data generated via an apply call.
`warm_start`	A boolean of whether to warm start the solver.
`verbose`	A boolean of whether to enable solver verbosity.
`feastol`	The feasible tolerance on the primal and dual residual.
`reltol`	The relative tolerance on the duality gap.
`abstol`	The absolute tolerance on the duality gap.
`num_iter`	The maximum number of iterations.
`solver_opts`	A list of Solver specific options
`solver_cache`	Cache for the solver.

Methods (by generic)

- `mip_capable`: Can the solver handle mixed-integer programs?
- `status_map`: Converts status returned by the CPLEX solver to its respective CVXPY status.
- `name`: Returns the name of the solver.
- `import_solver`: Imports the solver.
- `invert`: Returns the solution to the original problem given the inverse_data.
- `solve_via_data`: Solve a problem represented by data returned from apply.

CumMax-class *The CumMax class.*

Description

This class represents the cumulative maximum of an expression.

Usage

```
CumMax(expr, axis = 2)

## S4 method for signature 'CumMax'
to_numeric(object, values)

## S4 method for signature 'CumMax'
.grad(object, values)
```

```
## S4 method for signature 'CumMax'
.column_grad(object, value)

## S4 method for signature 'CumMax'
dim_from_args(object)

## S4 method for signature 'CumMax'
sign_from_args(object)

## S4 method for signature 'CumMax'
get_data(object)

## S4 method for signature 'CumMax'
is_atom_convex(object)

## S4 method for signature 'CumMax'
is_atom_concave(object)

## S4 method for signature 'CumMax'
is_incr(object, idx)

## S4 method for signature 'CumMax'
is_decr(object, idx)
```

Arguments

expr	An Expression.
axis	A numeric vector indicating the axes along which to apply the function. For a 2D matrix, 1 indicates rows, 2 indicates columns, and c(1,2) indicates rows and columns.
object	A CumMax object.
values	A list of numeric values for the arguments
value	A numeric value.
idx	An index into the atom.

Methods (by generic)

- to_numeric: The cumulative maximum along the axis.
- .grad: Gives the (sub/super)gradient of the atom w.r.t. each variable
- .column_grad: Gives the (sub/super)gradient of the atom w.r.t. each column variable
- dim_from_args: The dimensions of the atom determined from its arguments.
- sign_from_args: The (is positive, is negative) sign of the atom.
- get_data: Returns the axis along which the cumulative max is taken.
- is_atom_convex: Is the atom convex?
- is_atom_concave: Is the atom concave?
- is_incr: Is the atom weakly increasing in the index?
- is_decr: Is the atom weakly decreasing in the index?

Slots

`expr` An Expression.

`axis` A numeric vector indicating the axes along which to apply the function. For a 2D matrix, `1` indicates rows, `2` indicates columns, and `c(1,2)` indicates rows and columns.

`cummax_axis` *Cumulative Maximum*

Description

The cumulative maximum, $\max_{i=1,\ldots,k} x_i$ for $k = 1, \ldots, n$. When calling `cummax`, matrices are automatically flattened into column-major order before the max is taken.

Usage

```
cummax_axis(expr, axis = 2)

## S4 method for signature 'Expression'
cummax(x)
```

Arguments

`axis`	(Optional) The dimension across which to apply the function: `1` indicates rows, and `2` indicates columns. The default is `2`.
`x, expr`	An Expression, vector, or matrix.

Examples

```
val <- cbind(c(1,2), c(3,4))
value(cummax(Constant(val)))
value(cummax_axis(Constant(val)))

x <- Variable(2,2)
prob <- Problem(Minimize(cummax(x)[4]), list(x == val))
result <- solve(prob)
result$value
result$getValue(cummax(x))
```

CumSum-class *The CumSum class.*

Description

This class represents the cumulative sum.

Usage

```
CumSum(expr, axis = 2)

## S4 method for signature 'CumSum'
to_numeric(object, values)

## S4 method for signature 'CumSum'
dim_from_args(object)

## S4 method for signature 'CumSum'
get_data(object)

## S4 method for signature 'CumSum'
.grad(object, values)

## S4 method for signature 'CumSum'
graph_implementation(object, arg_objs, dim, data = NA_real_)
```

Arguments

`expr`	An Expression to be summed.
`axis`	(Optional) The dimension across which to apply the function: `1` indicates rows, and `2` indicates columns. The default is `2`.
`object`	A CumSum object.
`values`	A list of numeric values for the arguments
`arg_objs`	A list of linear expressions for each argument.
`dim`	A vector representing the dimensions of the resulting expression.
`data`	A list of additional data required by the atom.

Methods (by generic)

- `to_numeric`: The cumulative sum of the values along the specified axis.
- `dim_from_args`: The dimensions of the atom.
- `get_data`: Returns the axis along which the cumulative sum is taken.
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable
- `graph_implementation`: The graph implementation of the atom.

Slots

`expr` An Expression to be summed.

`axis` (Optional) The dimension across which to apply the function: 1 indicates rows, and 2 indicates columns. The default is 2.

`cumsum_axis` *Cumulative Sum*

Description

The cumulative sum, $\sum_{i=1}^{k} x_i$ for $k = 1, \ldots, n$. When calling `cumsum`, matrices are automatically flattened into column-major order before the sum is taken.

Usage

```
cumsum_axis(expr, axis = 2)

## S4 method for signature 'Expression'
cumsum(x)
```

Arguments

`axis`	(Optional) The dimension across which to apply the function: 1 indicates rows, and 2 indicates columns. The default is 2.
`x, expr`	An Expression, vector, or matrix.

Examples

```
val <- cbind(c(1,2), c(3,4))
value(cumsum(Constant(val)))
value(cumsum_axis(Constant(val)))

x <- Variable(2,2)
prob <- Problem(Minimize(cumsum(x)[4]), list(x == val))
result <- solve(prob)
result$value
result$getValue(cumsum(x))
```

curvature *Curvature of Expression*

Description

The curvature of an expression.

The curvature of an expression.

Usage

```
curvature(object)

## S4 method for signature 'Expression'
curvature(object)
```

Arguments

object	An Expression object.

Value

A string indicating the curvature of the expression, either "CONSTANT", "AFFINE", "CONVEX, "CONCAVE", or "UNKNOWN".

A string indicating the curvature of the expression, either "CONSTANT", "AFFINE", "CONVEX", "CONCAVE", or "UNKNOWN".

Examples

```
x <- Variable()
c <- Constant(5)

curvature(c)
curvature(x)
curvature(x^2)
curvature(sqrt(x))
curvature(log(x^3) + sqrt(x))
```

curvature-atom *Curvature of an Atom*

Description

Determine if an atom is convex, concave, or affine.

Usage

```
is_atom_convex(object)

is_atom_concave(object)

is_atom_affine(object)

## S4 method for signature 'Atom'
is_atom_convex(object)

## S4 method for signature 'Atom'
is_atom_concave(object)

## S4 method for signature 'Atom'
is_atom_affine(object)

## S4 method for signature 'Atom'
is_atom_log_log_convex(object)

## S4 method for signature 'Atom'
is_atom_log_log_concave(object)

## S4 method for signature 'Atom'
is_atom_log_log_affine(object)
```

Arguments

`object`	A Atom object.

Value

A logical value.

Examples

```
x <- Variable()

is_atom_convex(x^2)
is_atom_convex(sqrt(x))
is_atom_convex(log(x))

is_atom_concave(-abs(x))
is_atom_concave(x^2)
is_atom_concave(sqrt(x))

is_atom_affine(2*x)
is_atom_affine(x^2)
```

curvature-comp *Curvature of Composition*

Description

Determine whether a composition is non-decreasing or non-increasing in an index.

Usage

```
is_incr(object, idx)

is_decr(object, idx)

## S4 method for signature 'Atom'
is_incr(object, idx)

## S4 method for signature 'Atom'
is_decr(object, idx)
```

Arguments

object	A Atom object.
idx	An index into the atom.

Value

A logical value.

Examples

```
x <- Variable()
is_incr(log(x), 1)
is_incr(x^2, 1)
is_decr(min(x), 1)
is_decr(abs(x), 1)
```

curvature-methods *Curvature Properties*

Description

Determine if an expression is constant, affine, convex, concave, quadratic, piecewise linear (pwl), or quadratic/piecewise affine (qpwa).

Usage

```
is_constant(object)

is_affine(object)

is_convex(object)

is_concave(object)

is_quadratic(object)

is_pwl(object)

is_qpwa(object)
```

Arguments

`object`	An Expression object.

Value

A logical value.

Examples

```
x <- Variable()
c <- Constant(5)

is_constant(c)
is_constant(x)

is_affine(c)
is_affine(x)
is_affine(x^2)

is_convex(c)
is_convex(x)
is_convex(x^2)
is_convex(sqrt(x))

is_concave(c)
is_concave(x)
is_concave(x^2)
is_concave(sqrt(x))

is_quadratic(x^2)
is_quadratic(sqrt(x))

is_pwl(c)
is_pwl(x)
is_pwl(x^2)
```

CvxAttr2Constr-class *The CvxAttr2Constr class.*

Description

This class represents a reduction that expands convex variable attributes into constraints.

Usage

```
## S4 method for signature 'CvxAttr2Constr,Problem'
perform(object, problem)

## S4 method for signature 'CvxAttr2Constr,Solution,list'
invert(object, solution, inverse_data)
```

Arguments

`object`	A CvxAttr2Constr object.
`problem`	A Problem object.
`solution`	A Solution to a problem that generated the inverse data.
`inverse_data`	The inverse data returned by an invocation to apply.

Methods (by generic)

- `perform`: Expand convex variable attributes to constraints.
- `invert`: Performs the reduction on a problem and returns an equivalent problem.

CVXOPT-class *An interface for the CVXOPT solver.*

Description

An interface for the CVXOPT solver.

Usage

```
## S4 method for signature 'CVXOPT'
mip_capable(solver)

## S4 method for signature 'CVXOPT'
status_map(solver, status)

## S4 method for signature 'CVXOPT'
name(x)
```

```
## S4 method for signature 'CVXOPT'
import_solver(solver)

## S4 method for signature 'CVXOPT,Problem'
accepts(object, problem)

## S4 method for signature 'CVXOPT,Problem'
perform(object, problem)

## S4 method for signature 'CVXOPT,list,list'
invert(object, solution, inverse_data)

## S4 method for signature 'CVXOPT'
solve_via_data(
  object,
  data,
  warm_start,
  verbose,
  feastol,
  reltol,
  abstol,
  num_iter,
  solver_opts,
  solver_cache
)
```

Arguments

`solver, object, x`	A CVXOPT object.
`status`	A status code returned by the solver.
`problem`	A Problem object.
`solution`	The raw solution returned by the solver.
`inverse_data`	A list containing data necessary for the inversion.
`data`	Data generated via an apply call.
`warm_start`	A boolean of whether to warm start the solver.
`verbose`	A boolean of whether to enable solver verbosity.
`feastol`	The feasible tolerance on the primal and dual residual.
`reltol`	The relative tolerance on the duality gap.
`abstol`	The absolute tolerance on the duality gap.
`num_iter`	The maximum number of iterations.
`solver_opts`	A list of Solver specific options
`solver_cache`	Cache for the solver.

Methods (by generic)

- `mip_capable`: Can the solver handle mixed-integer programs?
- `status_map`: Converts status returned by the CVXOPT solver to its respective CVXPY status.
- `name`: Returns the name of the solver.
- `import_solver`: Imports the solver.
- `accepts`: Can CVXOPT solve the problem?
- `perform`: Returns a new problem and data for inverting the new solution.
- `invert`: Returns the solution to the original problem given the inverse_data.
- `solve_via_data`: Solve a problem represented by data returned from apply.

---

cvxr_norm *Matrix Norm (Alternative)*

Description

A wrapper on the different norm atoms. This is different from the standard "norm" method in the R base package. If `p = 2`, `axis = NA`, and `x` is a matrix, this returns the maximium singular value.

Usage

```
cvxr_norm(x, p = 2, axis = NA_real_, keepdims = FALSE)
```

Arguments

`x`	An Expression or numeric constant representing a vector or matrix.
`p`	The type of norm. May be a number (p-norm), "inf" (infinity-norm), "nuc" (nuclear norm), or "fro" (Frobenius norm). The default is `p = 2`.
`axis`	(Optional) The dimension across which to apply the function: `1` indicates rows, `2` indicates columns, and `NA` indicates rows and columns. The default is `NA`.
`keepdims`	(Optional) Should dimensions be maintained when applying the atom along an axis? If `FALSE`, result will be collapsed into an $nx1$ column vector. The default is `FALSE`.

Value

An Expression representing the norm.

See Also

norm

`Dcp2Cone-class` *Reduce DCP Problem to Conic Form*

Description

This reduction takes as input (minimization) DCP problems and converts them into problems with affine objectives and conic constraints whose arguments are affine.

Usage

```
## S4 method for signature 'Dcp2Cone,Problem'
accepts(object, problem)

## S4 method for signature 'Dcp2Cone,Problem'
perform(object, problem)
```

Arguments

`object`	A Dcp2Cone object.
`problem`	A Problem object.

Methods (by generic)

- `accepts`: A problem is accepted if it is a minimization and is DCP.
- `perform`: Converts a DCP problem to a conic form.

`Dcp2Cone.entr_canon` *Dcp2Cone canonicalizer for the entropy atom*

Description

Dcp2Cone canonicalizer for the entropy atom

Usage

```
Dcp2Cone.entr_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of Constraint objects

Value

A cone program constructed from an entropy atom where the objective function is just the variable t with an ExpCone constraint.

Dcp2Cone.exp_canon *Dcp2Cone canonicalizer for the exponential atom*

Description

Dcp2Cone canonicalizer for the exponential atom

Usage

```
Dcp2Cone.exp_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of Constraint objects

Value

A cone program constructed from an exponential atom where the objective function is the variable t with an ExpCone constraint.

Dcp2Cone.geo_mean_canon *Dcp2Cone canonicalizer for the geometric mean atom*

Description

Dcp2Cone canonicalizer for the geometric mean atom

Usage

```
Dcp2Cone.geo_mean_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of Constraint objects

Value

A cone program constructed from a geometric mean atom where the objective function is the variable t with geometric mean constraints

Dcp2Cone.huber_canon *Dcp2Cone canonicalizer for the huber atom*

Description

Dcp2Cone canonicalizer for the huber atom

Usage

```
Dcp2Cone.huber_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of Constraint objects

Value

A cone program constructed from a huber atom where the objective function is the variable t with square and absolute constraints

Dcp2Cone.indicator_canon *Dcp2Cone canonicalizer for the indicator atom*

Description

Dcp2Cone canonicalizer for the indicator atom

Usage

```
Dcp2Cone.indicator_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of Constraint objects

Value

A cone program constructed from an indicator atom and where 0 is the objective function with the given constraints in the function.

Dcp2Cone.kl_div_canon *Dcp2Cone canonicalizer for the KL Divergence atom*

Description

Dcp2Cone canonicalizer for the KL Divergence atom

Usage

```
Dcp2Cone.kl_div_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of Constraint objects

Value

A cone program constructed from a KL divergence atom where t is the objective function with the ExpCone constraints.

Dcp2Cone.lambda_max_canon *Dcp2Cone canonicalizer for the lambda maximization atom*

Description

Dcp2Cone canonicalizer for the lambda maximization atom

Usage

```
Dcp2Cone.lambda_max_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of Constraint objects

Value

A cone program constructed from a lambda maximization atom where t is the objective function and a PSD constraint and a constraint requiring I*t to be symmetric.

`Dcp2Cone.lambda_sum_largest_canon`
Dcp2Cone canonicalizer for the largest lambda sum atom

Description

Dcp2Cone canonicalizer for the largest lambda sum atom

Usage

```
Dcp2Cone.lambda_sum_largest_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of Constraint objects

Value

A cone program constructed from a lambda sum of the k largest elements atom where k*t + trace(Z) is the objective function. t denotes the variable subject to constraints and Z is a PSD matrix variable whose dimensions consist of the length of the vector at hand. The constraints require the the diagonal matrix of the vector to be symmetric and PSD.

`Dcp2Cone.log1p_canon` *Dcp2Cone canonicalizer for the log 1p atom*

Description

Dcp2Cone canonicalizer for the log 1p atom

Usage

```
Dcp2Cone.log1p_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of Constraint objects

Value

A cone program constructed from a log 1p atom where t is the objective function and the constraints consist of ExpCone constraints + 1.

Dcp2Cone.logistic_canon *Dcp2Cone canonicalizer for the logistic function atom*

Description

Dcp2Cone canonicalizer for the logistic function atom

Usage

```
Dcp2Cone.logistic_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of Constraint objects

Value

A cone program constructed from the logistic atom where the objective function is given by t0 and the constraints consist of the ExpCone constraints.

Dcp2Cone.log_canon *Dcp2Cone canonicalizer for the log atom*

Description

Dcp2Cone canonicalizer for the log atom

Usage

```
Dcp2Cone.log_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of Constraint objects

Value

A cone program constructed from a log atom where t is the objective function and the constraints consist of ExpCone constraints

---

`Dcp2Cone.log_det_canon`
Dcp2Cone canonicalizer for the log determinant atom

Description

Dcp2Cone canonicalizer for the log determinant atom

Usage

```
Dcp2Cone.log_det_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of Constraint objects

Value

A cone program constructed from a log determinant atom where the objective function is the sum of the log of the vector D and the constraints consist of requiring the matrix Z to be diagonal and the diagonal Z to equal D, Z to be upper triangular and DZ; t(Z)A to be positive semidefinite, where A is a n by n matrix.

`Dcp2Cone.log_sum_exp_canon`
Dcp2Cone canonicalizer for the log sum of the exp atom

Description

Dcp2Cone canonicalizer for the log sum of the exp atom

Usage

```
Dcp2Cone.log_sum_exp_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of Constraint objects

Value

A cone program constructed from the log sum of the exp atom where the objective is the t variable and the constraints consist of the ExpCone constraints and requiring t to be less than a matrix of ones of the same size.

Dcp2Cone.matrix_frac_canon

Dcp2Cone canonicalizer for the matrix fraction atom

Description

Dcp2Cone canonicalizer for the matrix fraction atom

Usage

```
Dcp2Cone.matrix_frac_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of Constraint objects

Value

A cone program constructed from the matrix fraction atom, where the objective function is the trace of Tvar, a m by m matrix where the constraints consist of the matrix of the Schur complement of Tvar to consist of P, an n by n, given matrix, X, an n by m given matrix, and Tvar.

Dcp2Cone.normNuc_canon

Dcp2Cone canonicalizer for the nuclear norm atom

Description

Dcp2Cone canonicalizer for the nuclear norm atom

Usage

```
Dcp2Cone.normNuc_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of Constraint objects

Value

A cone program constructed from a nuclear norm atom, where the objective function consists of .5 times the trace of a matrix X of size m+n by m+n where the constraint consist of the top right corner of the matrix being the original matrix.

Dcp2Cone.pnorm_canon *Dcp2Cone canonicalizer for the p norm atom*

Description

Dcp2Cone canonicalizer for the p norm atom

Usage

```
Dcp2Cone.pnorm_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of Constraint objects

Value

A cone program constructed from a pnorm atom, where the objective is a variable t of dimension of the original vector in the problem and the constraints consist of geometric mean constraints.

Dcp2Cone.power_canon *Dcp2Cone canonicalizer for the power atom*

Description

Dcp2Cone canonicalizer for the power atom

Usage

```
Dcp2Cone.power_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of Constraint objects

Value

A cone program constructed from a power atom, where the objective function consists of the variable t which is of the dimension of the original vector from the power atom and the constraints consists of geometric mean constraints.

Dcp2Cone.quad_form_canon

Dcp2Cone canonicalizer for the quadratic form atom

Description

Dcp2Cone canonicalizer for the quadratic form atom

Usage

```
Dcp2Cone.quad_form_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of Constraint objects

Value

A cone program constructed from a quadratic form atom, where the objective function consists of the scaled objective function from the quadratic over linear canonicalization and same with the constraints.

Dcp2Cone.quad_over_lin_canon

Dcp2Cone canonicalizer for the quadratic over linear term atom

Description

Dcp2Cone canonicalizer for the quadratic over linear term atom

Usage

```
Dcp2Cone.quad_over_lin_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of Constraint objects

Value

A cone program constructed from a quadratic over linear term atom where the objective function consists of a one dimensional variable t with SOC constraints.

`Dcp2Cone.sigma_max_canon` *Dcp2Cone canonicalizer for the sigma max atom*

Description

Dcp2Cone canonicalizer for the sigma max atom

Usage

```
Dcp2Cone.sigma_max_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of Constraint objects

Value

A cone program constructed from a sigma max atom where the objective function consists of the variable t that is of the same dimension as the original expression with specified constraints in the function.

`Dgp2Dcp-class` *Reduce DGP problems to DCP problems.*

Description

This reduction takes as input a DGP problem and returns an equivalent DCP problem. Because every (generalized) geometric program is a DGP problem, this reduction can be used to convert geometric programs into convex form.

Usage

```
## S4 method for signature 'Dgp2Dcp,Problem'
accepts(object, problem)

## S4 method for signature 'Dgp2Dcp,Problem'
perform(object, problem)

## S4 method for signature 'Dgp2Dcp'
canonicalize_expr(object, expr, args)

## S4 method for signature 'Dgp2Dcp,Solution,InverseData'
invert(object, solution, inverse_data)
```

Arguments

object	A Dgp2Dcp object.
problem	A Problem object.
expr	An Expression object corresponding to the DGP problem.
args	A list of values corresponding to the DGP expression
solution	A Solution object to invert.
inverse_data	A InverseData object containing data necessary for the inversion.

Methods (by generic)

- `accepts`: Is the problem DGP?
- `perform`: Converts the DGP problem to a DCP problem.
- `canonicalize_expr`: Canonicalizes each atom within an Dgp2Dcp expression.
- `invert`: Returns the solution to the original problem given the inverse_data.

Dgp2Dcp.add_canon — *Dgp2Dcp canonicalizer for the addition atom*

Description

Dgp2Dcp canonicalizer for the addition atom

Usage

```
Dgp2Dcp.add_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of values for the expr variable

Value

A canonicalization of the addition atom of a DGP expression, where the returned expression is the transformed DCP equivalent.

Dgp2Dcp.constant_canon

Dgp2Dcp canonicalizer for the constant atom

Description

Dgp2Dcp canonicalizer for the constant atom

Usage

```
Dgp2Dcp.constant_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of values for the expr variable

Value

A canonicalization of the constant atom of a DGP expression, where the returned expression is the DCP equivalent resulting from the log of the expression.

Dgp2Dcp.div_canon

Dgp2Dcp canonicalizer for the division atom

Description

Dgp2Dcp canonicalizer for the division atom

Usage

```
Dgp2Dcp.div_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of values for the expr variable

Value

A canonicalization of the division atom of a DGP expression, where the returned expression is the log transformed DCP equivalent.

Dgp2Dcp.exp_canon *Dgp2Dcp canonicalizer for the exp atom*

Description

Dgp2Dcp canonicalizer for the exp atom

Usage

```
Dgp2Dcp.exp_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of values for the expr variable

Value

A canonicalization of the exp atom of a DGP expression, where the returned expression is the transformed DCP equivalent.

Dgp2Dcp.eye_minus_inv_canon *Dgp2Dcp canonicalizer for the (I - X)^-1 atom*

Description

Dgp2Dcp canonicalizer for the (I - X)^-1 atom

Usage

```
Dgp2Dcp.eye_minus_inv_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of values for the expr variable

Value

A canonicalization of the (I - X)^-1 atom of a DGP expression, where the returned expression is the transformed DCP equivalent.

Dgp2Dcp.geo_mean_canon *Dgp2Dcp canonicalizer for the geometric mean atom*

Description

Dgp2Dcp canonicalizer for the geometric mean atom

Usage

```
Dgp2Dcp.geo_mean_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of values for the expr variable

Value

A canonicalization of the geometric mean atom of a DGP expression, where the returned expression is the transformed DCP equivalent.

Dgp2Dcp.log_canon *Dgp2Dcp canonicalizer for the log atom*

Description

Dgp2Dcp canonicalizer for the log atom

Usage

```
Dgp2Dcp.log_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of values for the expr variable

Value

A canonicalization of the log atom of a DGP expression, where the returned expression is the log of the original expression..

Dgp2Dcp.mulexpression_canon

Dgp2Dcp canonicalizer for the multiplication expression atom

Description

Dgp2Dcp canonicalizer for the multiplication expression atom

Usage

```
Dgp2Dcp.mulexpression_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of values for the expr variable

Value

A canonicalization of the multiplication expression atom of a DGP expression, where the returned expression is the transformed DCP equivalent.

Dgp2Dcp.mul_canon

Dgp2Dcp canonicalizer for the multiplication atom

Description

Dgp2Dcp canonicalizer for the multiplication atom

Usage

```
Dgp2Dcp.mul_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of values for the expr variable

Value

A canonicalization of the multiplication atom of a DGP expression, where the returned expression is the transformed DCP equivalent.

`Dgp2Dcp.nonpos_constr_canon` *Dgp2Dcp canonicalizer for the non-positive constraint atom*

Description

Dgp2Dcp canonicalizer for the non-positive constraint atom

Usage

```
Dgp2Dcp.nonpos_constr_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of values for the expr variable

Value

A canonicalization of the non-positive contraint atom of a DGP expression, where the returned expression is the transformed DCP equivalent.

`Dgp2Dcp.norm1_canon` *Dgp2Dcp canonicalizer for the 1 norm atom*

Description

Dgp2Dcp canonicalizer for the 1 norm atom

Usage

```
Dgp2Dcp.norm1_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of values for the expr variable

Value

A canonicalization of the norm1 atom of a DGP expression, where the returned expression is the transformed DCP equivalent.

`Dgp2Dcp.norm_inf_canon`
Dgp2Dcp canonicalizer for the infinite norm atom

Description

Dgp2Dcp canonicalizer for the infinite norm atom

Usage

```
Dgp2Dcp.norm_inf_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of values for the expr variable

Value

A canonicalization of the infinity norm atom of a DGP expression, where the returned expression is the transformed DCP equivalent.

`Dgp2Dcp.one_minus_pos_canon`
Dgp2Dcp canonicalizer for the 1-x atom

Description

Dgp2Dcp canonicalizer for the 1-x atom

Usage

```
Dgp2Dcp.one_minus_pos_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of values for the expr variable

Value

A canonicalization of the 1-x with $0 < x < 1$ atom of a DGP expression, where the returned expression is the transformed DCP equivalent.

`Dgp2Dcp.parameter_canon` *Dgp2Dcp canonicalizer for the parameter atom*

Description

Dgp2Dcp canonicalizer for the parameter atom

Usage

```
Dgp2Dcp.parameter_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of values for the expr variable

Value

A canonicalization of the parameter atom of a DGP expression, where the returned expression is the transformed DCP equivalent.

`Dgp2Dcp.pf_eigenvalue_canon` *Dgp2Dcp canonicalizer for the spectral radius atom*

Description

Dgp2Dcp canonicalizer for the spectral radius atom

Usage

```
Dgp2Dcp.pf_eigenvalue_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of values for the expr variable

Value

A canonicalization of the spectral radius atom of a DGP expression, where the returned expression is the transformed DCP equivalent.

Dgp2Dcp.pnorm_canon *Dgp2Dcp canonicalizer for the p norm atom*

Description

Dgp2Dcp canonicalizer for the p norm atom

Usage

```
Dgp2Dcp.pnorm_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of values for the expr variable

Value

A canonicalization of the pnorm atom of a DGP expression, where the returned expression is the transformed DCP equivalent.

Dgp2Dcp.power_canon *Dgp2Dcp canonicalizer for the power atom*

Description

Dgp2Dcp canonicalizer for the power atom

Usage

```
Dgp2Dcp.power_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of values for the expr variable

Value

A canonicalization of the power atom of a DGP expression, where the returned expression is the transformed DCP equivalent.

`Dgp2Dcp.prod_canon` *Dgp2Dcp canonicalizer for the product atom*

Description

Dgp2Dcp canonicalizer for the product atom

Usage

```
Dgp2Dcp.prod_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of values for the expr variable

Value

A canonicalization of the product atom of a DGP expression, where the returned expression is the transformed DCP equivalent.

`Dgp2Dcp.quad_form_canon` *Dgp2Dcp canonicalizer for the quadratic form atom*

Description

Dgp2Dcp canonicalizer for the quadratic form atom

Usage

```
Dgp2Dcp.quad_form_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of values for the expr variable

Value

A canonicalization of the quadratic form atom of a DGP expression, where the returned expression is the transformed DCP equivalent.

Dgp2Dcp.quad_over_lin_canon

Dgp2Dcp canonicalizer for the quadratic over linear term atom

Description

Dgp2Dcp canonicalizer for the quadratic over linear term atom

Usage

```
Dgp2Dcp.quad_over_lin_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of values for the expr variable

Value

A canonicalization of the quadratic over linear atom of a DGP expression, where the returned expression is the transformed DCP equivalent.

Dgp2Dcp.sum_canon

Dgp2Dcp canonicalizer for the sum atom

Description

Dgp2Dcp canonicalizer for the sum atom

Usage

```
Dgp2Dcp.sum_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of values for the expr variable

Value

A canonicalization of the sum atom of a DGP expression, where the returned expression is the transformed DCP equivalent.

Dgp2Dcp.trace_canon *Dgp2Dcp canonicalizer for the trace atom*

Description

Dgp2Dcp canonicalizer for the trace atom

Usage

```
Dgp2Dcp.trace_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of values for the expr variable

Value

A canonicalization of the trace atom of a DGP expression, where the returned expression is the transformed DCP equivalent.

Dgp2Dcp.zero_constr_canon *Dgp2Dcp canonicalizer for the zero constraint atom*

Description

Dgp2Dcp canonicalizer for the zero constraint atom

Usage

```
Dgp2Dcp.zero_constr_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of values for the expr variable

Value

A canonicalization of the zero constraint atom of a DGP expression, where the returned expression is the transformed DCP equivalent.

DgpCanonMethods-class *DGP canonical methods class.*

Description

Canonicalization of DGPs is a stateful procedure, hence the need for a class.

Usage

```
## S4 method for signature 'DgpCanonMethods'
names(x)

## S4 method for signature 'DgpCanonMethods'
x$name
```

Arguments

x	A DgpCanonMethods object.
name	The name of the atom or expression to canonicalize.

Methods (by generic)

- `names`: Returns the name of all the canonicalization methods
- `$`: Returns either a canonicalized variable or a corresponding Dgp2Dcp canonicalization method

Diag *Turns an expression into a DiagVec object*

Description

Turns an expression into a DiagVec object

Usage

```
Diag(expr)
```

Arguments

expr	An Expression that represents a vector or square matrix.

Value

An Expression representing the diagonal vector/matrix.

`diag,Expression-method` *Matrix Diagonal*

Description

Extracts the diagonal from a matrix or makes a vector into a diagonal matrix.

Usage

```
## S4 method for signature 'Expression'
diag(x = 1, nrow, ncol)
```

Arguments

`x`	An Expression, vector, or square matrix.
`nrow, ncol`	(Optional) Dimensions for the result when `x` is not a matrix.

Value

An Expression representing the diagonal vector or matrix.

Examples

```
C <- Variable(3,3)
obj <- Maximize(C[1,3])
constraints <- list(diag(C) == 1, C[1,2] == 0.6, C[2,3] == -0.3, C == Variable(3,3, PSD = TRUE))
prob <- Problem(obj, constraints)
result <- solve(prob)
result$value
result$getValue(C)
```

`DiagMat-class` *The DiagMat class.*

Description

This class represents the extraction of the diagonal from a square matrix.

Usage

```
DiagMat(expr)

## S4 method for signature 'DiagMat'
to_numeric(object, values)

## S4 method for signature 'DiagMat'
dim_from_args(object)

## S4 method for signature 'DiagMat'
is_atom_log_log_convex(object)

## S4 method for signature 'DiagMat'
is_atom_log_log_concave(object)

## S4 method for signature 'DiagMat'
graph_implementation(object, arg_objs, dim, data = NA_real_)
```

Arguments

`expr`	An Expression representing the matrix whose diagonal we are interested in.
`object`	A DiagMat object.
`values`	A list of arguments to the atom.
`arg_objs`	A list of linear expressions for each argument.
`dim`	A vector representing the dimensions of the resulting expression.
`data`	A list of additional data required by the atom.

Methods (by generic)

- `to_numeric`: Extract the diagonal from a square matrix constant.
- `dim_from_args`: The size of the atom.
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `graph_implementation`: The graph implementation of the atom.

Slots

`expr` An Expression representing the matrix whose diagonal we are interested in.

DiagVec-class *The DiagVec class.*

Description

This class represents the conversion of a vector into a diagonal matrix.

Usage

```
DiagVec(expr)

## S4 method for signature 'DiagVec'
to_numeric(object, values)

## S4 method for signature 'DiagVec'
dim_from_args(object)

## S4 method for signature 'DiagVec'
is_atom_log_log_convex(object)

## S4 method for signature 'DiagVec'
is_atom_log_log_concave(object)

## S4 method for signature 'DiagVec'
is_symmetric(object)

## S4 method for signature 'DiagVec'
is_hermitian(object)

## S4 method for signature 'DiagVec'
graph_implementation(object, arg_objs, dim, data = NA_real_)
```

Arguments

`expr`	An Expression representing the vector to convert.
`object`	A DiagVec object.
`values`	A list of arguments to the atom.
`arg_objs`	A list of linear expressions for each argument.
`dim`	A vector representing the dimensions of the resulting expression.
`data`	A list of additional data required by the atom.

Methods (by generic)

- `to_numeric`: Convert the vector constant into a diagonal matrix.
- `dim_from_args`: The dimensions of the atom.

- is_atom_log_log_convex: Is the atom log-log convex?
- is_atom_log_log_concave: Is the atom log-log concave?
- is_symmetric: Is the expression symmetric?
- is_hermitian: Is the expression hermitian?
- graph_implementation: The graph implementation of the atom.

Slots

expr An Expression representing the vector to convert.

Diff *Takes the k-th order differences*

Description

Takes the k-th order differences

Usage

```
Diff(x, lag = 1, k = 1, axis = 2)
```

Arguments

x	An Expression that represents a vector
lag	The degree of lag between differences
k	The integer value of the order of differences
axis	The axis along which to apply the function. For a 2D matrix, 1 indicates rows and 2 indicates columns.

Value

Takes in a vector of length n and returns a vector of length n-k of the kth order differences

---

`diff,Expression-method`
Lagged and Iterated Differences

Description

The lagged and iterated differences of a vector. If `x` is length `n`, this function returns a length $n - k$ vector of the kth order difference between the lagged terms. `diff(x)` returns the vector of differences between adjacent elements in the vector, i.e. [x[2] - x[1], x[3] - x[2], ...]. `diff(x,1,2)` is the second-order differences vector, equivalently diff(diff(x)). `diff(x,1,0)` returns the vector x unchanged. `diff(x,2)` returns the vector of differences [x[3] - x[1], x[4] - x[2], ...], equivalent to `x[(1+lag):n] -x[1:(n-lag)]`.

Usage

```
## S4 method for signature 'Expression'
diff(x, lag = 1, differences = 1, ...)
```

Arguments

`x`	An Expression.
`lag`	An integer indicating which lag to use.
`differences`	An integer indicating the order of the difference.
`...`	(Optional) Addition `axis` argument, specifying the dimension across which to apply the function: `1` indicates rows, `2` indicates columns, and `NA` indicates rows and columns. The default is `axis = 1`.

Value

An Expression representing the kth order difference.

Examples

```
## Problem data
m <- 101
L <- 2
h <- L/(m-1)

## Form objective and constraints
x <- Variable(m)
y <- Variable(m)
obj <- sum(y)
constr <- list(x[1] == 0, y[1] == 1, x[m] == 1, y[m] == 1, diff(x)^2 + diff(y)^2 <= h^2)

## Solve the catenary problem
prob <- Problem(Minimize(obj), constr)
result <- solve(prob)
```

```
## Plot and compare with ideal catenary
xs <- result$getValue(x)
ys <- result$getValue(y)
plot(c(0, 1), c(0, 1), type = 'n', xlab = "x", ylab = "y")
lines(xs, ys, col = "blue", lwd = 2)
grid()
```

DiffPos *The DiffPos atom.*

Description

The difference between expressions, $x - y$, where $x > y > 0$.

Usage

```
DiffPos(x, y)
```

Arguments

x	An Expression
y	An Expression

Value

The difference x - y with domain x,y: x > y > 0.

---

dim_from_args *Atom Dimensions*

Description

Determine the dimensions of an atom based on its arguments.

Usage

```
dim_from_args(object)

## S4 method for signature 'Atom'
dim_from_args(object)
```

Arguments

object	A Atom object.

Value

A numeric vector `c(row,col)` indicating the dimensions of the atom.

domain *Domain*

Description

A list of constraints describing the closure of the region where the expression is finite.

Usage

```
domain(object)
```

Arguments

object	An Expression object.

Value

A list of Constraint objects.

Examples

```
a <- Variable(name = "a")
dom <- domain(p_norm(a, -0.5))
prob <- Problem(Minimize(a), dom)
result <- solve(prob)
result$value

b <- Variable()
dom <- domain(kl_div(a, b))
result <- solve(Problem(Minimize(a + b), dom))
result$getValue(a)
result$getValue(b)

A <- Variable(2, 2, name = "A")
dom <- domain(lambda_max(A))
A0 <- rbind(c(1,2), c(3,4))
result <- solve(Problem(Minimize(norm2(A - A0)), dom))
result$getValue(A)

dom <- domain(log_det(A + diag(rep(1,2))))
prob <- Problem(Minimize(sum(diag(A))), dom)
result <- solve(prob, solver = "SCS")
result$value
```

dspop *Direct Standardization: Population*

Description

Randomly generated data for direct standardization example. Sex was drawn from a Bernoulli distribution, and age was drawn from a uniform distribution on 10,...,60. The response was drawn from a normal distribution with a mean that depends on sex and age, and a variance of 1.

Usage

```
dspop
```

Format

A data frame with 1000 rows and 3 variables:

y Response variable

sex Sex of individual, coded male (0) and female (1)

age Age of individual

See Also

dssamp

---

dssamp *Direct Standardization: Sample*

Description

A sample of `dspop` for direct standardization example. The sample is skewed such that young males are overrepresented in comparison to the population.

Usage

```
dssamp
```

Format

A data frame with 100 rows and 3 variables:

y Response variable

sex Sex of individual, coded male (0) and female (1)

age Age of individual

See Also

dspop

dual_value-methods *Get and Set Dual Value*

Description

Get and set the value of the dual variable in a constraint.

Usage

```
dual_value(object)

dual_value(object) <- value
```

Arguments

object	A Constraint object.
value	A numeric scalar, vector, or matrix to assign to the object.

ECOS-class *An interface for the ECOS solver*

Description

An interface for the ECOS solver

Usage

```
ECOS()

## S4 method for signature 'ECOS'
mip_capable(solver)

## S4 method for signature 'ECOS'
status_map(solver, status)

## S4 method for signature 'ECOS'
import_solver(solver)

## S4 method for signature 'ECOS'
name(x)

## S4 method for signature 'ECOS,Problem'
perform(object, problem)

## S4 method for signature 'ECOS,list,list'
invert(object, solution, inverse_data)
```

Arguments

solver, object, x
: A ECOS object.

solver, object, x	A ECOS object.
status	A status code returned by the solver.
problem	A Problem object.
solution	The raw solution returned by the solver.
inverse_data	A list containing data necessary for the inversion.

Methods (by generic)

- `mip_capable`: Can the solver handle mixed-integer programs?
- `status_map`: Converts status returned by the ECOS solver to its respective CVXPY status.
- `import_solver`: Imports the solver
- `name`: Returns the name of the solver
- `perform`: Returns a new problem and data for inverting the new solution.
- `invert`: Returns the solution to the original problem given the inverse_data.

ECOS.dims_to_solver_dict

Utility method for formatting a ConeDims instance into a dictionary that can be supplied to ECOS.

Description

Utility method for formatting a ConeDims instance into a dictionary that can be supplied to ECOS.

Usage

```
ECOS.dims_to_solver_dict(cone_dims)
```

Arguments

cone_dims	A ConeDims instance.

Value

A dictionary of cone dimensions

ECOS_BB-class *An interface for the ECOS BB solver.*

Description

An interface for the ECOS BB solver.

Usage

```
ECOS_BB()

## S4 method for signature 'ECOS_BB'
mip_capable(solver)

## S4 method for signature 'ECOS_BB'
name(x)

## S4 method for signature 'ECOS_BB,Problem'
perform(object, problem)

## S4 method for signature 'ECOS_BB'
solve_via_data(
  object,
  data,
  warm_start,
  verbose,
  feastol,
  reltol,
  abstol,
  num_iter,
  solver_opts,
  solver_cache
)
```

Arguments

`solver, object, x`	A ECOS_BB object.
`problem`	A Problem object.
`data`	Data generated via an apply call.
`warm_start`	A boolean of whether to warm start the solver.
`verbose`	A boolean of whether to enable solver verbosity.
`feastol`	The feasible tolerance.
`reltol`	The relative tolerance.
`abstol`	The absolute tolerance.

num_iter	The maximum number of iterations.
solver_opts	A list of Solver specific options
solver_cache	Cache for the solver.

Methods (by generic)

- mip_capable: Can the solver handle mixed-integer programs?
- name: Returns the name of the solver.
- perform: Returns a new problem and data for inverting the new solution.
- solve_via_data: Solve a problem represented by data returned from apply.

Elementwise-class *The Elementwise class.*

Description

This virtual class represents an elementwise atom.

Usage

```
## S4 method for signature 'Elementwise'
dim_from_args(object)

## S4 method for signature 'Elementwise'
validate_args(object)

## S4 method for signature 'Elementwise'
is_symmetric(object)
```

Arguments

object	An Elementwise object.

Methods (by generic)

- dim_from_args: Dimensions is the same as the sum of the arguments' dimensions.
- validate_args: Verify that all the dimensions are the same or can be promoted.
- is_symmetric: Is the expression symmetric?

EliminatePwl-class *The EliminatePwl class.*

Description

This class eliminates piecewise linear atoms.

Usage

```
## S4 method for signature 'EliminatePwl,Problem'
accepts(object, problem)
```

Arguments

object	An EliminatePwl object.
problem	A Problem object.

Methods (by generic)

- `accepts`: Does this problem contain piecewise linear atoms?

EliminatePwl.abs_canon *EliminatePwl canonicalizer for the absolute atom*

Description

EliminatePwl canonicalizer for the absolute atom

Usage

```
EliminatePwl.abs_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of Constraint objects

Value

A canonicalization of the picewise-lienar atom constructed from an absolute atom where the objective function consists of the variable that is of the same dimension as the original expression and the constraints consist of splitting the absolute value into two inequalities.

EliminatePwl.cummax_canon

EliminatePwl canonicalizer for the cumulative max atom

Description

EliminatePwl canonicalizer for the cumulative max atom

Usage

```
EliminatePwl.cummax_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of Constraint objects

Value

A canonicalization of the piecewise-lienar atom constructed from a cumulative max atom where the objective function consists of the variable Y which is of the same dimension as the original expression and the constraints consist of row/column constraints depending on the axis

EliminatePwl.cumsum_canon

EliminatePwl canonicalizer for the cumulative sum atom

Description

EliminatePwl canonicalizer for the cumulative sum atom

Usage

```
EliminatePwl.cumsum_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of Constraint objects

Value

A canonicalization of the piecewise-lienar atom constructed from a cumulative sum atom where the objective is Y that is of the same dimension as the matrix of the expression and the constraints consist of various row constraints

---

`EliminatePwl.max_elemwise_canon`

EliminatePwl canonicalizer for the elementwise maximum atom

Description

EliminatePwl canonicalizer for the elementwise maximum atom

Usage

```
EliminatePwl.max_elemwise_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of Constraint objects

Value

A canonicalization of the piecewise-lienar atom constructed by a elementwise maximum atom where the objective function is the variable t of the same dimension as the expression and the constraints consist of a simple inequality.

`EliminatePwl.max_entries_canon`

EliminatePwl canonicalizer for the max entries atom

Description

EliminatePwl canonicalizer for the max entries atom

Usage

```
EliminatePwl.max_entries_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of Constraint objects

Value

A canonicalization of the piecewise-lienar atom constructed from the max entries atom where the objective function consists of the variable t of the same size as the original expression and the constraints consist of a vector multiplied by a vector of 1's.

`EliminatePwl.min_elemwise_canon`
EliminatePwl canonicalizer for the elementwise minimum atom

Description

EliminatePwl canonicalizer for the elementwise minimum atom

Usage

```
EliminatePwl.min_elemwise_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of Constraint objects

Value

A canonicalization of the piecewise-lienar atom constructed by a minimum elementwise atom where the objective function is the negative of variable t t produced by max_elemwise_canon of the same dimension as the expression and the constraints consist of a simple inequality.

`EliminatePwl.min_entries_canon`
EliminatePwl canonicalizer for the minimum entries atom

Description

EliminatePwl canonicalizer for the minimum entries atom

Usage

```
EliminatePwl.min_entries_canon(expr, args)
```

Arguments

`expr`	An Expression object
`args`	A list of Constraint objects

Value

A canonicalization of the piecewise-lienar atom constructed by a minimum entries atom where the objective function is the negative of variable t produced by max_elemwise_canon of the same dimension as the expression and the constraints consist of a simple inequality.

`EliminatePwl.norm1_canon`

EliminatePwl canonicalizer for the 1 norm atom

Description

EliminatePwl canonicalizer for the 1 norm atom

Usage

```
EliminatePwl.norm1_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of Constraint objects

Value

A canonicalization of the piecewise-lienar atom constructed by the norm1 atom where the objective functino consists of the sum of the variables created by the abs_canon function and the constraints consist of constraints generated by abs_canon.

`EliminatePwl.norm_inf_canon`

EliminatePwl canonicalizer for the infinite norm atom

Description

EliminatePwl canonicalizer for the infinite norm atom

Usage

```
EliminatePwl.norm_inf_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of Constraint objects

Value

A canonicalization of the piecewise-lienar atom constructed by the infinite norm atom where the objective function consists variable t of the same dimension as the expression and the constraints consist of a vector constructed by multiplying t to a vector of 1's

EliminatePwl.sum_largest_canon

EliminatePwl canonicalizer for the largest sum atom

Description

EliminatePwl canonicalizer for the largest sum atom

Usage

```
EliminatePwl.sum_largest_canon(expr, args)
```

Arguments

expr	An Expression object
args	A list of Constraint objects

Value

A canonicalization of the piecewise-lienar atom constructed by the k largest sums atom where the objective function consists of the sum of variables t that is of the same dimension as the expression plus k

entr

Entropy Function

Description

The elementwise entropy function, $-xlog(x)$.

Usage

```
entr(x)
```

Arguments

x	An Expression, vector, or matrix.

Value

An Expression representing the entropy of the input.

Examples

```
x <- Variable(5)
obj <- Maximize(sum(entr(x)))
prob <- Problem(obj, list(sum(x) == 1))
result <- solve(prob)
result$getValue(x)
```

Entr-class   *The Entr class.*

Description

This class represents the elementwise operation $-xlog(x)$.

Usage

```
Entr(x)

## S4 method for signature 'Entr'
to_numeric(object, values)

## S4 method for signature 'Entr'
sign_from_args(object)

## S4 method for signature 'Entr'
is_atom_convex(object)

## S4 method for signature 'Entr'
is_atom_concave(object)

## S4 method for signature 'Entr'
is_incr(object, idx)

## S4 method for signature 'Entr'
is_decr(object, idx)

## S4 method for signature 'Entr'
.grad(object, values)

## S4 method for signature 'Entr'
.domain(object)
```

Arguments

x	An Expression or numeric constant.
object	An Entr object.
values	A list of numeric values for the arguments
idx	An index into the atom.

Methods (by generic)

- `to_numeric`: The elementwise entropy function evaluated at the value.
- `sign_from_args`: The sign of the atom is unknown.
- `is_atom_convex`: The atom is not convex.
- `is_atom_concave`: The atom is concave.
- `is_incr`: The atom is weakly increasing.
- `is_decr`: The atom is weakly decreasing.
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable
- `.domain`: Returns constraints descrbing the domain of the node

Slots

`x` An Expression or numeric constant.

`EvalParams-class` *The EvalParams class.*

Description

This class represents a reduction that replaces symbolic parameters with their constaint values.

Usage

```
## S4 method for signature 'EvalParams,Problem'
perform(object, problem)

## S4 method for signature 'EvalParams,Solution,list'
invert(object, solution, inverse_data)
```

Arguments

`object`	A EvalParams object.
`problem`	A Problem object.
`solution`	A Solution to a problem that generated the inverse data.
`inverse_data`	The inverse data returned by an invocation to apply.

Methods (by generic)

- `perform`: Replace parameters with constant values.
- `invert`: Returns a solution to the original problem given the inverse_data.

exp,Expression-method *Natural Exponential*

Description

The elementwise natural exponential.

Usage

```
## S4 method for signature 'Expression'
exp(x)
```

Arguments

x	An Expression.

Value

An Expression representing the natural exponential of the input.

Examples

```
x <- Variable(5)
obj <- Minimize(sum(exp(x)))
prob <- Problem(obj, list(sum(x) == 1))
result <- solve(prob)
result$getValue(x)
```

Exp-class *The Exp class.*

Description

This class represents the elementwise natural exponential e^x.

Usage

```
Exp(x)

## S4 method for signature 'Exp'
to_numeric(object, values)

## S4 method for signature 'Exp'
sign_from_args(object)

## S4 method for signature 'Exp'
```

```
is_atom_convex(object)

## S4 method for signature 'Exp'
is_atom_concave(object)

## S4 method for signature 'Exp'
is_atom_log_log_convex(object)

## S4 method for signature 'Exp'
is_atom_log_log_concave(object)

## S4 method for signature 'Exp'
is_incr(object, idx)

## S4 method for signature 'Exp'
is_decr(object, idx)

## S4 method for signature 'Exp'
.grad(object, values)
```

Arguments

x	An Expression object.
object	An Exp object.
values	A list of numeric values for the arguments
idx	An index into the atom.

Methods (by generic)

- `to_numeric`: The matrix with each element exponentiated.
- `sign_from_args`: The atom is positive.
- `is_atom_convex`: The atom is convex.
- `is_atom_concave`: The atom is not concave.
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `is_incr`: The atom is weakly increasing.
- `is_decr`: The atom is not weakly decreasing.
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable

Slots

`x` An Expression object.

ExpCone-class *The ExpCone class.*

Description

This class represents a reformulated exponential cone constraint operating elementwise on a, b, c.

Usage

```
ExpCone(x, y, z, id = NA_integer_)

## S4 method for signature 'ExpCone'
as.character(x)

## S4 method for signature 'ExpCone'
residual(object)

## S4 method for signature 'ExpCone'
size(object)

## S4 method for signature 'ExpCone'
num_cones(object)

## S4 method for signature 'ExpCone'
cone_sizes(object)

## S4 method for signature 'ExpCone'
is_dcp(object)

## S4 method for signature 'ExpCone'
is_dgp(object)

## S4 method for signature 'ExpCone'
canonicalize(object)
```

Arguments

x	The variable x in the exponential cone.
y	The variable y in the exponential cone.
z	The variable z in the exponential cone.
id	(Optional) A numeric value representing the constraint ID.
object	A ExpCone object.

Details

Original cone:

$$K = \{(x, y, z) | y > 0, ye^{x/y} \leq z\} \cup \{(x, y, z) | x \leq 0, y = 0, z \geq 0\}$$

Reformulated cone:

$$K = \{(x, y, z) | y, z > 0, y \log(y) + x \leq y \log(z)\} \cup \{(x, y, z) | x \leq 0, y = 0, z \geq 0\}$$

Methods (by generic)

- `residual`: The size of the `x` argument.
- `size`: The number of entries in the combined cones.
- `num_cones`: The number of elementwise cones.
- `cone_sizes`: The dimensions of the exponential cones.
- `is_dcp`: An exponential constraint is DCP if each argument is affine.
- `is_dgp`: Is the constraint DGP?
- `canonicalize`: Canonicalizes by converting expressions to LinOps.

Slots

`x` The variable x in the exponential cone.

`y` The variable y in the exponential cone.

`z` The variable z in the exponential cone.

`Expression-class` *The Expression class.*

Description

This class represents a mathematical expression.

Usage

```
## S4 method for signature 'Expression'
value(object)

## S4 method for signature 'Expression'
grad(object)

## S4 method for signature 'Expression'
domain(object)

## S4 method for signature 'Expression'
as.character(x)
```

```
## S4 method for signature 'Expression'
name(x)

## S4 method for signature 'Expression'
expr(object)

## S4 method for signature 'Expression'
is_constant(object)

## S4 method for signature 'Expression'
is_affine(object)

## S4 method for signature 'Expression'
is_convex(object)

## S4 method for signature 'Expression'
is_concave(object)

## S4 method for signature 'Expression'
is_dcp(object)

## S4 method for signature 'Expression'
is_log_log_constant(object)

## S4 method for signature 'Expression'
is_log_log_affine(object)

## S4 method for signature 'Expression'
is_log_log_convex(object)

## S4 method for signature 'Expression'
is_log_log_concave(object)

## S4 method for signature 'Expression'
is_dgp(object)

## S4 method for signature 'Expression'
is_hermitian(object)

## S4 method for signature 'Expression'
is_psd(object)

## S4 method for signature 'Expression'
is_nsd(object)

## S4 method for signature 'Expression'
is_quadratic(object)
```

```
## S4 method for signature 'Expression'
is_symmetric(object)

## S4 method for signature 'Expression'
is_pwl(object)

## S4 method for signature 'Expression'
is_qpwa(object)

## S4 method for signature 'Expression'
is_zero(object)

## S4 method for signature 'Expression'
is_nonneg(object)

## S4 method for signature 'Expression'
is_nonpos(object)

## S4 method for signature 'Expression'
dim(x)

## S4 method for signature 'Expression'
is_real(object)

## S4 method for signature 'Expression'
is_imag(object)

## S4 method for signature 'Expression'
is_complex(object)

## S4 method for signature 'Expression'
size(object)

## S4 method for signature 'Expression'
ndim(object)

## S4 method for signature 'Expression'
flatten(object)

## S4 method for signature 'Expression'
is_scalar(object)

## S4 method for signature 'Expression'
is_vector(object)

## S4 method for signature 'Expression'
is_matrix(object)
```

```
## S4 method for signature 'Expression'
nrow(x)

## S4 method for signature 'Expression'
ncol(x)
```

Arguments

x, object	An Expression object.

Methods (by generic)

- value: The value of the expression.
- grad: The (sub/super)-gradient of the expression with respect to each variable.
- domain: A list of constraints describing the closure of the region where the expression is finite.
- as.character: The string representation of the expression.
- name: The name of the expression.
- expr: The expression itself.
- is_constant: The expression is constant if it contains no variables or is identically zero.
- is_affine: The expression is affine if it is constant or both convex and concave.
- is_convex: A logical value indicating whether the expression is convex.
- is_concave: A logical value indicating whether the expression is concave.
- is_dcp: The expression is DCP if it is convex or concave.
- is_log_log_constant: Is the expression log-log constant, i.e., elementwise positive?
- is_log_log_affine: Is the expression log-log affine?
- is_log_log_convex: Is the expression log-log convex?
- is_log_log_concave: Is the expression log-log concave?
- is_dgp: The expression is DGP if it is log-log DCP.
- is_hermitian: A logical value indicating whether the expression is a Hermitian matrix.
- is_psd: A logical value indicating whether the expression is a positive semidefinite matrix.
- is_nsd: A logical value indicating whether the expression is a negative semidefinite matrix.
- is_quadratic: A logical value indicating whether the expression is quadratic.
- is_symmetric: A logical value indicating whether the expression is symmetric.
- is_pwl: A logical value indicating whether the expression is piecewise linear.
- is_qpwa: A logical value indicating whether the expression is quadratic of piecewise affine.
- is_zero: The expression is zero if it is both nonnegative and nonpositive.
- is_nonneg: A logical value indicating whether the expression is nonnegative.
- is_nonpos: A logical value indicating whether the expression is nonpositive.
- dim: The c(row,col) dimensions of the expression.
- is_real: A logical value indicating whether the expression is real.

- is_imag: A logical value indicating whether the expression is imaginary.
- is_complex: A logical value indicating whether the expression is complex.
- size: The number of entries in the expression.
- ndim: The number of dimensions of the expression.
- flatten: Vectorizes the expression.
- is_scalar: A logical value indicating whether the expression is a scalar.
- is_vector: A logical value indicating whether the expression is a row or column vector.
- is_matrix: A logical value indicating whether the expression is a matrix.
- nrow: Number of rows in the expression.
- ncol: Number of columns in the expression.

---

expression-parts *Parts of an Expression Leaf*

Description

List the variables, parameters, constants, or atoms in a canonical expression.

Usage

```
variables(object)

parameters(object)

constants(object)

atoms(object)
```

Arguments

object	A Leaf object.

Value

A list of Variable, Parameter, Constant, or Atom objects.

Examples

```
set.seed(67)
m <- 50
n <- 10
beta <- Variable(n)
y <- matrix(rnorm(m), nrow = m)
X <- matrix(rnorm(m*n), nrow = m, ncol = n)
lambda <- Parameter()
```

```
expr <- sum_squares(y - X %*% beta) + lambda*p_norm(beta, 1)
variables(expr)
parameters(expr)
constants(expr)
lapply(constants(expr), function(c) { value(c) })
```

`extract_dual_value` *Gets a specified value of a dual variable.*

Description

Gets a specified value of a dual variable.

Usage

```
extract_dual_value(result_vec, offset, constraint)
```

Arguments

`result_vec`	A vector containing the dual variable values.
`offset`	An offset to get correct index of dual values.
`constraint`	A list of the constraints in the problem.

Value

A list of a dual variable value and its offset.

`extract_mip_idx` *Coalesces bool, int indices for variables.*

Description

Coalesces bool, int indices for variables.

Usage

```
extract_mip_idx(variables)
```

Arguments

`variables`	A list of Variable objects.

Value

Coalesces bool, int indices for variables. The indexing scheme assumes that the variables will be coalesced into a single one-dimensional variable, with each variable being reshaped in Fortran order.

EyeMinusInv-class *The EyeMinusInv class.*

Description

This class represents the unity resolvent of an elementwise positive matrix X, i.e., $(I - X)^{-1}$, and it enforces the constraint that the spectral radius of X is at most 1. This atom is log-log convex.

Usage

```
EyeMinusInv(X)

## S4 method for signature 'EyeMinusInv'
to_numeric(object, values)

## S4 method for signature 'EyeMinusInv'
name(x)

## S4 method for signature 'EyeMinusInv'
dim_from_args(object)

## S4 method for signature 'EyeMinusInv'
sign_from_args(object)

## S4 method for signature 'EyeMinusInv'
is_atom_convex(object)

## S4 method for signature 'EyeMinusInv'
is_atom_concave(object)

## S4 method for signature 'EyeMinusInv'
is_atom_log_log_convex(object)

## S4 method for signature 'EyeMinusInv'
is_atom_log_log_concave(object)

## S4 method for signature 'EyeMinusInv'
is_incr(object, idx)

## S4 method for signature 'EyeMinusInv'
is_decr(object, idx)

## S4 method for signature 'EyeMinusInv'
.grad(object, values)
```

Arguments

X	An Expression or numeric matrix.

object, x	An EyeMinusInv object.
values	A list of numeric values for the arguments
idx	An index into the atom.

Methods (by generic)

- `to_numeric`: The unity resolvent of the matrix.
- `name`: The name and arguments of the atom.
- `dim_from_args`: The dimensions of the atom determined from its arguments.
- `sign_from_args`: The (is positive, is negative) sign of the atom.
- `is_atom_convex`: Is the atom convex?
- `is_atom_concave`: Is the atom concave?
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `is_incr`: Is the atom weakly increasing in the index?
- `is_decr`: Is the atom weakly decreasing in the index?
- `.grad`: Gives EyeMinusInv the (sub/super)gradient of the atom w.r.t. each variable

Slots

`X` An Expression or numeric matrix.

---

eye_minus_inv *Unity Resolvent*

Description

The unity resolvent of a positive matrix. For an elementwise positive matrix X, this atom represents $(I - X)^{-1}$, and it enforces the constraint that the spectral radius of X is at most 1.

Usage

```
eye_minus_inv(X)
```

Arguments

X	An Expression or positive square matrix.

Details

This atom is log-log convex.

Value

An Expression representing the unity resolvent of the input.

Examples

```
A <- Variable(2,2, pos = TRUE)
prob <- Problem(Minimize(matrix_trace(A)), list(eye_minus_inv(A) <=1))
result <- solve(prob, gp = TRUE)
result$value
result$getValue(A)
```

`FlipObjective-class` *The FlipObjective class.*

Description

This class represents a reduction that flips a minimization objective to a maximization and vice versa.

Usage

```
## S4 method for signature 'FlipObjective,Problem'
perform(object, problem)

## S4 method for signature 'FlipObjective,Solution,list'
invert(object, solution, inverse_data)
```

Arguments

`object`	A FlipObjective object.
`problem`	A Problem object.
`solution`	A Solution to a problem that generated the inverse data.
`inverse_data`	The inverse data returned by an invocation to apply.

Methods (by generic)

- `perform`: Flip a minimization objective to a maximization and vice versa.
- `invert`: Map the solution of the flipped problem to that of the original.

`format_constr` *Format Constraints*

Description

Format constraints for the solver.

Usage

```
format_constr(object, eq_constr, leq_constr, dims, solver)
```

Arguments

`object`	A Constraint object.
`eq_constr`	A list of the equality constraints in the canonical problem.
`leq_constr`	A list of the inequality constraints in the canonical problem.
`dims`	A list with the dimensions of the conic constraints.
`solver`	A string representing the solver to be called.

Value

A list containing equality constraints, inequality constraints, and dimensions.

`GeoMean-class` *The GeoMean class.*

Description

This class represents the (weighted) geometric mean of vector x with optional powers given by p.

Usage

```
GeoMean(x, p = NA_real_, max_denom = 1024)

## S4 method for signature 'GeoMean'
to_numeric(object, values)

## S4 method for signature 'GeoMean'
.domain(object)

## S4 method for signature 'GeoMean'
.grad(object, values)

## S4 method for signature 'GeoMean'
name(x)
```

```
## S4 method for signature 'GeoMean'
dim_from_args(object)

## S4 method for signature 'GeoMean'
sign_from_args(object)

## S4 method for signature 'GeoMean'
is_atom_convex(object)

## S4 method for signature 'GeoMean'
is_atom_concave(object)

## S4 method for signature 'GeoMean'
is_atom_log_log_convex(object)

## S4 method for signature 'GeoMean'
is_atom_log_log_concave(object)

## S4 method for signature 'GeoMean'
is_incr(object, idx)

## S4 method for signature 'GeoMean'
is_decr(object, idx)

## S4 method for signature 'GeoMean'
get_data(object)

## S4 method for signature 'GeoMean'
copy(object, args = NULL, id_objects = list())
```

Arguments

x	An Expression or numeric vector.
p	(Optional) A vector of weights for the weighted geometric mean. The default is a vector of ones, giving the **unweighted** geometric mean $x_1^{1/n} \cdots x_n^{1/n}$.
max_denom	(Optional) The maximum denominator to use in approximating p/sum(p) with w. If w is not an exact representation, increasing max_denom may offer a more accurate representation, at the cost of requiring more convex inequalities to represent the geometric mean. Defaults to 1024.
object	A GeoMean object.
values	A list of numeric values for the arguments
idx	An index into the atom.
args	An optional list that contains the arguments to reconstruct the atom. Default is to use current arguments of the atom.
id_objects	Currently unused.

Details

$$(x_1^{p_1} \cdots x_n^{p_n})^{\frac{1}{\mathbf{1}^T p}}$$

The geometric mean includes an implicit constraint that $x_i \geq 0$ whenever $p_i > 0$. If $p_i = 0, x_i$ will be unconstrained. The only exception to this rule occurs when p has exactly one nonzero element, say p_i, in which case `GeoMean(x,p)` is equivalent to x_i (without the nonnegativity constraint). A specific case of this is when $x \in \mathbf{R}^1$.

Methods (by generic)

- `to_numeric`: The (weighted) geometric mean of the elements of `x`.
- `.domain`: Returns constraints describing the domain of the node
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable
- `name`: The name and arguments of the atom.
- `dim_from_args`: The atom is a scalar.
- `sign_from_args`: The atom is non-negative.
- `is_atom_convex`: The atom is not convex.
- `is_atom_concave`: The atom is concave.
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `is_incr`: The atom is weakly increasing in every argument.
- `is_decr`: The atom is not weakly decreasing in any argument.
- `get_data`: Returns `list(w,dyadic completion,tree of dyads)`.
- `copy`: Returns a shallow copy of the GeoMean atom

Slots

`x` An Expression or numeric vector.

`p` (Optional) A vector of weights for the weighted geometric mean. The default is a vector of ones, giving the **unweighted** geometric mean $x_1^{1/n} \cdots x_n^{1/n}$.

`max_denom` (Optional) The maximum denominator to use in approximating `p/sum(p)` with `w`. If `w` is not an exact representation, increasing `max_denom` may offer a more accurate representation, at the cost of requiring more convex inequalities to represent the geometric mean. Defaults to 1024.

`w` (Internal) A list of `bigq` objects that represent a rational approximation of `p/sum(p)`.

`approx_error` (Internal) The error in approximating `p/sum(p)` with `w`, given by $\|p/\mathbf{1}^T p - w\|_\infty$.

geo_mean *Geometric Mean*

Description

The (weighted) geometric mean of vector x with optional powers given by p.

Usage

```
geo_mean(x, p = NA_real_, max_denom = 1024)
```

Arguments

`x`	An Expression or vector.
`p`	(Optional) A vector of weights for the weighted geometric mean. Defaults to a vector of ones, giving the **unweighted** geometric mean $x_1^{1/n} \cdots x_n^{1/n}$.
`max_denom`	(Optional) The maximum denominator to use in approximating `p/sum(p)` with `w`. If `w` is not an exact representation, increasing `max_denom` may offer a more accurate representation, at the cost of requiring more convex inequalities to represent the geometric mean. Defaults to 1024.

Details

$$(x_1^{p_1} \cdots x_n^{p_n})^{\frac{1}{\mathbf{1}^T p}}$$

The geometric mean includes an implicit constraint that $x_i \geq 0$ whenever $p_i > 0$. If $p_i = 0, x_i$ will be unconstrained. The only exception to this rule occurs when p has exactly one nonzero element, say p_i, in which case `geo_mean(x,p)` is equivalent to x_i (without the nonnegativity constraint). A specific case of this is when $x \in \mathbf{R}^1$.

Value

An Expression representing the geometric mean of the input.

Examples

```
x <- Variable(2)
cost <- geo_mean(x)
prob <- Problem(Maximize(cost), list(sum(x) <= 1))
result <- solve(prob)
result$value
result$getValue(x)

## Not run:
  x <- Variable(5)
  p <- c(0.07, 0.12, 0.23, 0.19, 0.39)
  prob <- Problem(Maximize(geo_mean(x,p)), list(p_norm(x) <= 1))
```

```
  result <- solve(prob)
  result$value
  result$getValue(x)

## End(Not run)
```

`get_data` *Get Expression Data*

Description

Get information needed to reconstruct the expression aside from its arguments.

Usage

```
get_data(object)
```

Arguments

object	A Expression object.

Value

A list containing data.

`get_dual_values` *Gets the values of the dual variables.*

Description

Gets the values of the dual variables.

Usage

```
get_dual_values(result_vec, parse_func, constraints)
```

Arguments

result_vec	A vector containing the dual variable values.
parse_func	Function handle for the parser.
constraints	A list of the constraints in the problem.

Value

A map of constraint ID to dual variable value.

get_id *Get ID*

Description

Get the next identifier value.

Usage

```
get_id()
```

Value

A new unique integer identifier.

Examples

```
## Not run:
   get_id()

## End(Not run)
```

get_np *Get numpy handle*

Description

Get the numpy handle or fail if not available

Usage

```
get_np()
```

Value

the numpy handle

Examples

```
## Not run:
   get_np

## End(Not run)
```

get_problem_data *Get Problem Data*

Description

Get the problem data used in the call to the solver.

Usage

```
get_problem_data(object, solver, gp)
```

Arguments

object	A Problem object.
solver	A string indicating the solver that the problem data is for. Call `installed_solvers()` to see all available.
gp	(Optional) A logical value indicating whether the problem is a geometric program.

Value

A list containing the data for the solver, the solving chain for the problem, and the inverse data needed to invert the solution.

Examples

```
a <- Variable(name = "a")
data <- get_problem_data(Problem(Minimize(exp(a) + 2)), "SCS")[[1]]
data[["dims"]]
data[["c"]]
data[["A"]]

x <- Variable(2, name = "x")
data <- get_problem_data(Problem(Minimize(p_norm(x) + 3)), "ECOS")[[1]]
data[["dims"]]
data[["c"]]
data[["A"]]
data[["G"]]
```

`get_sp` *Get scipy handle*

Description

Get the scipy handle or fail if not available

Usage

```
get_sp()
```

Value

the scipy handle

Examples

```
## Not run:
  get_sp

## End(Not run)
```

`GLPK-class` *An interface for the GLPK solver.*

Description

An interface for the GLPK solver.

Usage

```
GLPK()

## S4 method for signature 'GLPK'
mip_capable(solver)

## S4 method for signature 'GLPK'
status_map(solver, status)

## S4 method for signature 'GLPK'
name(x)

## S4 method for signature 'GLPK'
import_solver(solver)

## S4 method for signature 'GLPK,list,list'
```

```
invert(object, solution, inverse_data)

## S4 method for signature 'GLPK'
solve_via_data(
  object,
  data,
  warm_start,
  verbose,
  feastol,
  reltol,
  abstol,
  num_iter,
  solver_opts,
  solver_cache
)
```

Arguments

`solver, object, x`	A GLPK object.
`status`	A status code returned by the solver.
`solution`	The raw solution returned by the solver.
`inverse_data`	A list containing data necessary for the inversion.
`data`	Data generated via an apply call.
`warm_start`	A boolean of whether to warm start the solver.
`verbose`	A boolean of whether to enable solver verbosity.
`feastol`	The feasible tolerance.
`reltol`	The relative tolerance.
`abstol`	The absolute tolerance.
`num_iter`	The maximum number of iterations.
`solver_opts`	A list of Solver specific options
`solver_cache`	Cache for the solver.

Methods (by generic)

- `mip_capable`: Can the solver handle mixed-integer programs?
- `status_map`: Converts status returned by the GLPK solver to its respective CVXPY status.
- `name`: Returns the name of the solver.
- `import_solver`: Imports the solver.
- `invert`: Returns the solution to the original problem given the inverse_data.
- `solve_via_data`: Solve a problem represented by data returned from apply.

GLPK_MI-class *An interface for the GLPK MI solver.*

Description

An interface for the GLPK MI solver.

Usage

```
GLPK_MI()

## S4 method for signature 'GLPK_MI'
mip_capable(solver)

## S4 method for signature 'GLPK_MI'
status_map(solver, status)

## S4 method for signature 'GLPK_MI'
name(x)

## S4 method for signature 'GLPK_MI'
solve_via_data(
  object,
  data,
  warm_start,
  verbose,
  feastol,
  reltol,
  abstol,
  num_iter,
  solver_opts,
  solver_cache
)
```

Arguments

solver, object, x	A GLPK_MI object.
status	A status code returned by the solver.
data	Data generated via an apply call.
warm_start	A boolean of whether to warm start the solver.
verbose	A boolean of whether to enable solver verbosity.
feastol	The feasible tolerance.
reltol	The relative tolerance.
abstol	The absolute tolerance.

num_iter	The maximum number of iterations.
solver_opts	A list of Solver specific options
solver_cache	Cache for the solver.

Methods (by generic)

- mip_capable: Can the solver handle mixed-integer programs?
- status_map: Converts status returned by the GLPK_MI solver to its respective CVXPY status.
- name: Returns the name of the solver.
- solve_via_data: Solve a problem represented by data returned from apply.

---

grad *Sub/Super-Gradient*

Description

The (sub/super)-gradient of the expression with respect to each variable. Matrix expressions are vectorized, so the gradient is a matrix. NA indicates variable values are unknown or outside the domain.

Usage

```
grad(object)
```

Arguments

object	An Expression object.

Value

A list mapping each variable to a sparse matrix.

Examples

```
x <- Variable(2, name = "x")
A <- Variable(2, 2, name = "A")

value(x) <- c(-3,4)
expr <- p_norm(x, 2)
grad(expr)

value(A) <- rbind(c(3,-4), c(4,3))
expr <- p_norm(A, 0.5)
grad(expr)

value(A) <- cbind(c(1,2), c(-1,0))
expr <- abs(A)
grad(expr)
```

graph_implementation *Graph Implementation*

Description

Reduces the atom to an affine expression and list of constraints.

Usage

```
graph_implementation(object, arg_objs, dim, data)
```

Arguments

`object`	An Expression object.
`arg_objs`	A list of linear expressions for each argument.
`dim`	A vector representing the dimensions of the resulting expression.
`data`	A list of additional data required by the atom.

Value

A list of `list(LinOp for objective,list of constraints)`, where LinOp is a list representing the linear operator.

group_constraints *Organize the constraints into a dictionary keyed by constraint names.*

Description

Organize the constraints into a dictionary keyed by constraint names.

Usage

```
group_constraints(constraints)
```

Arguments

`constraints`	a list of constraints.

Value

A list of constraint types where constr_map[[cone_type]] maps to a list.

GUROBI_CONIC-class *An interface for the GUROBI conic solver.*

Description

An interface for the GUROBI conic solver.

Usage

```
GUROBI_CONIC()

## S4 method for signature 'GUROBI_CONIC'
mip_capable(solver)

## S4 method for signature 'GUROBI_CONIC'
name(x)

## S4 method for signature 'GUROBI_CONIC'
import_solver(solver)

## S4 method for signature 'GUROBI_CONIC'
status_map(solver, status)

## S4 method for signature 'GUROBI_CONIC,Problem'
accepts(object, problem)

## S4 method for signature 'GUROBI_CONIC,Problem'
perform(object, problem)

## S4 method for signature 'GUROBI_CONIC,list,list'
invert(object, solution, inverse_data)

## S4 method for signature 'GUROBI_CONIC'
solve_via_data(
  object,
  data,
  warm_start,
  verbose,
  feastol,
  reltol,
  abstol,
  num_iter,
  solver_opts,
  solver_cache
)
```

Arguments

solver, object, x
: A GUROBI_CONIC object.

solver, object, x	A GUROBI_CONIC object.
status	A status code returned by the solver.
problem	A Problem object.
solution	The raw solution returned by the solver.
inverse_data	A list containing data necessary for the inversion.
data	Data generated via an apply call.
warm_start	A boolean of whether to warm start the solver.
verbose	A boolean of whether to enable solver verbosity.
feastol	The feasible tolerance.
reltol	The relative tolerance.
abstol	The absolute tolerance.
num_iter	The maximum number of iterations.
solver_opts	A list of Solver specific options
solver_cache	Cache for the solver.

Methods (by generic)

- `mip_capable`: Can the solver handle mixed-integer programs?
- `name`: Returns the name of the solver.
- `import_solver`: Imports the solver.
- `status_map`: Converts status returned by the GUROBI solver to its respective CVXPY status.
- `accepts`: Can GUROBI_CONIC solve the problem?
- `perform`: Returns a new problem and data for inverting the new solution.
- `invert`: Returns the solution to the original problem given the inverse_data.
- `solve_via_data`: Solve a problem represented by data returned from apply.

GUROBI_QP-class *An interface for the GUROBI_QP solver.*

Description

An interface for the GUROBI_QP solver.

Usage

```
GUROBI_QP()

## S4 method for signature 'GUROBI_QP'
mip_capable(solver)

## S4 method for signature 'GUROBI_QP'
status_map(solver, status)

## S4 method for signature 'GUROBI_QP'
name(x)

## S4 method for signature 'GUROBI_QP'
import_solver(solver)

## S4 method for signature 'GUROBI_QP'
solve_via_data(
  object,
  data,
  warm_start,
  verbose,
  feastol,
  reltol,
  abstol,
  num_iter,
  solver_opts,
  solver_cache
)

## S4 method for signature 'GUROBI_QP,list,InverseData'
invert(object, solution, inverse_data)
```

Arguments

`solver, object, x`	A GUROBI_QP object.
`status`	A status code returned by the solver.
`data`	Data generated via an apply call.
`warm_start`	A boolean of whether to warm start the solver.
`verbose`	A boolean of whether to enable solver verbosity.
`feastol`	The feasible tolerance.
`reltol`	The relative tolerance.
`abstol`	The absolute tolerance.
`num_iter`	The maximum number of iterations.
`solver_opts`	A list of Solver specific options

solver_cache	Cache for the solver.
solution	The raw solution returned by the solver.
inverse_data	A InverseData object containing data necessary for the inversion.

Methods (by generic)

- mip_capable: Can the solver handle mixed-integer programs?
- status_map: Converts status returned by the GUROBI solver to its respective CVXPY status.
- name: Returns the name of the solver.
- import_solver: Imports the solver.
- solve_via_data: Solve a problem represented by data returned from apply.
- invert: Returns the solution to the original problem given the inverse_data.

HarmonicMean *The HarmonicMean atom.*

Description

The harmonic mean of x, $\frac{1}{n}\sum_{i=1}^{n} x_i^{-1}$, where n is the length of x.

Usage

```
HarmonicMean(x)
```

Arguments

x	An expression or number whose harmonic mean is to be computed. Must have positive entries.

Value

The harmonic mean of x.

harmonic_mean *Harmonic Mean*

Description

The harmonic mean, $\left(\frac{1}{n}\sum_{i=1}^{n} x_i^{-1}\right)^{-1}$. For a matrix, the function is applied over all entries.

Usage

```
harmonic_mean(x)
```

Arguments

`x`	An Expression, vector, or matrix.

Value

An Expression representing the harmonic mean of the input.

Examples

```
x <- Variable()
prob <- Problem(Maximize(harmonic_mean(x)), list(x >= 0, x <= 5))
result <- solve(prob)
result$value
result$getValue(x)
```

hstack *Horizontal Concatenation*

Description

The horizontal concatenation of expressions. This is equivalent to `cbind` when applied to objects with the same number of rows.

Usage

```
hstack(...)
```

Arguments

`...`	Expression objects, vectors, or matrices. All arguments must have the same number of rows.

Value

An Expression representing the concatenated inputs.

Examples

```
x <- Variable(2)
y <- Variable(3)
c <- matrix(1, nrow = 1, ncol = 5)
prob <- Problem(Minimize(c %*% t(hstack(t(x), t(y)))), list(x == c(1,2), y == c(3,4,5)))
result <- solve(prob)
result$value

c <- matrix(1, nrow = 1, ncol = 4)
prob <- Problem(Minimize(c %*% t(hstack(t(x), t(x)))), list(x == c(1,2)))
result <- solve(prob)
result$value

A <- Variable(2,2)
C <- Variable(3,2)
c <- matrix(1, nrow = 2, ncol = 2)
prob <- Problem(Minimize(sum_entries(hstack(t(A), t(C)))), list(A >= 2*c, C == -2))
result <- solve(prob)
result$value
result$getValue(A)

D <- Variable(3,3)
expr <- hstack(C, D)
obj <- expr[1,2] + sum(hstack(expr, expr))
constr <- list(C >= 0, D >= 0, D[1,1] == 2, C[1,2] == 3)
prob <- Problem(Minimize(obj), constr)
result <- solve(prob)
result$value
result$getValue(C)
result$getValue(D)
```

HStack-class *The HStack class.*

Description

Horizontal concatenation of values.

Usage

```
HStack(...)

## S4 method for signature 'HStack'
to_numeric(object, values)

## S4 method for signature 'HStack'
dim_from_args(object)

## S4 method for signature 'HStack'
```

```
is_atom_log_log_convex(object)

## S4 method for signature 'HStack'
is_atom_log_log_concave(object)

## S4 method for signature 'HStack'
validate_args(object)

## S4 method for signature 'HStack'
graph_implementation(object, arg_objs, dim, data = NA_real_)
```

Arguments

...	Expression objects or matrices. All arguments must have the same dimensions except for axis 2 (columns).
object	A HStack object.
values	A list of arguments to the atom.
arg_objs	A list of linear expressions for each argument.
dim	A vector representing the dimensions of the resulting expression.
data	A list of additional data required by the atom.

Methods (by generic)

- `to_numeric`: Horizontally concatenate the values using `cbind`.
- `dim_from_args`: The dimensions of the atom.
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `validate_args`: Check all arguments have the same height.
- `graph_implementation`: The graph implementation of the atom.

Slots

`...` Expression objects or matrices. All arguments must have the same dimensions except for axis 2 (columns).

`huber` *Huber Function*

Description

The elementwise Huber function, $Huber(x, M) =$

- $2M|x| - M^2$for $|x| \geq |M|$
- $|x|^2$for $|x| \leq |M|$.

Usage

```
huber(x, M = 1)
```

Arguments

`x`	An Expression, vector, or matrix.
`M`	(Optional) A positive scalar value representing the threshold. Defaults to 1.

Value

An Expression representing the Huber function evaluated at the input.

Examples

```
set.seed(11)
n <- 10
m <- 450
p <- 0.1    # Fraction of responses with sign flipped

# Generate problem data
beta_true <- 5*matrix(stats::rnorm(n), nrow = n)
X <- matrix(stats::rnorm(m*n), nrow = m, ncol = n)
y_true <- X %*% beta_true
eps <- matrix(stats::rnorm(m), nrow = m)

# Randomly flip sign of some responses
factor <- 2*rbinom(m, size = 1, prob = 1-p) - 1
y <- factor * y_true + eps

# Huber regression
beta <- Variable(n)
obj <- sum(huber(y - X %*% beta, 1))
prob <- Problem(Minimize(obj))
result <- solve(prob)
result$getValue(beta)
```

`Huber-class` *The Huber class.*

Description

This class represents the elementwise Huber function, $Huber(x, M) =$

- $2M|x| - M^2$for $|x| \geq |M|$
- $|x|^2$for $|x| \leq |M|$.

Usage

```
Huber(x, M = 1)

## S4 method for signature 'Huber'
to_numeric(object, values)

## S4 method for signature 'Huber'
sign_from_args(object)

## S4 method for signature 'Huber'
is_atom_convex(object)

## S4 method for signature 'Huber'
is_atom_concave(object)

## S4 method for signature 'Huber'
is_incr(object, idx)

## S4 method for signature 'Huber'
is_decr(object, idx)

## S4 method for signature 'Huber'
is_quadratic(object)

## S4 method for signature 'Huber'
get_data(object)

## S4 method for signature 'Huber'
validate_args(object)

## S4 method for signature 'Huber'
.grad(object, values)
```

Arguments

`x`	An Expression object.
`M`	A positive scalar value representing the threshold. Defaults to 1.
`object`	A Huber object.
`values`	A list of numeric values for the arguments
`idx`	An index into the atom.

Methods (by generic)

- `to_numeric`: The Huber function evaluted elementwise on the input value.
- `sign_from_args`: The atom is positive.
- `is_atom_convex`: The atom is convex.

- `is_atom_concave`: The atom is not concave.
- `is_incr`: A logical value indicating whether the atom is weakly increasing.
- `is_decr`: A logical value indicating whether the atom is weakly decreasing.
- `is_quadratic`: The atom is quadratic if `x` is affine.
- `get_data`: A list containing the parameter `M`.
- `validate_args`: Check that `M` is a non-negative constant.
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable

Slots

`x` An Expression or numeric constant.

`M` A positive scalar value representing the threshold. Defaults to 1.

`id` *Identification Number*

Description

A unique identification number used internally to keep track of variables and constraints. Should not be modified by the user.

Usage

```
id(object)
```

Arguments

`object`	A Variable or Constraint object.

Value

A non-negative integer identifier.

See Also

`get_id` `setIdCounter`

Examples

```
x <- Variable()
constr <- (x >= 5)
id(x)
id(constr)
```

Imag-class *The Imag class.*

Description

This class represents the imaginary part of an expression.

Usage

```
Imag(expr)

## S4 method for signature 'Imag'
to_numeric(object, values)

## S4 method for signature 'Imag'
dim_from_args(object)

## S4 method for signature 'Imag'
is_imag(object)

## S4 method for signature 'Imag'
is_complex(object)

## S4 method for signature 'Imag'
is_symmetric(object)
```

Arguments

`expr`	An Expression representing a vector or matrix.
`object`	An Imag object.
`values`	A list of arguments to the atom.

Methods (by generic)

- `to_numeric`: The imaginary part of the given value.
- `dim_from_args`: The dimensions of the atom.
- `is_imag`: Is the atom imaginary?
- `is_complex`: Is the atom complex valued?
- `is_symmetric`: Is the atom symmetric?

Slots

`expr` An Expression representing a vector or matrix.

import_solver *Import Solver*

Description

Import the R library that interfaces with the specified solver.

Usage

```
import_solver(solver)
```

Arguments

solver	A ReductionSolver object.

Examples

```
import_solver(ECOS())
import_solver(SCS())
```

installed_solvers *List installed solvers*

Description

List available solvers, taking currently blacklisted solvers into account.

Usage

```
installed_solvers()

add_to_solver_blacklist(solvers)

remove_from_solver_blacklist(solvers)

set_solver_blacklist(solvers)
```

Arguments

solvers	a character vector of solver names, default character(0)

Value

The names of all the installed solvers as a character vector.

The current blacklist (character vector), invisibly.

Functions

- `add_to_solver_blacklist`: Add to solver blacklist, useful for temporarily disabling a solver
- `remove_from_solver_blacklist`: Remove solvers from blacklist
- `set_solver_blacklist`: Set solver blacklist to a value

`InverseData-class` *The InverseData class.*

Description

This class represents the data encoding an optimization problem.

`invert` *Return Original Solution*

Description

Returns a solution to the original problem given the inverse data.

Usage

```
invert(object, solution, inverse_data)
```

Arguments

`object`	A Reduction object.
`solution`	A Solution to a problem that generated `inverse_data`.
`inverse_data`	A InverseData object encoding the original problem.

Value

A Solution to the original problem.

inv_pos — *Reciprocal Function*

Description

The elementwise reciprocal function, $\frac{1}{x}$

Usage

```
inv_pos(x)
```

Arguments

x	An Expression, vector, or matrix.

Value

An Expression representing the reciprocal of the input.

Examples

```
A <- Variable(2,2)
val <- cbind(c(1,2), c(3,4))
prob <- Problem(Minimize(inv_pos(A)[1,2]), list(A == val))
result <- solve(prob)
result$value
```

is_dcp — *DCP Compliance*

Description

Determine if a problem or expression complies with the disciplined convex programming rules.

Usage

```
is_dcp(object)
```

Arguments

object	A Problem or Expression object.

Value

A logical value indicating whether the problem or expression is DCP compliant, i.e. no unknown curvatures.

Examples

```
x <- Variable()
prob <- Problem(Minimize(x^2), list(x >= 5))
is_dcp(prob)
solve(prob)
```

`is_dgp` *DGP Compliance*

Description

Determine if a problem or expression complies with the disciplined geometric programming rules.

Usage

```
is_dgp(object)
```

Arguments

object	A Problem or Expression object.

Value

A logical value indicating whether the problem or expression is DCP compliant, i.e. no unknown curvatures.

Examples

```
x <- Variable(pos = TRUE)
y <- Variable(pos = TRUE)
prob <- Problem(Minimize(x*y), list(x >= 5, y >= 5))
is_dgp(prob)
solve(prob, gp = TRUE)
```

`is_mixed_integer` *Is Problem Mixed Integer?*

Description

Determine if a problem is a mixed-integer program.

Usage

```
is_mixed_integer(object)
```

Arguments

`object`	A Problem object.

Value

A logical value indicating whether the problem is a mixed-integer program

---

`is_qp` *Is Problem a QP?*

Description

Determine if a problem is a quadratic program.

Usage

```
is_qp(object)
```

Arguments

`object`	A Problem object.

Value

A logical value indicating whether the problem is a quadratic program.

`is_stuffed_cone_constraint` *Is the constraint a stuffed cone constraint?*

Description

Is the constraint a stuffed cone constraint?

Usage

```
is_stuffed_cone_constraint(constraint)
```

Arguments

`constraint`	A Constraint object.

Value

Is the constraint a stuffed-cone constraint?

`is_stuffed_cone_objective` *Is the objective a stuffed cone objective?*

Description

Is the objective a stuffed cone objective?

Usage

```
is_stuffed_cone_objective(objective)
```

Arguments

`objective`	An Objective object.

Value

Is the objective a stuffed-cone objective?

`is_stuffed_qp_objective` *Is the QP objective stuffed?*

Description

Is the QP objective stuffed?

Usage

```
is_stuffed_qp_objective(objective)
```

Arguments

`objective`	A Minimize or Maximize object representing the optimization objective.

Value

Is the objective a stuffed QP?

KLDiv-class *The KLDiv class.*

Description

The elementwise KL-divergence $x \log(x/y) - x + y$.

Usage

```
KLDiv(x, y)

## S4 method for signature 'KLDiv'
to_numeric(object, values)

## S4 method for signature 'KLDiv'
sign_from_args(object)

## S4 method for signature 'KLDiv'
is_atom_convex(object)

## S4 method for signature 'KLDiv'
is_atom_concave(object)

## S4 method for signature 'KLDiv'
is_incr(object, idx)

## S4 method for signature 'KLDiv'
is_decr(object, idx)

## S4 method for signature 'KLDiv'
.grad(object, values)

## S4 method for signature 'KLDiv'
.domain(object)
```

Arguments

x	An Expression or numeric constant.
y	An Expression or numeric constant.
object	A KLDiv object.
values	A list of numeric values for the arguments
idx	An index into the atom.

Methods (by generic)

- `to_numeric`: The KL-divergence evaluted elementwise on the input value.
- `sign_from_args`: The atom is positive.
- `is_atom_convex`: The atom is convex.
- `is_atom_concave`: The atom is not concave.
- `is_incr`: The atom is not monotonic in any argument.
- `is_decr`: The atom is not monotonic in any argument.
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable
- `.domain`: Returns constraints describng the domain of the node

Slots

`x` An Expression or numeric constant.

`y` An Expression or numeric constant.

---

kl_div *Kullback-Leibler Divergence*

Description

The elementwise Kullback-Leibler divergence, $x \log(x/y) - x + y$.

Usage

```
kl_div(x, y)
```

Arguments

`x`	An Expression, vector, or matrix.
`y`	An Expression, vector, or matrix.

Value

An Expression representing the KL-divergence of the input.

Examples

```
n <- 5
alpha <- seq(10, n-1+10)/n
beta <- seq(10, n-1+10)/n
P_tot <- 0.5
W_tot <- 1.0

P <- Variable(n)
W <- Variable(n)
```

```
R <- kl_div(alpha*W, alpha*(W + beta*P)) - alpha*beta*P
obj <- sum(R)
constr <- list(P >= 0, W >= 0, sum(P) == P_tot, sum(W) == W_tot)
prob <- Problem(Minimize(obj), constr)
result <- solve(prob)

result$value
result$getValue(P)
result$getValue(W)
```

Kron-class *The Kron class.*

Description

This class represents the kronecker product.

Usage

```
Kron(lh_exp, rh_exp)

## S4 method for signature 'Kron'
to_numeric(object, values)

## S4 method for signature 'Kron'
validate_args(object)

## S4 method for signature 'Kron'
dim_from_args(object)

## S4 method for signature 'Kron'
sign_from_args(object)

## S4 method for signature 'Kron'
is_incr(object, idx)

## S4 method for signature 'Kron'
is_decr(object, idx)

## S4 method for signature 'Kron'
graph_implementation(object, arg_objs, dim, data = NA_real_)
```

Arguments

lh_exp	An Expression or numeric constant representing the left-hand matrix.
rh_exp	An Expression or numeric constant representing the right-hand matrix.
object	A Kron object.

values	A list of arguments to the atom.
idx	An index into the atom.
arg_objs	A list of linear expressions for each argument.
dim	A vector with two elements representing the size of the resulting expression.
data	A list of additional data required by the atom.

Methods (by generic)

- `to_numeric`: The kronecker product of the two values.
- `validate_args`: Check both arguments are vectors and the first is a constant.
- `dim_from_args`: The dimensions of the atom.
- `sign_from_args`: The sign of the atom.
- `is_incr`: Is the left-hand expression positive?
- `is_decr`: Is the right-hand expression negative?
- `graph_implementation`: The graph implementation of the atom.

Slots

`lh_exp` An Expression or numeric constant representing the left-hand matrix.

`rh_exp` An Expression or numeric constant representing the right-hand matrix.

`kronecker,Expression,ANY-method`
Kronecker Product

Description

The generalized kronecker product of two matrices.

Usage

```
## S4 method for signature 'Expression,ANY'
kronecker(X, Y, FUN = "*", make.dimnames = FALSE, ...)

## S4 method for signature 'ANY,Expression'
kronecker(X, Y, FUN = "*", make.dimnames = FALSE, ...)
```

Arguments

X	An Expression or matrix.
Y	An Expression or matrix.
FUN	Hardwired to "*" for the kronecker product.
make.dimnames	(Unimplemented) Dimension names are not supported in Expression objects.
...	(Unimplemented) Optional arguments.

Value

An Expression that represents the kronecker product.

Examples

```
X <- cbind(c(1,2), c(3,4))
Y <- Variable(2,2)
val <- cbind(c(5,6), c(7,8))

obj <- X %x% Y
prob <- Problem(Minimize(kronecker(X,Y)[1,1]), list(Y == val))
result <- solve(prob)
result$value
result$getValue(kronecker(X,Y))
```

LambdaMax-class *The LambdaMax class.*

Description

The maximum eigenvalue of a matrix, $\lambda_{\max}(A)$.

Usage

```
LambdaMax(A)

## S4 method for signature 'LambdaMax'
to_numeric(object, values)

## S4 method for signature 'LambdaMax'
.domain(object)

## S4 method for signature 'LambdaMax'
.grad(object, values)

## S4 method for signature 'LambdaMax'
validate_args(object)

## S4 method for signature 'LambdaMax'
dim_from_args(object)

## S4 method for signature 'LambdaMax'
sign_from_args(object)

## S4 method for signature 'LambdaMax'
is_atom_convex(object)

## S4 method for signature 'LambdaMax'
```

```
is_atom_concave(object)

## S4 method for signature 'LambdaMax'
is_incr(object, idx)

## S4 method for signature 'LambdaMax'
is_decr(object, idx)
```

Arguments

A	An Expression or numeric matrix.
object	A LambdaMax object.
values	A list of arguments to the atom.
idx	An index into the atom.

Methods (by generic)

- `to_numeric`: The largest eigenvalue of `A`. Requires that `A` be symmetric.
- `.domain`: Returns the constraints describing the domain of the atom.
- `.grad`: Gives the (sub/super)gradient of the atom with respect to each argument. Matrix expressions are vectorized, so the gradient is a matrix.
- `validate_args`: Check that `A` is square.
- `dim_from_args`: The atom is a scalar.
- `sign_from_args`: The sign of the atom is unknown.
- `is_atom_convex`: The atom is convex.
- `is_atom_concave`: The atom is not concave.
- `is_incr`: The atom is not monotonic in any argument.
- `is_decr`: The atom is not monotonic in any argument.

Slots

`A` An Expression or numeric matrix.

`LambdaMin` *The LambdaMin atom.*

Description

The minimum eigenvalue of a matrix, $\lambda_{\min}(A)$.

Usage

```
LambdaMin(A)
```

Arguments

A	An Expression or numeric matrix.

Value

Returns the minimum eigenvalue of a matrix.

LambdaSumLargest-class
The LambdaSumLargest class.

Description

This class represents the sum of the k largest eigenvalues of a matrix.

Usage

```
LambdaSumLargest(A, k)

## S4 method for signature 'LambdaSumLargest'
allow_complex(object)

## S4 method for signature 'LambdaSumLargest'
to_numeric(object, values)

## S4 method for signature 'LambdaSumLargest'
validate_args(object)

## S4 method for signature 'LambdaSumLargest'
get_data(object)

## S4 method for signature 'LambdaSumLargest'
.grad(object, values)
```

Arguments

A	An Expression or numeric matrix.
k	A positive integer.
object	A LambdaSumLargest object.
values	A list of numeric values for the arguments

Methods (by generic)

- `allow_complex`: Does the atom handle complex numbers?
- `to_numeric`: Returns the largest eigenvalue of `A`, which must be symmetric.
- `validate_args`: Verify that the argument `A` is square.
- `get_data`: Returns the parameter `k`.
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable

Slots

`k` A positive integer.

`LambdaSumSmallest` *The LambdaSumSmallest atom.*

Description

This class represents the sum of the `k` smallest eigenvalues of a matrix.

Usage

```
LambdaSumSmallest(A, k)
```

Arguments

`A`	An Expression or numeric matrix.
`k`	A positive integer.

Value

Returns the sum of the `k` smallest eigenvalues of a matrix.

`lambda_max` *Maximum Eigenvalue*

Description

The maximum eigenvalue of a matrix, $\lambda_{\max}(A)$.

Usage

```
lambda_max(A)
```

Arguments

`A`	An Expression or matrix.

Value

An Expression representing the maximum eigenvalue of the input.

Examples

```
A <- Variable(2,2)
prob <- Problem(Minimize(lambda_max(A)), list(A >= 2))
result <- solve(prob)
result$value
result$getValue(A)

obj <- Maximize(A[2,1] - A[1,2])
prob <- Problem(obj, list(lambda_max(A) <= 100, A[1,1] == 2, A[2,2] == 2, A[2,1] == 2))
result <- solve(prob)
result$value
result$getValue(A)
```

`lambda_min` *Minimum Eigenvalue*

Description

The minimum eigenvalue of a matrix, $\lambda_{\min}(A)$.

Usage

```
lambda_min(A)
```

Arguments

A	An Expression or matrix.

Value

An Expression representing the minimum eigenvalue of the input.

Examples

```
A <- Variable(2,2)
val <- cbind(c(5,7), c(7,-3))
prob <- Problem(Maximize(lambda_min(A)), list(A == val))
result <- solve(prob)
result$value
result$getValue(A)
```

lambda_sum_largest *Sum of Largest Eigenvalues*

Description

The sum of the largest k eigenvalues of a matrix.

Usage

```
lambda_sum_largest(A, k)
```

Arguments

A	An Expression or matrix.
k	The number of eigenvalues to sum over.

Value

An Expression representing the sum of the largest k eigenvalues of the input.

Examples

```
C <- Variable(3,3)
val <- cbind(c(1,2,3), c(2,4,5), c(3,5,6))
prob <- Problem(Minimize(lambda_sum_largest(C,2)), list(C == val))
result <- solve(prob)
result$value
result$getValue(C)
```

lambda_sum_smallest *Sum of Smallest Eigenvalues*

Description

The sum of the smallest k eigenvalues of a matrix.

Usage

```
lambda_sum_smallest(A, k)
```

Arguments

A	An Expression or matrix.
k	The number of eigenvalues to sum over.

Value

An Expression representing the sum of the smallest k eigenvalues of the input.

Examples

```
C <- Variable(3,3)
val <- cbind(c(1,2,3), c(2,4,5), c(3,5,6))
prob <- Problem(Maximize(lambda_sum_smallest(C,2)), list(C == val))
result <- solve(prob)
result$value
result$getValue(C)
```

---

leaf-attr *Attributes of an Expression Leaf*

Description

Determine if an expression is positive or negative.

Usage

```
is_pos(object)

is_neg(object)
```

Arguments

object	A Leaf object.

Value

A logical value.

Leaf-class *The Leaf class.*

Description

This class represents a leaf node, i.e. a Variable, Constant, or Parameter.

Usage

```
## S4 method for signature 'Leaf'
get_data(object)

## S4 method for signature 'Leaf'
dim(x)

## S4 method for signature 'Leaf'
variables(object)

## S4 method for signature 'Leaf'
parameters(object)

## S4 method for signature 'Leaf'
constants(object)

## S4 method for signature 'Leaf'
atoms(object)

## S4 method for signature 'Leaf'
is_convex(object)

## S4 method for signature 'Leaf'
is_concave(object)

## S4 method for signature 'Leaf'
is_log_log_convex(object)

## S4 method for signature 'Leaf'
is_log_log_concave(object)

## S4 method for signature 'Leaf'
is_nonneg(object)

## S4 method for signature 'Leaf'
is_nonpos(object)

## S4 method for signature 'Leaf'
is_pos(object)

## S4 method for signature 'Leaf'
is_neg(object)

## S4 method for signature 'Leaf'
is_hermitian(object)

## S4 method for signature 'Leaf'
is_symmetric(object)
```

```
## S4 method for signature 'Leaf'
is_imag(object)

## S4 method for signature 'Leaf'
is_complex(object)

## S4 method for signature 'Leaf'
domain(object)

## S4 method for signature 'Leaf'
project(object, value)

## S4 method for signature 'Leaf'
project_and_assign(object, value)

## S4 method for signature 'Leaf'
value(object)

## S4 replacement method for signature 'Leaf'
value(object) <- value

## S4 method for signature 'Leaf'
validate_val(object, val)

## S4 method for signature 'Leaf'
is_psd(object)

## S4 method for signature 'Leaf'
is_nsd(object)

## S4 method for signature 'Leaf'
is_quadratic(object)

## S4 method for signature 'Leaf'
is_pwl(object)
```

Arguments

`object, x`	A Leaf object.
`value`	A numeric scalar, vector, or matrix.
`val`	The assigned value.

Methods (by generic)

- `get_data`: Leaves are not copied.
- `dim`: The dimensions of the leaf node.
- `variables`: List of Variable objects in the leaf node.

- parameters: List of Parameter objects in the leaf node.
- constants: List of Constant objects in the leaf node.
- atoms: List of Atom objects in the leaf node.
- is_convex: A logical value indicating whether the leaf node is convex.
- is_concave: A logical value indicating whether the leaf node is concave.
- is_log_log_convex: Is the expression log-log convex?
- is_log_log_concave: Is the expression log-log concave?
- is_nonneg: A logical value indicating whether the leaf node is nonnegative.
- is_nonpos: A logical value indicating whether the leaf node is nonpositive.
- is_pos: Is the expression positive?
- is_neg: Is the expression negative?
- is_hermitian: A logical value indicating whether the leaf node is hermitian.
- is_symmetric: A logical value indicating whether the leaf node is symmetric.
- is_imag: A logical value indicating whether the leaf node is imaginary.
- is_complex: A logical value indicating whether the leaf node is complex.
- domain: A list of constraints describing the closure of the region where the leaf node is finite. Default is the full domain.
- project: Project value onto the attribute set of the leaf.
- project_and_assign: Project and assign a value to the leaf.
- value: Get the value of the leaf.
- value<-: Set the value of the leaf.
- validate_val: Check that val satisfies symbolic attributes of leaf.
- is_psd: A logical value indicating whether the leaf node is a positive semidefinite matrix.
- is_nsd: A logical value indicating whether the leaf node is a negative semidefinite matrix.
- is_quadratic: Leaf nodes are always quadratic.
- is_pwl: Leaf nodes are always piecewise linear.

Slots

id (Internal) A unique integer identification number used internally.

dim The dimensions of the leaf.

value The numeric value of the leaf.

nonneg Is the leaf nonnegative?

nonpos Is the leaf nonpositive?

complex Is the leaf a complex number?

imag Is the leaf imaginary?

symmetric Is the leaf a symmetric matrix?

diag Is the leaf a diagonal matrix?

PSD Is the leaf positive semidefinite?

NSD Is the leaf negative semidefinite?

hermitian Is the leaf hermitian?

boolean Is the leaf boolean? Is the variable boolean? May be TRUE = entire leaf is boolean, FALSE = entire leaf is not boolean, or a vector of indices which should be constrained as boolean, where each index is a vector of length exactly equal to the length of dim.

integer Is the leaf integer? The semantics are the same as the boolean argument.

sparsity A matrix representing the fixed sparsity pattern of the leaf.

pos Is the leaf strictly positive?

neg Is the leaf strictly negative?

---

linearize *Affine Approximation to an Expression*

Description

Gives an elementwise lower (upper) bound for convex (concave) expressions that is tight at the current variable/parameter values. No guarantees for non-DCP expressions.

Usage

```
linearize(expr)
```

Arguments

expr	An Expression to linearize.

Details

If f and g are convex, the objective f-g can be (heuristically) minimized using the implementation below of the convex-concave method:

```
for(iters in 1:N) solve(Problem(Minimize(f -linearize(g))))
```

Value

An affine expression or NA if cannot be linearized.

`ListORConstr-class` *A Class Union of List and Constraint*

Description

A Class Union of List and Constraint

Usage

```
## S4 method for signature 'ListORConstr'
id(object)
```

Arguments

`object`	A list or Constraint object.

Methods (by generic)

- `id`: Returns the ID associated with the list or constraint.

`log,Expression-method` *Logarithms*

Description

The elementwise logarithm. `log` computes the logarithm, by default the natural logarithm, `log10` computes the common (i.e., base 10) logarithm, and `log2` computes the binary (i.e., base 2) logarithms. The general form `log(x,base)` computes logarithms with base `base`. `log1p` computes elementwise the function $\log(1+x)$.

Usage

```
## S4 method for signature 'Expression'
log(x, base = base::exp(1))

## S4 method for signature 'Expression'
log10(x)

## S4 method for signature 'Expression'
log2(x)

## S4 method for signature 'Expression'
log1p(x)
```

Arguments

x	An Expression.
base	(Optional) A positive number that is the base with respect to which the logarithm is computed. Defaults to e.

Value

An Expression representing the exponentiated input.

Examples

```
# Log in objective
x <- Variable(2)
obj <- Maximize(sum(log(x)))
constr <- list(x <= matrix(c(1, exp(1))))
prob <- Problem(obj, constr)
result <- solve(prob)
result$value
result$getValue(x)

# Log in constraint
obj <- Minimize(sum(x))
constr <- list(log2(x) >= 0, x <= matrix(c(1,1)))
prob <- Problem(obj, constr)
result <- solve(prob)
result$value
result$getValue(x)

# Index into log
obj <- Maximize(log10(x)[2])
constr <- list(x <= matrix(c(1, exp(1))))
prob <- Problem(obj, constr)
result <- solve(prob)
result$value

# Scalar log
obj <- Maximize(log1p(x[2]))
constr <- list(x <= matrix(c(1, exp(1))))
prob <- Problem(obj, constr)
result <- solve(prob)
result$value
```

Log-class *The Log class.*

Description

This class represents the elementwise natural logarithm $\log(x)$.

Usage

```
Log(x)

## S4 method for signature 'Log'
to_numeric(object, values)

## S4 method for signature 'Log'
sign_from_args(object)

## S4 method for signature 'Log'
is_atom_convex(object)

## S4 method for signature 'Log'
is_atom_concave(object)

## S4 method for signature 'Log'
is_atom_log_log_convex(object)

## S4 method for signature 'Log'
is_atom_log_log_concave(object)

## S4 method for signature 'Log'
is_incr(object, idx)

## S4 method for signature 'Log'
is_decr(object, idx)

## S4 method for signature 'Log'
.grad(object, values)

## S4 method for signature 'Log'
.domain(object)
```

Arguments

`x`	An Expression or numeric constant.
`object`	A Log object.
`values`	A list of numeric values for the arguments
`idx`	An index into the atom.

Methods (by generic)

- `to_numeric`: The elementwise natural logarithm of the input value.
- `sign_from_args`: The sign of the atom is unknown.
- `is_atom_convex`: The atom is not convex.
- `is_atom_concave`: The atom is concave.

- is_atom_log_log_convex: Is the atom log-log convex?
- is_atom_log_log_concave: Is the atom log-log concave?
- is_incr: The atom is weakly increasing.
- is_decr: The atom is not weakly decreasing.
- .grad: Gives the (sub/super)gradient of the atom w.r.t. each variable
- .domain: Returns constraints describng the domain of the node

Slots

x An Expression or numeric constant.

Log1p-class *The Log1p class.*

Description

This class represents the elementwise operation $\log(1+x)$.

Usage

```
Log1p(x)

## S4 method for signature 'Log1p'
to_numeric(object, values)

## S4 method for signature 'Log1p'
sign_from_args(object)

## S4 method for signature 'Log1p'
.grad(object, values)

## S4 method for signature 'Log1p'
.domain(object)
```

Arguments

x	An Expression or numeric constant.
object	A Log1p object.
values	A list of numeric values for the arguments

Methods (by generic)

- to_numeric: The elementwise natural logarithm of one plus the input value.
- sign_from_args: The sign of the atom.
- .grad: Gives the (sub/super)gradient of the atom w.r.t. each variable
- .domain: Returns constraints describng the domain of the node

Slots

x An Expression or numeric constant.

LogDet-class *The LogDet class.*

Description

The natural logarithm of the determinant of a matrix, $\log\det(A)$.

Usage

```
LogDet(A)

## S4 method for signature 'LogDet'
to_numeric(object, values)

## S4 method for signature 'LogDet'
validate_args(object)

## S4 method for signature 'LogDet'
dim_from_args(object)

## S4 method for signature 'LogDet'
sign_from_args(object)

## S4 method for signature 'LogDet'
is_atom_convex(object)

## S4 method for signature 'LogDet'
is_atom_concave(object)

## S4 method for signature 'LogDet'
is_incr(object, idx)

## S4 method for signature 'LogDet'
is_decr(object, idx)

## S4 method for signature 'LogDet'
.grad(object, values)

## S4 method for signature 'LogDet'
.domain(object)
```

Arguments

`A`	An Expression or numeric matrix.
`object`	A LogDet object.
`values`	A list of numeric values for the arguments
`idx`	An index into the atom.

Methods (by generic)

- `to_numeric`: The log-determinant of SDP matrix `A`. This is the sum of logs of the eigenvalues and is equivalent to the nuclear norm of the matrix logarithm of `A`.
- `validate_args`: Check that `A` is square.
- `dim_from_args`: The atom is a scalar.
- `sign_from_args`: The atom is non-negative.
- `is_atom_convex`: The atom is not convex.
- `is_atom_concave`: The atom is concave.
- `is_incr`: The atom is not monotonic in any argument.
- `is_decr`: The atom is not monotonic in any argument.
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable
- `.domain`: Returns constraints describing the domain of the node

Slots

`A` An Expression or numeric matrix.

`logistic` *Logistic Function*

Description

The elementwise logistic function, $\log(1+e^x)$. This is a special case of log(sum(exp)) that evaluates to a vector rather than to a scalar, which is useful for logistic regression.

Usage

```
logistic(x)
```

Arguments

`x`	An Expression, vector, or matrix.

Value

An Expression representing the logistic function evaluated at the input.

Examples

```
set.seed(92)
n <- 20
m <- 1000
sigma <- 45

beta_true <- stats::rnorm(n)
idxs <- sample(n, size = 0.8*n, replace = FALSE)
beta_true[idxs] <- 0
X <- matrix(stats::rnorm(m*n, 0, 5), nrow = m, ncol = n)
y <- sign(X %*% beta_true + stats::rnorm(m, 0, sigma))

beta <- Variable(n)
X_sign <- apply(X, 2, function(x) { ifelse(y <= 0, -1, 1) * x })
obj <- -sum(logistic(-X[y <= 0,] %*% beta)) - sum(logistic(X[y == 1,] %*% beta))
prob <- Problem(Maximize(obj))
result <- solve(prob)

log_odds <- result$getValue(X %*% beta)
beta_res <- result$getValue(beta)
y_probs <- 1/(1 + exp(-X %*% beta_res))
log(y_probs/(1 - y_probs))
```

`Logistic-class` *The Logistic class.*

Description

This class represents the elementwise operation $\log(1+e^x)$. This is a special case of log(sum(exp)) that evaluates to a vector rather than to a scalar, which is useful for logistic regression.

Usage

```
Logistic(x)

## S4 method for signature 'Logistic'
to_numeric(object, values)

## S4 method for signature 'Logistic'
sign_from_args(object)

## S4 method for signature 'Logistic'
is_atom_convex(object)

## S4 method for signature 'Logistic'
is_atom_concave(object)

## S4 method for signature 'Logistic'
```

```
is_incr(object, idx)

## S4 method for signature 'Logistic'
is_decr(object, idx)

## S4 method for signature 'Logistic'
.grad(object, values)
```

Arguments

x	An Expression or numeric constant.
object	A Logistic object.
values	A list of numeric values for the arguments
idx	An index into the atom.

Methods (by generic)

- `to_numeric`: Evaluates `e^x` elementwise, adds one, and takes the natural logarithm.
- `sign_from_args`: The atom is positive.
- `is_atom_convex`: The atom is convex.
- `is_atom_concave`: The atom is not concave.
- `is_incr`: The atom is weakly increasing.
- `is_decr`: The atom is not weakly decreasing.
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable

Slots

`x` An Expression or numeric constant.

LogSumExp-class *The LogSumExp class.*

Description

The natural logarithm of the sum of the elementwise exponential, $\log \sum_{i=1}^{n} e^{x_i}$.

Usage

```
LogSumExp(x, axis = NA_real_, keepdims = FALSE)

## S4 method for signature 'LogSumExp'
to_numeric(object, values)

## S4 method for signature 'LogSumExp'
.grad(object, values)
```

```
## S4 method for signature 'LogSumExp'
.column_grad(object, value)

## S4 method for signature 'LogSumExp'
sign_from_args(object)

## S4 method for signature 'LogSumExp'
is_atom_convex(object)

## S4 method for signature 'LogSumExp'
is_atom_concave(object)

## S4 method for signature 'LogSumExp'
is_incr(object, idx)

## S4 method for signature 'LogSumExp'
is_decr(object, idx)
```

Arguments

`x`	An Expression representing a vector or matrix.
`axis`	(Optional) The dimension across which to apply the function: `1` indicates rows, `2` indicates columns, and `NA` indicates rows and columns. The default is `NA`.
`keepdims`	(Optional) Should dimensions be maintained when applying the atom along an axis? If `FALSE`, result will be collapsed into an $nx1$ column vector. The default is `FALSE`.
`object`	A LogSumExp object.
`values`	A list of numeric values.
`value`	A numeric value.
`idx`	An index into the atom.

Methods (by generic)

- `to_numeric`: Evaluates e^x elementwise, sums, and takes the natural log.
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable
- `.column_grad`: Gives the (sub/super)gradient of the atom w.r.t. each column variable.
- `sign_from_args`: Returns sign (is positive, is negative) of the atom.
- `is_atom_convex`: The atom is convex.
- `is_atom_concave`: The atom is not concave.
- `is_incr`: The atom is weakly increasing in the index.
- `is_decr`: The atom is not weakly decreasing in the index.

Slots

x An Expression representing a vector or matrix.

axis (Optional) The dimension across which to apply the function: 1 indicates rows, 2 indicates columns, and NA indicates rows and columns. The default is NA.

keepdims (Optional) Should dimensions be maintained when applying the atom along an axis? If FALSE, result will be collapsed into an $nx1$ column vector. The default is FALSE.

---

log_det *Log-Determinant*

Description

The natural logarithm of the determinant of a matrix, $\log\det(A)$.

Usage

```
log_det(A)
```

Arguments

A An Expression or matrix.

Value

An Expression representing the log-determinant of the input.

Examples

```
x <- t(data.frame(c(0.55, 0.25, -0.2, -0.25, -0.0, 0.4),
                  c(0.0, 0.35, 0.2, -0.1, -0.3, -0.2)))
n <- nrow(x)
m <- ncol(x)

A <- Variable(n,n)
b <- Variable(n)
obj <- Maximize(log_det(A))
constr <- lapply(1:m, function(i) { p_norm(A %*% as.matrix(x[,i]) + b) <= 1 })
prob <- Problem(obj, constr)
result <- solve(prob)
result$value
```

log_log_curvature *Log-Log Curvature of Expression*

Description

The log-log curvature of an expression.

The log-log curvature of an expression.

Usage

```
log_log_curvature(object)

## S4 method for signature 'Expression'
log_log_curvature(object)
```

Arguments

object	An Expression object.

Value

A string indicating the log-log curvature of the expression, either "LOG_LOG_CONSTANT", "LOG_LOG_AFFINE", "LOG_LOG_CONVEX, "LOG_LOG_CONCAVE", or "UNKNOWN".

A string indicating the log-log curvature of the expression, either "LOG_LOG_CONSTANT", "LOG_LOG_AFFINE", "LOG_LOG_CONVEX", "LOG_LOG_CONCAVE", or "UNKNOWN".

log_log_curvature-atom *Log-Log Curvature of an Atom*

Description

Determine if an atom is log-log convex, concave, or affine.

Usage

```
is_atom_log_log_convex(object)

is_atom_log_log_concave(object)

is_atom_log_log_affine(object)
```

Arguments

object	A Atom object.

Value

A logical value.

`log_log_curvature-methods` *Log-Log Curvature Properties*

Description

Determine if an expression is log-log constant, log-log affine, log-log convex, or log-log concave.

Usage

```
is_log_log_constant(object)

is_log_log_affine(object)

is_log_log_convex(object)

is_log_log_concave(object)
```

Arguments

`object`	An Expression object.

Value

A logical value.

`log_sum_exp` *Log-Sum-Exponential*

Description

The natural logarithm of the sum of the elementwise exponential, $\log \sum_{i=1}^{n} e^{x_i}$.

Usage

```
log_sum_exp(x, axis = NA_real_, keepdims = FALSE)
```

Arguments

x	An Expression, vector, or matrix.
axis	(Optional) The dimension across which to apply the function: 1 indicates rows, 2 indicates columns, and NA indicates rows and columns. The default is NA.
keepdims	(Optional) Should dimensions be maintained when applying the atom along an axis? If FALSE, result will be collapsed into an $nx1$ column vector. The default is FALSE.

Value

An Expression representing the log-sum-exponential of the input.

Examples

```
A <- Variable(2,2)
val <- cbind(c(5,7), c(0,-3))
prob <- Problem(Minimize(log_sum_exp(A)), list(A == val))
result <- solve(prob)
result$getValue(A)
```

MatrixFrac-class *The MatrixFrac class.*

Description

The matrix fraction function $tr(X^T P^{-1} X)$.

Usage

```
MatrixFrac(X, P)

## S4 method for signature 'MatrixFrac'
allow_complex(object)

## S4 method for signature 'MatrixFrac'
to_numeric(object, values)

## S4 method for signature 'MatrixFrac'
validate_args(object)

## S4 method for signature 'MatrixFrac'
dim_from_args(object)

## S4 method for signature 'MatrixFrac'
sign_from_args(object)

## S4 method for signature 'MatrixFrac'
```

```
is_atom_convex(object)

## S4 method for signature 'MatrixFrac'
is_atom_concave(object)

## S4 method for signature 'MatrixFrac'
is_incr(object, idx)

## S4 method for signature 'MatrixFrac'
is_decr(object, idx)

## S4 method for signature 'MatrixFrac'
is_quadratic(object)

## S4 method for signature 'MatrixFrac'
is_qpwa(object)

## S4 method for signature 'MatrixFrac'
.domain(object)

## S4 method for signature 'MatrixFrac'
.grad(object, values)
```

Arguments

`X`	An Expression or numeric matrix.
`P`	An Expression or numeric matrix.
`object`	A MatrixFrac object.
`values`	A list of numeric values for the arguments
`idx`	An index into the atom.

Methods (by generic)

- `allow_complex`: Does the atom handle complex numbers?
- `to_numeric`: The trace of $X^T P^{-1} X$.
- `validate_args`: Check that the dimensions of `x` and `P` match.
- `dim_from_args`: The atom is a scalar.
- `sign_from_args`: The atom is positive.
- `is_atom_convex`: The atom is convex.
- `is_atom_concave`: The atom is not concave.
- `is_incr`: The atom is not monotonic in any argument.
- `is_decr`: The atom is not monotonic in any argument.
- `is_quadratic`: True if x is affine and P is constant.
- `is_qpwa`: True if x is piecewise linear and P is constant.
- `.domain`: Returns constraints describing the domain of the node
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable

Slots

X An Expression or numeric matrix.

P An Expression or numeric matrix.

`MatrixStuffing-class` *The MatrixStuffing class.*

Description

The MatrixStuffing class.

Usage

```
## S4 method for signature 'MatrixStuffing,Problem'
perform(object, problem)

## S4 method for signature 'MatrixStuffing,Solution,InverseData'
invert(object, solution, inverse_data)
```

Arguments

object	A MatrixStuffing object.
problem	A Problem object to stuff; the arguments of every constraint must be affine.
solution	A Solution to a problem that generated the inverse data.
inverse_data	The data encoding the original problem.

Methods (by generic)

- `perform`: Returns a stuffed problem. The returned problem is a minimization problem in which every constraint in the problem has affine arguments that are expressed in the form A
- `invert`: Returns the solution to the original problem given the inverse_data.

`matrix_frac` *Matrix Fraction*

Description

$tr(X^T P^{-1} X)$.

Usage

```
matrix_frac(X, P)
```

Arguments

X	An Expression or matrix. Must have the same number of rows as P.
P	An Expression or matrix. Must be an invertible square matrix.

Value

An Expression representing the matrix fraction evaluated at the input.

Examples

```
## Not run:
set.seed(192)
m <- 100
n <- 80
r <- 70

A <- matrix(stats::rnorm(m*n), nrow = m, ncol = n)
b <- matrix(stats::rnorm(m), nrow = m, ncol = 1)
G <- matrix(stats::rnorm(r*n), nrow = r, ncol = n)
h <- matrix(stats::rnorm(r), nrow = r, ncol = 1)

# ||Ax-b||^2 = x^T (A^T A) x - 2(A^T b)^T x + ||b||^2
P <- t(A) %*% A
q <- -2 * t(A) %*% b
r <- t(b) %*% b
Pinv <- base::solve(P)

x <- Variable(n)
obj <- matrix_frac(x, Pinv) + t(q) %*% x + r
constr <- list(G %*% x == h)
prob <- Problem(Minimize(obj), constr)
result <- solve(prob)
result$value

## End(Not run)
```

`matrix_prop-methods` *Matrix Properties*

Description

Determine if an expression is positive semidefinite, negative semidefinite, hermitian, and/or symmetric.

Usage

```
is_psd(object)

is_nsd(object)

is_hermitian(object)

is_symmetric(object)
```

Arguments

`object`	An Expression object.

Value

A logical value.

`matrix_trace` *Matrix Trace*

Description

The sum of the diagonal entries in a matrix.

Usage

```
matrix_trace(expr)
```

Arguments

`expr`	An Expression or matrix.

Value

An Expression representing the trace of the input.

Examples

```
C <- Variable(3,3)
val <- cbind(3:5, 6:8, 9:11)
prob <- Problem(Maximize(matrix_trace(C)), list(C == val))
result <- solve(prob)
result$value
```

MaxElemwise-class *The MaxElemwise class.*

Description

This class represents the elementwise maximum.

Usage

```
MaxElemwise(arg1, arg2, ...)

## S4 method for signature 'MaxElemwise'
to_numeric(object, values)

## S4 method for signature 'MaxElemwise'
sign_from_args(object)

## S4 method for signature 'MaxElemwise'
is_atom_convex(object)

## S4 method for signature 'MaxElemwise'
is_atom_concave(object)

## S4 method for signature 'MaxElemwise'
is_atom_log_log_convex(object)

## S4 method for signature 'MaxElemwise'
is_atom_log_log_concave(object)

## S4 method for signature 'MaxElemwise'
is_incr(object, idx)

## S4 method for signature 'MaxElemwise'
is_decr(object, idx)

## S4 method for signature 'MaxElemwise'
is_pwl(object)

## S4 method for signature 'MaxElemwise'
.grad(object, values)
```

Arguments

arg1	The first Expression in the maximum operation.
arg2	The second Expression in the maximum operation.
...	Additional Expression objects in the maximum operation.

`object`	A MaxElemwise object.
`values`	A list of numeric values for the arguments
`idx`	An index into the atom.

Methods (by generic)

- `to_numeric`: The elementwise maximum.
- `sign_from_args`: The sign of the atom.
- `is_atom_convex`: The atom is convex.
- `is_atom_concave`: The atom is not concave.
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `is_incr`: The atom is weakly increasing.
- `is_decr`: The atom is not weakly decreasing.
- `is_pwl`: Are all the arguments piecewise linear?
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable

Slots

`arg1` The first Expression in the maximum operation.

`arg2` The second Expression in the maximum operation.

`...` Additional Expression objects in the maximum operation.

MaxEntries-class *The MaxEntries class.*

Description

The maximum of an expression.

Usage

```
MaxEntries(x, axis = NA_real_, keepdims = FALSE)

## S4 method for signature 'MaxEntries'
to_numeric(object, values)

## S4 method for signature 'MaxEntries'
sign_from_args(object)

## S4 method for signature 'MaxEntries'
is_atom_convex(object)

## S4 method for signature 'MaxEntries'
```

```
is_atom_concave(object)

## S4 method for signature 'MaxEntries'
is_atom_log_log_convex(object)

## S4 method for signature 'MaxEntries'
is_atom_log_log_concave(object)

## S4 method for signature 'MaxEntries'
is_incr(object, idx)

## S4 method for signature 'MaxEntries'
is_decr(object, idx)

## S4 method for signature 'MaxEntries'
is_pwl(object)

## S4 method for signature 'MaxEntries'
.grad(object, values)

## S4 method for signature 'MaxEntries'
.column_grad(object, value)
```

Arguments

x	An Expression representing a vector or matrix.
axis	(Optional) The dimension across which to apply the function: 1 indicates rows, 2 indicates columns, and NA indicates rows and columns. The default is NA.
keepdims	(Optional) Should dimensions be maintained when applying the atom along an axis? If FALSE, result will be collapsed into an $nx1$ column vector. The default is FALSE.
object	A MaxEntries object.
values	A list of numeric values for the arguments
idx	An index into the atom.
value	A numeric value

Methods (by generic)

- `to_numeric`: The largest entry in `x`.
- `sign_from_args`: The sign of the atom.
- `is_atom_convex`: The atom is convex.
- `is_atom_concave`: The atom is not concave.
- `is_atom_log_log_convex`: Is the atom log-log convex.
- `is_atom_log_log_concave`: Is the atom log-log concave.
- `is_incr`: The atom is weakly increasing in every argument.

- is_decr: The atom is not weakly decreasing in any argument.
- is_pwl: Is x piecewise linear?
- .grad: Gives the (sub/super)gradient of the atom w.r.t. each variable
- .column_grad: Gives the (sub/super)gradient of the atom w.r.t. each column variable

Slots

x An Expression representing a vector or matrix.

axis (Optional) The dimension across which to apply the function: 1 indicates rows, 2 indicates columns, and NA indicates rows and columns. The default is NA.

keepdims (Optional) Should dimensions be maintained when applying the atom along an axis? If FALSE, result will be collapsed into an $nx1$ column vector. The default is FALSE.

Maximize-class *The Maximize class.*

Description

This class represents an optimization objective for maximization.

Usage

```
Maximize(expr)

## S4 method for signature 'Maximize'
canonicalize(object)

## S4 method for signature 'Maximize'
is_dcp(object)

## S4 method for signature 'Maximize'
is_dgp(object)
```

Arguments

expr	A scalar Expression to maximize.
object	A Maximize object.

Methods (by generic)

- canonicalize: Negates the target expression's objective.
- is_dcp: A logical value indicating whether the objective is concave.
- is_dgp: A logical value indicating whether the objective is log-log concave.

Slots

expr A scalar Expression to maximize.

Examples

```
x <- Variable(3)
alpha <- c(0.8,1.0,1.2)
obj <- sum(log(alpha + x))
constr <- list(x >= 0, sum(x) == 1)
prob <- Problem(Maximize(obj), constr)
result <- solve(prob)
result$value
result$getValue(x)
```

---

max_elemwise *Elementwise Maximum*

Description

The elementwise maximum.

Usage

```
max_elemwise(arg1, arg2, ...)
```

Arguments

arg1	An Expression, vector, or matrix.
arg2	An Expression, vector, or matrix.
...	Additional Expression objects, vectors, or matrices.

Value

An Expression representing the elementwise maximum of the inputs.

Examples

```
c <- matrix(c(1,-1))
prob <- Problem(Minimize(max_elemwise(t(c), 2, 2 + t(c))[2]))
result <- solve(prob)
result$value
```

`max_entries` *Maximum*

Description

The maximum of an expression.

Usage

```
max_entries(x, axis = NA_real_, keepdims = FALSE)

## S3 method for class 'Expression'
max(..., na.rm = FALSE)
```

Arguments

`x`	An Expression, vector, or matrix.
`axis`	(Optional) The dimension across which to apply the function: `1` indicates rows, `2` indicates columns, and `NA` indicates rows and columns. The default is `NA`.
`keepdims`	(Optional) Should dimensions be maintained when applying the atom along an axis? If `FALSE`, result will be collapsed into an $nx1$ column vector. The default is `FALSE`.
`...`	Numeric scalar, vector, matrix, or Expression objects.
`na.rm`	(Unimplemented) A logical value indicating whether missing values should be removed.

Value

An Expression representing the maximum of the input.

Examples

```
x <- Variable(2)
val <- matrix(c(-5,-10))
prob <- Problem(Minimize(max_entries(x)), list(x == val))
result <- solve(prob)
result$value

A <- Variable(2,2)
val <- rbind(c(-5,2), c(-3,1))
prob <- Problem(Minimize(max_entries(A, axis = 1)[2,1]), list(A == val))
result <- solve(prob)
result$value
x <- Variable(2)
val <- matrix(c(-5,-10))
prob <- Problem(Minimize(max_entries(x)), list(x == val))
result <- solve(prob)
```

```
result$value

A <- Variable(2,2)
val <- rbind(c(-5,2), c(-3,1))
prob <- Problem(Minimize(max_entries(A, axis = 1)[2,1]), list(A == val))
result <- solve(prob)
result$value
```

---

mean.Expression *Arithmetic Mean*

Description

The arithmetic mean of an expression.

Usage

```
## S3 method for class 'Expression'
mean(x, trim = 0, na.rm = FALSE, ...)
```

Arguments

x	An Expression object.
trim	(Unimplemented) The fraction (0 to 0.5) of observations to be trimmed from each end of x before the mean is computed.
na.rm	(Unimplemented) A logical value indicating whether missing values should be removed.
...	(Unimplemented) Optional arguments.

Value

An Expression representing the mean of the input.

Examples

```
A <- Variable(2,2)
val <- cbind(c(-5,2), c(-3,1))
prob <- Problem(Minimize(mean(A)), list(A == val))
result <- solve(prob)
result$value
```

MinElemwise-class *The MinElemwise class.*

Description

This class represents the elementwise minimum.

Usage

```
MinElemwise(arg1, arg2, ...)

## S4 method for signature 'MinElemwise'
to_numeric(object, values)

## S4 method for signature 'MinElemwise'
sign_from_args(object)

## S4 method for signature 'MinElemwise'
is_atom_convex(object)

## S4 method for signature 'MinElemwise'
is_atom_concave(object)

## S4 method for signature 'MinElemwise'
is_atom_log_log_convex(object)

## S4 method for signature 'MinElemwise'
is_atom_log_log_concave(object)

## S4 method for signature 'MinElemwise'
is_incr(object, idx)

## S4 method for signature 'MinElemwise'
is_decr(object, idx)

## S4 method for signature 'MinElemwise'
is_pwl(object)

## S4 method for signature 'MinElemwise'
.grad(object, values)
```

Arguments

arg1	The first Expression in the minimum operation.
arg2	The second Expression in the minimum operation.
...	Additional Expression objects in the minimum operation.

object	A MinElemwise object.
values	A list of numeric values for the arguments
idx	An index into the atom.

Methods (by generic)

- `to_numeric`: The elementwise minimum.
- `sign_from_args`: The sign of the atom.
- `is_atom_convex`: The atom is not convex.
- `is_atom_concave`: The atom is not concave.
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `is_incr`: The atom is weakly increasing.
- `is_decr`: The atom is not weakly decreasing.
- `is_pwl`: Are all the arguments piecewise linear?
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable

Slots

`arg1` The first Expression in the minimum operation.

`arg2` The second Expression in the minimum operation.

`...` Additional Expression objects in the minimum operation.

MinEntries-class *The MinEntries class.*

Description

The minimum of an expression.

Usage

```
MinEntries(x, axis = NA_real_, keepdims = FALSE)

## S4 method for signature 'MinEntries'
to_numeric(object, values)

## S4 method for signature 'MinEntries'
sign_from_args(object)

## S4 method for signature 'MinEntries'
is_atom_convex(object)

## S4 method for signature 'MinEntries'
```

```
is_atom_concave(object)

## S4 method for signature 'MinEntries'
is_atom_log_log_convex(object)

## S4 method for signature 'MinEntries'
is_atom_log_log_concave(object)

## S4 method for signature 'MinEntries'
is_incr(object, idx)

## S4 method for signature 'MinEntries'
is_decr(object, idx)

## S4 method for signature 'MinEntries'
is_pwl(object)

## S4 method for signature 'MinEntries'
.grad(object, values)

## S4 method for signature 'MinEntries'
.column_grad(object, value)
```

Arguments

x	An Expression representing a vector or matrix.
axis	(Optional) The dimension across which to apply the function: 1 indicates rows, 2 indicates columns, and NA indicates rows and columns. The default is NA.
keepdims	(Optional) Should dimensions be maintained when applying the atom along an axis? If FALSE, result will be collapsed into an $nx1$ column vector. The default is FALSE.
object	A MinEntries object.
values	A list of numeric values for the arguments
idx	An index into the atom.
value	A numeric value

Methods (by generic)

- to_numeric: The largest entry in x.
- sign_from_args: The sign of the atom.
- is_atom_convex: The atom is not convex.
- is_atom_concave: The atom is concave.
- is_atom_log_log_convex: Is the atom log-log convex?
- is_atom_log_log_concave: Is the atom log-log concave?
- is_incr: The atom is weakly increasing in every argument.

- `is_decr`: The atom is not weakly decreasing in any argument.
- `is_pwl`: Is `x` piecewise linear?
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable
- `.column_grad`: Gives the (sub/super)gradient of the atom w.r.t. each column variable

Slots

`x` An Expression representing a vector or matrix.

`axis` (Optional) The dimension across which to apply the function: `1` indicates rows, `2` indicates columns, and `NA` indicates rows and columns. The default is `NA`.

`keepdims` (Optional) Should dimensions be maintained when applying the atom along an axis? If `FALSE`, result will be collapsed into an $nx1$ column vector. The default is `FALSE`.

Minimize-class *The Minimize class.*

Description

This class represents an optimization objective for minimization.

Usage

```
Minimize(expr)

## S4 method for signature 'Minimize'
canonicalize(object)

## S4 method for signature 'Minimize'
is_dcp(object)

## S4 method for signature 'Minimize'
is_dgp(object)
```

Arguments

`expr`	A scalar Expression to minimize.
`object`	A Minimize object.

Methods (by generic)

- `canonicalize`: Pass on the target expression's objective and constraints.
- `is_dcp`: A logical value indicating whether the objective is convex.
- `is_dgp`: A logical value indicating whether the objective is log-log convex.

Slots

`expr` A scalar Expression to minimize.

min_elemwise *Elementwise Minimum*

Description

The elementwise minimum.

Usage

```
min_elemwise(arg1, arg2, ...)
```

Arguments

arg1	An Expression, vector, or matrix.
arg2	An Expression, vector, or matrix.
...	Additional Expression objects, vectors, or matrices.

Value

An Expression representing the elementwise minimum of the inputs.

Examples

```
a <- cbind(c(-5,2), c(-3,-1))
b <- cbind(c(5,4), c(-1,2))
prob <- Problem(Minimize(min_elemwise(a, 0, b)[1,2]))
result <- solve(prob)
result$value
```

min_entries *Minimum*

Description

The minimum of an expression.

Usage

```
min_entries(x, axis = NA_real_, keepdims = FALSE)

## S3 method for class 'Expression'
min(..., na.rm = FALSE)
```

Arguments

x	An Expression, vector, or matrix.
axis	(Optional) The dimension across which to apply the function: 1 indicates rows, 2 indicates columns, and NA indicates rows and columns. The default is NA.
keepdims	(Optional) Should dimensions be maintained when applying the atom along an axis? If FALSE, result will be collapsed into an $nx1$ column vector. The default is FALSE.
...	Numeric scalar, vector, matrix, or Expression objects.
na.rm	(Unimplemented) A logical value indicating whether missing values should be removed.

Value

An Expression representing the minimum of the input.

Examples

```
A <- Variable(2,2)
val <- cbind(c(-5,2), c(-3,1))
prob <- Problem(Maximize(min_entries(A)), list(A == val))
result <- solve(prob)
result$value
A <- Variable(2,2)
val <- cbind(c(-5,2), c(-3,1))
prob <- Problem(Maximize(min_entries(A)), list(A == val))
result <- solve(prob)
result$value
```

---

mip_capable *Solver Capabilities*

Description

Determine if a solver is capable of solving a mixed-integer program (MIP).

Usage

```
mip_capable(solver)
```

Arguments

solver	A ReductionSolver object.

Value

A logical value.

Examples

```
mip_capable(ECOS())
```

`MixedNorm` *The MixedNorm atom.*

Description

The $l_{p,q}$ norm of X, $(\sum_k (\sum_l ||X_{k,l}||^p)^{q/p})^{1/q}$.

Usage

```
MixedNorm(X, p = 2, q = 1)
```

Arguments

X	The matrix to take the $l_{p,q}$ norm of
p	The type of inner norm
q	The type of outer norm

Value

Returns the mixed norm of X with specified parameters p and q

---

`mixed_norm` *Mixed Norm*

Description

$l_{p,q}(x) = \left(\sum_{i=1}^n (\sum_{j=1}^m |x_{i,j}|)^{q/p}\right)^{1/q}$.

Usage

```
mixed_norm(X, p = 2, q = 1)
```

Arguments

X	An Expression, vector, or matrix.
p	The type of inner norm.
q	The type of outer norm.

Value

An Expression representing the $l_{p,q}$ norm of the input.

Examples

```
A <- Variable(2,2)
val <- cbind(c(3,3), c(4,4))
prob <- Problem(Minimize(mixed_norm(A,2,1)), list(A == val))
result <- solve(prob)
result$value
result$getValue(A)

val <- cbind(c(1,4), c(5,6))
prob <- Problem(Minimize(mixed_norm(A,1,Inf)), list(A == val))
result <- solve(prob)
result$value
result$getValue(A)
```

MOSEK-class *An interface for the MOSEK solver.*

Description

An interface for the MOSEK solver.

Usage

```
MOSEK()

## S4 method for signature 'MOSEK'
mip_capable(solver)

## S4 method for signature 'MOSEK'
import_solver(solver)

## S4 method for signature 'MOSEK'
name(x)

## S4 method for signature 'MOSEK,Problem'
accepts(object, problem)

## S4 method for signature 'MOSEK'
block_format(object, problem, constraints, exp_cone_order = NA)

## S4 method for signature 'MOSEK,Problem'
perform(object, problem)

## S4 method for signature 'MOSEK'
solve_via_data(
  object,
  data,
```

```
    warm_start,
    verbose,
    feastol,
    reltol,
    abstol,
    num_iter,
    solver_opts,
    solver_cache
  )

## S4 method for signature 'MOSEK,ANY,ANY'
invert(object, solution, inverse_data)
```

Arguments

solver, object, x	A MOSEK object.
problem	A Problem object.
constraints	A list of Constraint objects for which coefficient andd offset data ("G", "h" respectively) is needed
exp_cone_order	A parameter that is only used when a Constraint object describes membership in the exponential cone.
data	Data generated via an apply call.
warm_start	A boolean of whether to warm start the solver.
verbose	A boolean of whether to enable solver verbosity.
feastol	The feasible tolerance.
reltol	The relative tolerance.
abstol	The absolute tolerance.
num_iter	The maximum number of iterations.
solver_opts	A list of Solver specific options
solver_cache	Cache for the solver.
solution	The raw solution returned by the solver.
inverse_data	A list containing data necessary for the inversion.

Methods (by generic)

- `mip_capable`: Can the solver handle mixed-integer programs?
- `import_solver`: Imports the solver.
- `name`: Returns the name of the solver.
- `accepts`: Can MOSEK solve the problem?
- `block_format`: Returns a large matrix "coeff" and a vector of constants "offset" such that every Constraint in "constraints" holds at z in R^n iff "coeff" * z <=_K offset", where K is a product of cones supported by MOSEK and CVXR (zero cone, nonnegative orthant, second order cone, exponential cone). The nature of K is inferred later by accessing the data in "lengths" and "ids".

- `perform`: Returns a new problem and data for inverting the new solution.
- `solve_via_data`: Solve a problem represented by data returned from apply.
- `invert`: Returns the solution to the original problem given the inverse_data.

`MOSEK.parse_dual_vars` *Parses MOSEK dual variables into corresponding CVXR constraints and dual values*

Description

Parses MOSEK dual variables into corresponding CVXR constraints and dual values

Usage

```
MOSEK.parse_dual_vars(dual_var, constr_id_to_constr_dim)
```

Arguments

`dual_var`	List of the dual variables returned by the MOSEK solution.
`constr_id_to_constr_dim`	A list that contains the mapping of entry "id" that is the index of the CVXR Constraint object to which the next "dim" entries of the dual variable belong.

Value

A list with the mapping of the CVXR Constraint object indices with the corresponding dual values.

`MOSEK.recover_dual_variables` *Recovers MOSEK solutions dual variables*

Description

Recovers MOSEK solutions dual variables

Usage

```
MOSEK.recover_dual_variables(sol, inverse_data)
```

Arguments

`sol`	List of the solutions returned by the MOSEK solver.
`inverse_data`	A list of the data returned by the perform function.

Value

A list containing the mapping of CVXR's Constraint object's id to its corresponding dual variables in the current solution.

multiply *Elementwise Multiplication*

Description

The elementwise product of two expressions. The first expression must be constant.

Usage

```
multiply(lh_exp, rh_exp)
```

Arguments

lh_exp	An Expression, vector, or matrix representing the left-hand value.
rh_exp	An Expression, vector, or matrix representing the right-hand value.

Value

An Expression representing the elementwise product of the inputs.

Examples

```
A <- Variable(2,2)
c <- cbind(c(1,-1), c(2,-2))
expr <- multiply(c, A)
obj <- Minimize(norm_inf(expr))
prob <- Problem(obj, list(A == 5))
result <- solve(prob)
result$value
result$getValue(expr)
```

Multiply-class *The Multiply class.*

Description

This class represents the elementwise product of two expressions.

Usage

```
Multiply(lh_exp, rh_exp)

## S4 method for signature 'Multiply'
to_numeric(object, values)

## S4 method for signature 'Multiply'
```

```
dim_from_args(object)

## S4 method for signature 'Multiply'
is_atom_log_log_convex(object)

## S4 method for signature 'Multiply'
is_atom_log_log_concave(object)

## S4 method for signature 'Multiply'
is_psd(object)

## S4 method for signature 'Multiply'
is_nsd(object)

## S4 method for signature 'Multiply'
graph_implementation(object, arg_objs, dim, data = NA_real_)
```

Arguments

lh_exp	An Expression or R numeric data.
rh_exp	An Expression or R numeric data.
object	A Multiply object.
values	A list of arguments to the atom.
arg_objs	A list of linear expressions for each argument.
dim	A vector representing the dimensions of the resulting expression.
data	A list of additional data required by the atom.

Methods (by generic)

- `to_numeric`: Multiplies the values elementwise.
- `dim_from_args`: The sum of the argument dimensions - 1.
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `is_psd`: Is the expression a positive semidefinite matrix?
- `is_nsd`: Is the expression a negative semidefinite matrix?
- `graph_implementation`: The graph implementation of the expression.

name — *Variable, Parameter, or Expression Name*

Description

The string representation of a variable, parameter, or expression.

Usage

```
name(x)
```

Arguments

x	A Variable, Parameter, or Expression object.

Value

For Variable or Parameter objects, the value in the name slot. For Expression objects, a string indicating the nested atoms and their respective arguments.

Examples

```
x <- Variable()
y <- Variable(3, name = "yVar")

name(x)
name(y)
```

Neg — *An alias for -MinElemwise(x, 0)*

Description

An alias for -MinElemwise(x, 0)

Usage

```
Neg(x)
```

Arguments

x	An R numeric value or Expression.

Value

An alias for -MinElemwise(x, 0)

neg *Elementwise Negative*

Description

The elementwise absolute negative portion of an expression, $-\min(x_i, 0)$. This is equivalent to `-min_elemwise(x,0)`.

Usage

```
neg(x)
```

Arguments

x	An Expression, vector, or matrix.

Value

An Expression representing the negative portion of the input.

Examples

```
x <- Variable(2)
val <- matrix(c(-3,3))
prob <- Problem(Minimize(neg(x)[1]), list(x == val))
result <- solve(prob)
result$value
```

NonlinearConstraint-class *The NonlinearConstraint class.*

Description

This class represents a nonlinear inequality constraint, $f(x) \leq 0$ where f is twice-differentiable.

Usage

```
NonlinearConstraint(f, vars_, id = NA_integer_)
```

Arguments

f	A nonlinear function.
vars_	A list of variables involved in the function.
id	(Optional) An integer representing the unique ID of the contraint.

Slots

f A nonlinear function.

vars_ A list of variables involved in the function.

.x_dim (Internal) The dimensions of a column vector with number of elements equal to the total elements in all the variables.

NonPosConstraint-class
The NonPosConstraint class

Description

The NonPosConstraint class

Usage

```
## S4 method for signature 'NonPosConstraint'
name(x)

## S4 method for signature 'NonPosConstraint'
is_dcp(object)

## S4 method for signature 'NonPosConstraint'
is_dgp(object)

## S4 method for signature 'NonPosConstraint'
canonicalize(object)

## S4 method for signature 'NonPosConstraint'
residual(object)
```

Arguments

x, object	A NonPosConstraint object.

Methods (by generic)

- name: The string representation of the constraint.
- is_dcp: Is the constraint DCP?
- is_dgp: Is the constraint DGP?
- canonicalize: The graph implementation of the object.
- residual: The residual of the constraint.

`Norm` *The Norm atom.*

Description

Wrapper around the different norm atoms.

Usage

```
Norm(x, p = 2, axis = NA_real_, keepdims = FALSE)
```

Arguments

`x`	The matrix to take the norm of
`p`	The type of norm. Valid options include any positive integer, 'fro' (for frobenius), 'nuc' (sum of singular values), np.inf or 'inf' (infinity norm).
`axis`	(Optional) The dimension across which to apply the function: `1` indicates rows, `2` indicates columns, and `NA` indicates rows and columns. The default is `NA`.
`keepdims`	(Optional) Should dimensions be maintained when applying the atom along an axis? If `FALSE`, result will be collapsed into an $nx1$ column vector. The default is `FALSE`.

Value

Returns the specified norm of x.

`norm,Expression,character-method`
Matrix Norm

Description

The matrix norm, which can be the 1-norm ("1"), infinity-norm ("I"), Frobenius norm ("F"), maximum modulus of all the entries ("M"), or the spectral norm ("2"), as determined by the value of type.

Usage

```
## S4 method for signature 'Expression,character'
norm(x, type)
```

Arguments

x An Expression.

type A character indicating the type of norm desired.

- "O", "o" or "1" specifies the 1-norm (maximum absolute column sum).
- "I" or "i" specifies the infinity-norm (maximum absolute row sum).
- "F" or "f" specifies the Frobenius norm (Euclidean norm of the vectorized x).
- "M" or "m" specifies the maximum modulus of all the elements in x.
- "2" specifies the spectral norm, which is the largest singular value of x.

Value

An Expression representing the norm of the input.

See Also

The p_norm function calculates the vector p-norm.

Examples

```
C <- Variable(3,2)
val <- Constant(rbind(c(1,2), c(3,4), c(5,6)))
prob <- Problem(Minimize(norm(C, "F")), list(C == val))
result <- solve(prob, solver = "SCS")
result$value
```

---

norm1 *1-Norm*

Description

$\|x\|_1 = \sum_{i=1}^{n} |x_i|$.

Usage

```
norm1(x, axis = NA_real_, keepdims = FALSE)
```

Arguments

x An Expression, vector, or matrix.

axis (Optional) The dimension across which to apply the function: 1 indicates rows, 2 indicates columns, and NA indicates rows and columns. The default is NA.

keepdims (Optional) Should dimensions be maintained when applying the atom along an axis? If FALSE, result will be collapsed into an $nx1$ column vector. The default is FALSE.

Value

An Expression representing the 1-norm of the input.

Examples

```
a <- Variable()
prob <- Problem(Minimize(norm1(a)), list(a <= -2))
result <- solve(prob)
result$value
result$getValue(a)

prob <- Problem(Maximize(-norm1(a)), list(a <= -2))
result <- solve(prob)
result$value
result$getValue(a)

x <- Variable(2)
z <- Variable(2)
prob <- Problem(Minimize(norm1(x - z) + 5), list(x >= c(2,3), z <= c(-1,-4)))
result <- solve(prob)
result$value
result$getValue(x[1] - z[1])
```

Norm1-class *The Norm1 class.*

Description

This class represents the 1-norm of an expression.

Usage

```
Norm1(x, axis = NA_real_, keepdims = FALSE)

## S4 method for signature 'Norm1'
name(x)

## S4 method for signature 'Norm1'
to_numeric(object, values)

## S4 method for signature 'Norm1'
allow_complex(object)

## S4 method for signature 'Norm1'
sign_from_args(object)

## S4 method for signature 'Norm1'
is_atom_convex(object)
```

```
## S4 method for signature 'Norm1'
is_atom_concave(object)

## S4 method for signature 'Norm1'
is_incr(object, idx)

## S4 method for signature 'Norm1'
is_decr(object, idx)

## S4 method for signature 'Norm1'
is_pwl(object)

## S4 method for signature 'Norm1'
get_data(object)

## S4 method for signature 'Norm1'
.domain(object)

## S4 method for signature 'Norm1'
.grad(object, values)

## S4 method for signature 'Norm1'
.column_grad(object, value)
```

Arguments

x	An Expression object.
axis	(Optional) The dimension across which to apply the function: 1 indicates rows, 2 indicates columns, and NA indicates rows and columns. The default is NA.
keepdims	(Optional) Should dimensions be maintained when applying the atom along an axis? If FALSE, result will be collapsed into an $nx1$ column vector. The default is FALSE.
object	A Norm1 object.
values	A list of numeric values for the arguments
idx	An index into the atom.
value	A numeric value

Methods (by generic)

- name: The name and arguments of the atom.
- to_numeric: Returns the 1-norm of x along the given axis.
- allow_complex: Does the atom handle complex numbers?
- sign_from_args: The atom is always positive.
- is_atom_convex: The atom is convex.
- is_atom_concave: The atom is not concave.

- `is_incr`: Is the composition weakly increasing in argument `idx`?
- `is_decr`: Is the composition weakly decreasing in argument `idx`?
- `is_pwl`: Is the atom piecewise linear?
- `get_data`: Returns the axis.
- `.domain`: Returns constraints describing the domain of the node
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable
- `.column_grad`: Gives the (sub/super)gradient of the atom w.r.t. each column variable

Slots

`x` An Expression object.

`Norm2` *The Norm2 atom.*

Description

The 2-norm of an expression.

Usage

```
Norm2(x, axis = NA_real_, keepdims = FALSE)
```

Arguments

`x`	An Expression object.
`axis`	(Optional) The dimension across which to apply the function: `1` indicates rows, `2` indicates columns, and `NA` indicates rows and columns. The default is `NA`.
`keepdims`	(Optional) Should dimensions be maintained when applying the atom along an axis? If `FALSE`, result will be collapsed into an $nx1$ column vector. The default is `FALSE`.

Value

Returns the 2-norm of x.

norm2 *Euclidean Norm*

Description

$\|x\|_2 = \left(\sum_{i=1}^n x_i^2\right)^{1/2}$.

Usage

```
norm2(x, axis = NA_real_, keepdims = FALSE)
```

Arguments

x	An Expression, vector, or matrix.
axis	(Optional) The dimension across which to apply the function: 1 indicates rows, 2 indicates columns, and NA indicates rows and columns. The default is NA.
keepdims	(Optional) Should dimensions be maintained when applying the atom along an axis? If FALSE, result will be collapsed into an $nx1$ column vector. The default is FALSE.

Value

An Expression representing the Euclidean norm of the input.

Examples

```
a <- Variable()
prob <- Problem(Minimize(norm2(a)), list(a <= -2))
result <- solve(prob)
result$value
result$getValue(a)

prob <- Problem(Maximize(-norm2(a)), list(a <= -2))
result <- solve(prob)
result$value
result$getValue(a)

x <- Variable(2)
z <- Variable(2)
prob <- Problem(Minimize(norm2(x - z) + 5), list(x >= c(2,3), z <= c(-1,-4)))
result <- solve(prob)
result$value
result$getValue(x)
result$getValue(z)

prob <- Problem(Minimize(norm2(t(x - z)) + 5), list(x >= c(2,3), z <= c(-1,-4)))
result <- solve(prob)
result$value
result$getValue(x)
```

```
result$getValue(z)
```

NormInf-class *The NormInf class.*

Description

This class represents the infinity-norm.

Usage

```
## S4 method for signature 'NormInf'
name(x)

## S4 method for signature 'NormInf'
to_numeric(object, values)

## S4 method for signature 'NormInf'
allow_complex(object)

## S4 method for signature 'NormInf'
sign_from_args(object)

## S4 method for signature 'NormInf'
is_atom_convex(object)

## S4 method for signature 'NormInf'
is_atom_concave(object)

## S4 method for signature 'NormInf'
is_atom_log_log_convex(object)

## S4 method for signature 'NormInf'
is_atom_log_log_concave(object)

## S4 method for signature 'NormInf'
is_incr(object, idx)

## S4 method for signature 'NormInf'
is_decr(object, idx)

## S4 method for signature 'NormInf'
is_pwl(object)

## S4 method for signature 'NormInf'
get_data(object)
```

```
## S4 method for signature 'NormInf'
.domain(object)

## S4 method for signature 'NormInf'
.grad(object, values)

## S4 method for signature 'NormInf'
.column_grad(object, value)
```

Arguments

`x, object`	A NormInf object.
`values`	A list of numeric values for the arguments
`idx`	An index into the atom.
`value`	A numeric value

Methods (by generic)

- `name`: The name and arguments of the atom.
- `to_numeric`: Returns the infinity norm of `x`.
- `allow_complex`: Does the atom handle complex numbers?
- `sign_from_args`: The atom is always positive.
- `is_atom_convex`: The atom is convex.
- `is_atom_concave`: The atom is not concave.
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `is_incr`: Is the composition weakly increasing in argument `idx`?
- `is_decr`: Is the composition weakly decreasing in argument `idx`?
- `is_pwl`: Is the atom piecewise linear?
- `get_data`: Returns the axis.
- `.domain`: Returns constraints describing the domain of the node
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable
- `.column_grad`: Gives the (sub/super)gradient of the atom w.r.t. each column variable

NormNuc-class *The NormNuc class.*

Description

The nuclear norm, i.e. sum of the singular values of a matrix.

Usage

```
NormNuc(A)

## S4 method for signature 'NormNuc'
to_numeric(object, values)

## S4 method for signature 'NormNuc'
allow_complex(object)

## S4 method for signature 'NormNuc'
dim_from_args(object)

## S4 method for signature 'NormNuc'
sign_from_args(object)

## S4 method for signature 'NormNuc'
is_atom_convex(object)

## S4 method for signature 'NormNuc'
is_atom_concave(object)

## S4 method for signature 'NormNuc'
is_incr(object, idx)

## S4 method for signature 'NormNuc'
is_decr(object, idx)

## S4 method for signature 'NormNuc'
.grad(object, values)
```

Arguments

A	An Expression or numeric matrix.
object	A NormNuc object.
values	A list of numeric values for the arguments
idx	An index into the atom.

Methods (by generic)

- `to_numeric`: The nuclear norm (i.e., the sum of the singular values) of `A`.
- `allow_complex`: Does the atom handle complex numbers?
- `dim_from_args`: The atom is a scalar.
- `sign_from_args`: The atom is positive.
- `is_atom_convex`: The atom is convex.
- `is_atom_concave`: The atom is not concave.
- `is_incr`: The atom is not monotonic in any argument.
- `is_decr`: The atom is not monotonic in any argument.
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable

Slots

`A` An Expression or numeric matrix.

`norm_inf` *Infinity-Norm*

Description

$\|x\|_\infty = \max_{i=1,\ldots,n} |x_i|$.

Usage

```
norm_inf(x, axis = NA_real_, keepdims = FALSE)
```

Arguments

`x`	An Expression, vector, or matrix.
`axis`	(Optional) The dimension across which to apply the function: `1` indicates rows, `2` indicates columns, and `NA` indicates rows and columns. The default is `NA`.
`keepdims`	(Optional) Should dimensions be maintained when applying the atom along an axis? If `FALSE`, result will be collapsed into an $nx1$ column vector. The default is `FALSE`.

Value

An Expression representing the infinity-norm of the input.

Examples

```
a <- Variable()
b <- Variable()
c <- Variable()

prob <- Problem(Minimize(norm_inf(a)), list(a >= 2))
result <- solve(prob)
result$value
result$getValue(a)

prob <- Problem(Minimize(3*norm_inf(a + 2*b) + c), list(a >= 2, b <= -1, c == 3))
result <- solve(prob)
result$value
result$getValue(a + 2*b)
result$getValue(c)

prob <- Problem(Maximize(-norm_inf(a)), list(a <= -2))
result <- solve(prob)
result$value
result$getValue(a)

x <- Variable(2)
z <- Variable(2)
prob <- Problem(Minimize(norm_inf(x - z) + 5), list(x >= c(2,3), z <= c(-1,-4)))
result <- solve(prob)
result$value
result$getValue(x[1] - z[1])
```

---

norm_nuc *Nuclear Norm*

Description

The nuclear norm, i.e. sum of the singular values of a matrix.

Usage

```
norm_nuc(A)
```

Arguments

A	An Expression or matrix.

Value

An Expression representing the nuclear norm of the input.

Examples

```
C <- Variable(3,3)
val <- cbind(3:5, 6:8, 9:11)
prob <- Problem(Minimize(norm_nuc(C)), list(C == val))
result <- solve(prob)
result$value
```

Objective-arith *Arithmetic Operations on Objectives*

Description

Add, subtract, multiply, or divide optimization objectives.

Usage

```
## S4 method for signature 'Objective,numeric'
e1 + e2

## S4 method for signature 'numeric,Objective'
e1 + e2

## S4 method for signature 'Minimize,missing'
e1 - e2

## S4 method for signature 'Minimize,Minimize'
e1 + e2

## S4 method for signature 'Minimize,Maximize'
e1 + e2

## S4 method for signature 'Objective,Minimize'
e1 - e2

## S4 method for signature 'Objective,Maximize'
e1 - e2

## S4 method for signature 'Minimize,Objective'
e1 - e2

## S4 method for signature 'Maximize,Objective'
e1 - e2

## S4 method for signature 'Objective,numeric'
e1 - e2

## S4 method for signature 'numeric,Objective'
```

```
e1 - e2

## S4 method for signature 'Minimize,numeric'
e1 * e2

## S4 method for signature 'Maximize,numeric'
e1 * e2

## S4 method for signature 'numeric,Minimize'
e1 * e2

## S4 method for signature 'numeric,Maximize'
e1 * e2

## S4 method for signature 'Objective,numeric'
e1 / e2

## S4 method for signature 'Maximize,missing'
e1 - e2

## S4 method for signature 'Maximize,Maximize'
e1 + e2

## S4 method for signature 'Maximize,Minimize'
e1 + e2
```

Arguments

e1	The left-hand Minimize, Maximize, or numeric value.
e2	The right-hand Minimize, Maximize, or numeric value.

Value

A Minimize or Maximize object.

`Objective-class` *The Objective class.*

Description

This class represents an optimization objective.

Usage

```
Objective(expr)

## S4 method for signature 'Objective'
```

```
value(object)

## S4 method for signature 'Objective'
is_quadratic(object)

## S4 method for signature 'Objective'
is_qpwa(object)
```

Arguments

`expr`	A scalar Expression to optimize.
`object`	An Objective object.

Methods (by generic)

- `value`: The value of the objective expression.
- `is_quadratic`: Is the objective a quadratic function?
- `is_qpwa`: Is the objective a quadratic of piecewise affine function?

Slots

`expr` A scalar Expression to optimize.

`OneMinusPos-class` *The OneMinusPos class.*

Description

This class represents the difference $1 - x$ with domain $\{x : 0 < x < 1\}$

Usage

```
OneMinusPos(x)

## S4 method for signature 'OneMinusPos'
name(x)

## S4 method for signature 'OneMinusPos'
to_numeric(object, values)

## S4 method for signature 'OneMinusPos'
dim_from_args(object)

## S4 method for signature 'OneMinusPos'
sign_from_args(object)

## S4 method for signature 'OneMinusPos'
```

```
is_atom_convex(object)

## S4 method for signature 'OneMinusPos'
is_atom_concave(object)

## S4 method for signature 'OneMinusPos'
is_atom_log_log_convex(object)

## S4 method for signature 'OneMinusPos'
is_atom_log_log_concave(object)

## S4 method for signature 'OneMinusPos'
is_incr(object, idx)

## S4 method for signature 'OneMinusPos'
is_decr(object, idx)

## S4 method for signature 'OneMinusPos'
.grad(object, values)
```

Arguments

x	An Expression or numeric matrix.
object	A OneMinusPos object.
values	A list of numeric values for the arguments
idx	An index into the atom.

Methods (by generic)

- `name`: The name and arguments of the atom.
- `to_numeric`: Returns one minus the value.
- `dim_from_args`: The dimensions of the atom.
- `sign_from_args`: Returns the sign (is positive, is negative) of the atom.
- `is_atom_convex`: Is the atom convex?
- `is_atom_concave`: Is the atom concave?
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `is_incr`: Is the atom weakly increasing in the argument `idx`?
- `is_decr`: Is the atom weakly decreasing in the argument `idx`?
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable

Slots

`x` An Expression or numeric matrix.

one_minus_pos — *Difference on Restricted Domain*

Description

The difference $1 - x$ with domain $\{x : 0 < x < 1\}$.

Usage

```
one_minus_pos(x)
```

Arguments

x	An Expression, vector, or matrix.

Details

This atom is log-log concave.

Value

An Expression representing one minus the input restricted to $(0, 1)$.

Examples

```
x <- Variable(pos = TRUE)
y <- Variable(pos = TRUE)
prob <- Problem(Maximize(one_minus_pos(x*y)), list(x <= 2 * y^2, y >= .2))
result <- solve(prob, gp = TRUE)
result$value
result$getValue(x)
result$getValue(y)
```

OSQP-class — *An interface for the OSQP solver.*

Description

An interface for the OSQP solver.

Usage

```
OSQP()

## S4 method for signature 'OSQP'
status_map(solver, status)

## S4 method for signature 'OSQP'
name(x)

## S4 method for signature 'OSQP'
import_solver(solver)

## S4 method for signature 'OSQP,list,InverseData'
invert(object, solution, inverse_data)

## S4 method for signature 'OSQP'
solve_via_data(
  object,
  data,
  warm_start,
  verbose,
  feastol,
  reltol,
  abstol,
  num_iter,
  solver_opts,
  solver_cache
)
```

Arguments

`solver, object, x`	A OSQP object.
`status`	A status code returned by the solver.
`solution`	The raw solution returned by the solver.
`inverse_data`	A InverseData object containing data necessary for the inversion.
`data`	Data generated via an apply call.
`warm_start`	A boolean of whether to warm start the solver.
`verbose`	A boolean of whether to enable solver verbosity.
`feastol`	The feasible tolerance.
`reltol`	The relative tolerance.
`abstol`	The absolute tolerance.
`num_iter`	The maximum number of iterations.
`solver_opts`	A list of Solver specific options
`solver_cache`	Cache for the solver.

Methods (by generic)

- `status_map`: Converts status returned by the OSQP solver to its respective CVXPY status.
- `name`: Returns the name of the solver.
- `import_solver`: Imports the solver.
- `invert`: Returns the solution to the original problem given the inverse_data.
- `solve_via_data`: Solve a problem represented by data returned from apply.

Parameter-class *The Parameter class.*

Description

This class represents a parameter, either scalar or a matrix.

Usage

```
Parameter(
  rows = NULL,
  cols = NULL,
  name = NA_character_,
  value = NA_real_,
  ...
)

## S4 method for signature 'Parameter'
get_data(object)

## S4 method for signature 'Parameter'
name(x)

## S4 method for signature 'Parameter'
value(object)

## S4 replacement method for signature 'Parameter'
value(object) <- value

## S4 method for signature 'Parameter'
grad(object)

## S4 method for signature 'Parameter'
parameters(object)

## S4 method for signature 'Parameter'
canonicalize(object)
```

Arguments

`rows`	The number of rows in the parameter.
`cols`	The number of columns in the parameter.
`name`	(Optional) A character string representing the name of the parameter.
`value`	(Optional) A numeric element, vector, matrix, or data.frame. Defaults to `NA` and may be changed with `value<-` later.
`...`	Additional attribute arguments. See Leaf for details.
`object, x`	A Parameter object.

Methods (by generic)

- `get_data`: Returns `list(dim,name,value,attributes)`.
- `name`: The name of the parameter.
- `value`: The value of the parameter.
- `value<-`: Set the value of the parameter.
- `grad`: An empty list since the gradient of a parameter is zero.
- `parameters`: Returns itself as a parameter.
- `canonicalize`: The canonical form of the parameter.

Slots

`rows` The number of rows in the parameter.

`cols` The number of columns in the parameter.

`name` (Optional) A character string representing the name of the parameter.

`value` (Optional) A numeric element, vector, matrix, or data.frame. Defaults to `NA` and may be changed with `value<-` later.

Examples

```
x <- Parameter(3, name = "x0", nonpos = TRUE) ## 3-vec negative
is_nonneg(x)
is_nonpos(x)
size(x)
```

perform *Perform Reduction*

Description

Performs the reduction on a problem and returns an equivalent problem.

Usage

```
perform(object, problem)
```

Arguments

object	A Reduction object.
problem	A Problem on which the reduction will be performed.

Value

A list containing

- "problem"A Problem or list representing the equivalent problem.
- "inverse_data"A InverseData or list containing the data needed to invert this particular reduction.

PfEigenvalue-class *The PfEigenvalue class.*

Description

This class represents the Perron-Frobenius eigenvalue of a positive matrix.

Usage

```
PfEigenvalue(X)

## S4 method for signature 'PfEigenvalue'
name(x)

## S4 method for signature 'PfEigenvalue'
to_numeric(object, values)

## S4 method for signature 'PfEigenvalue'
dim_from_args(object)

## S4 method for signature 'PfEigenvalue'
```

```
sign_from_args(object)

## S4 method for signature 'PfEigenvalue'
is_atom_convex(object)

## S4 method for signature 'PfEigenvalue'
is_atom_concave(object)

## S4 method for signature 'PfEigenvalue'
is_atom_log_log_convex(object)

## S4 method for signature 'PfEigenvalue'
is_atom_log_log_concave(object)

## S4 method for signature 'PfEigenvalue'
is_incr(object, idx)

## S4 method for signature 'PfEigenvalue'
is_decr(object, idx)

## S4 method for signature 'PfEigenvalue'
.grad(object, values)
```

Arguments

X	An Expression or numeric matrix.
x, object	A PfEigenvalue object.
values	A list of numeric values for the arguments
idx	An index into the atom.

Methods (by generic)

- name: The name and arguments of the atom.
- to_numeric: Returns the Perron-Frobenius eigenvalue of X.
- dim_from_args: The dimensions of the atom.
- sign_from_args: Returns the sign (is positive, is negative) of the atom.
- is_atom_convex: Is the atom convex?
- is_atom_concave: Is the atom concave?
- is_atom_log_log_convex: Is the atom log-log convex?
- is_atom_log_log_concave: Is the atom log-log concave?
- is_incr: Is the atom weakly increasing in the argument idx?
- is_decr: Is the atom weakly decreasing in the argument idx?
- .grad: Gives the (sub/super)gradient of the atom w.r.t. each variable

Slots

X An Expression or numeric matrix.

---

pf_eigenvalue *Perron-Frobenius Eigenvalue*

Description

The Perron-Frobenius eigenvalue of a positive matrix.

Usage

```
pf_eigenvalue(X)
```

Arguments

X	An Expression or positive square matrix.

Details

For an elementwise positive matrix X, this atom represents its spectral radius, i.e., the magnitude of its largest eigenvalue. Because X is positive, the spectral radius equals its largest eigenvalue, which is guaranteed to be positive.

This atom is log-log convex.

Value

An Expression representing the largest eigenvalue of the input.

Examples

```
n <- 3
X <- Variable(n, n, pos=TRUE)
objective_fn <- pf_eigenvalue(X)
constraints <- list( X[1,1]== 1.0,
                     X[1,3] == 1.9,
                     X[2,2] == .8,
                     X[3,1] == 3.2,
                     X[3,2] == 5.9,
                     X[1, 2] * X[2, 1] * X[2,3] * X[3,3] == 1)
problem <- Problem(Minimize(objective_fn), constraints)
result <- solve(problem, gp=TRUE)
result$value
result$getValue(X)
```

Pnorm-class *The Pnorm class.*

Description

This class represents the vector p-norm.

Usage

```
Pnorm(x, p = 2, axis = NA_real_, keepdims = FALSE, max_denom = 1024)

## S4 method for signature 'Pnorm'
allow_complex(object)

## S4 method for signature 'Pnorm'
to_numeric(object, values)

## S4 method for signature 'Pnorm'
validate_args(object)

## S4 method for signature 'Pnorm'
sign_from_args(object)

## S4 method for signature 'Pnorm'
is_atom_convex(object)

## S4 method for signature 'Pnorm'
is_atom_concave(object)

## S4 method for signature 'Pnorm'
is_atom_log_log_convex(object)

## S4 method for signature 'Pnorm'
is_atom_log_log_concave(object)

## S4 method for signature 'Pnorm'
is_incr(object, idx)

## S4 method for signature 'Pnorm'
is_decr(object, idx)

## S4 method for signature 'Pnorm'
is_pwl(object)

## S4 method for signature 'Pnorm'
get_data(object)
```

```
## S4 method for signature 'Pnorm'
name(x)

## S4 method for signature 'Pnorm'
.domain(object)

## S4 method for signature 'Pnorm'
.grad(object, values)

## S4 method for signature 'Pnorm'
.column_grad(object, value)
```

Arguments

`x`	An Expression representing a vector or matrix.
`p`	A number greater than or equal to 1, or equal to positive infinity.
`axis`	(Optional) The dimension across which to apply the function: `1` indicates rows, `2` indicates columns, and `NA` indicates rows and columns. The default is `NA`.
`keepdims`	(Optional) Should dimensions be maintained when applying the atom along an axis? If `FALSE`, result will be collapsed into an $nx1$ column vector. The default is `FALSE`.
`max_denom`	(Optional) The maximum denominator considered in forming a rational approximation for p. The default is 1024.
`object`	A Pnorm object.
`values`	A list of numeric values for the arguments
`idx`	An index into the atom.
`value`	A numeric value

Details

If given a matrix variable, `Pnorm` will treat it as a vector and compute the p-norm of the concatenated columns.

For $p \geq 1$, the p-norm is given by

$$\|x\|_p = \left(\sum_{i=1}^n |x_i|^p\right)^{1/p}$$

with domain $x \in \mathbf{R}^n$. For $p < 1, p \neq 0$, the p-norm is given by

$$\|x\|_p = \left(\sum_{i=1}^n x_i^p\right)^{1/p}$$

with domain $x \in \mathbf{R}^n_+$.

- Note that the "p-norm" is actually a **norm** only when $p \geq 1$ or $p = +\infty$. For these cases, it is convex.
- The expression is undefined when $p = 0$.
- Otherwise, when $p < 1$, the expression is concave, but not a true norm.

Methods (by generic)

- allow_complex: Does the atom handle complex numbers?
- to_numeric: The p-norm of x.
- validate_args: Check that the arguments are valid.
- sign_from_args: The atom is positive.
- is_atom_convex: The atom is convex if $p \geq 1$.
- is_atom_concave: The atom is concave if $p < 1$.
- is_atom_log_log_convex: Is the atom log-log convex?
- is_atom_log_log_concave: Is the atom log-log concave?
- is_incr: The atom is weakly increasing if $p < 1$ or $p > 1$ and x is positive.
- is_decr: The atom is weakly decreasing if $p > 1$ and x is negative.
- is_pwl: The atom is not piecewise linear unless $p = 1$ or $p = \infty$.
- get_data: Returns list(p,axis).
- name: The name and arguments of the atom.
- .domain: Returns constraints describing the domain of the node
- .grad: Gives the (sub/super)gradient of the atom w.r.t. each variable
- .column_grad: Gives the (sub/super)gradient of the atom w.r.t. each column variable

Slots

x An Expression representing a vector or matrix.

p A number greater than or equal to 1, or equal to positive infinity.

max_denom The maximum denominator considered in forming a rational approximation for p.

axis (Optional) The dimension across which to apply the function: 1 indicates rows, 2 indicates columns, and NA indicates rows and columns. The default is NA.

keepdims (Optional) Should dimensions be maintained when applying the atom along an axis? If FALSE, result will be collapsed into an $nx1$ column vector. The default is FALSE.

.approx_error (Internal) The absolute difference between p and its rational approximation.

.original_p (Internal) The original input p.

Pos *An alias for MaxElemwise(x, 0)*

Description

An alias for MaxElemwise(x, 0)

Usage

```
Pos(x)
```

Arguments

x	An R numeric value or Expression.

Value

An alias for MaxElemwise(x, 0)

`pos` *Elementwise Positive*

Description

The elementwise positive portion of an expression, $\max(x_i, 0)$. This is equivalent to `max_elemwise(x,0)`.

Usage

```
pos(x)
```

Arguments

x	An Expression, vector, or matrix.

Value

An Expression representing the positive portion of the input.

Examples

```
x <- Variable(2)
val <- matrix(c(-3,2))
prob <- Problem(Minimize(pos(x)[1]), list(x == val))
result <- solve(prob)
result$value
```

`Power-class` *The Power class.*

Description

This class represents the elementwise power function $f(x) = x^p$. If `expr` is a CVXR expression, then `expr^p` is equivalent to `Power(expr,p)`.

Usage

```
Power(x, p, max_denom = 1024)

## S4 method for signature 'Power'
to_numeric(object, values)

## S4 method for signature 'Power'
sign_from_args(object)

## S4 method for signature 'Power'
is_atom_convex(object)

## S4 method for signature 'Power'
is_atom_concave(object)

## S4 method for signature 'Power'
is_atom_log_log_convex(object)

## S4 method for signature 'Power'
is_atom_log_log_concave(object)

## S4 method for signature 'Power'
is_constant(object)

## S4 method for signature 'Power'
is_incr(object, idx)

## S4 method for signature 'Power'
is_decr(object, idx)

## S4 method for signature 'Power'
is_quadratic(object)

## S4 method for signature 'Power'
is_qpwa(object)

## S4 method for signature 'Power'
.grad(object, values)

## S4 method for signature 'Power'
.domain(object)

## S4 method for signature 'Power'
get_data(object)

## S4 method for signature 'Power'
copy(object, args = NULL, id_objects = list())
```

```
## S4 method for signature 'Power'
name(x)
```

Arguments

x	The Expression to be raised to a power.
p	A numeric value indicating the scalar power.
max_denom	The maximum denominator considered in forming a rational approximation of p.
object	A Power object.
values	A list of numeric values for the arguments
idx	An index into the atom.
args	A list of arguments to reconstruct the atom. If args=NULL, use the current args of the atom
id_objects	Currently unused.

Details

#' For $p = 0$, $f(x) = 1$, constant, positive. For $p = 1$, $f(x) = x$, affine, increasing, same sign as x. For $p = 2, 4, 8, ...$, $f(x) = |x|^p$, convex, signed monotonicity, positive. For $p < 0$ and $f(x) =$

- x^p for $x > 0$
- $+\infty x \leq 0$

, this function is convex, decreasing, and positive. For $0 < p < 1$ and $f(x) =$

- x^p for $x \geq 0$
- $-\infty x < 0$

, this function is concave, increasing, and positive. For $p > 1, p \neq 2, 4, 8, \ldots$ and $f(x) =$

- x^p for $x \geq 0$
- $+\infty x < 0$

, this function is convex, increasing, and positive.

Methods (by generic)

- `to_numeric`: Throw an error if the power is negative and cannot be handled.
- `sign_from_args`: The sign of the atom.
- `is_atom_convex`: Is $p \leq 0$ or $p \geq 1$?
- `is_atom_concave`: Is $p \geq 0$ or $p \leq 1$?
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `is_constant`: A logical value indicating whether the atom is constant.
- `is_incr`: A logical value indicating whether the atom is weakly increasing.

- is_decr: A logical value indicating whether the atom is weakly decreasing.
- is_quadratic: A logical value indicating whether the atom is quadratic.
- is_qpwa: A logical value indicating whether the atom is quadratic of piecewise affine.
- .grad: Gives the (sub/super)gradient of the atom w.r.t. each variable
- .domain: Returns constraints describng the domain of the node
- get_data: A list containing the output of pow_low, pow_mid, or pow_high depending on the input power.
- copy: Returns a shallow copy of the power atom
- name: Returns the expression in string form.

Slots

x The Expression to be raised to a power.

p A numeric value indicating the scalar power.

max_denom The maximum denominator considered in forming a rational approximation of p.

Problem-arith *Arithmetic Operations on Problems*

Description

Add, subtract, multiply, or divide DCP optimization problems.

Usage

```
## S4 method for signature 'Problem,missing'
e1 + e2

## S4 method for signature 'Problem,missing'
e1 - e2

## S4 method for signature 'Problem,numeric'
e1 + e2

## S4 method for signature 'numeric,Problem'
e1 + e2

## S4 method for signature 'Problem,Problem'
e1 + e2

## S4 method for signature 'Problem,numeric'
e1 - e2

## S4 method for signature 'numeric,Problem'
```

```
e1 - e2

## S4 method for signature 'Problem,Problem'
e1 - e2

## S4 method for signature 'Problem,numeric'
e1 * e2

## S4 method for signature 'numeric,Problem'
e1 * e2

## S4 method for signature 'Problem,numeric'
e1 / e2
```

Arguments

e1	The left-hand Problem object.
e2	The right-hand Problem object.

Value

A Problem object.

Problem-class *The Problem class.*

Description

This class represents a convex optimization problem.

Usage

```
Problem(objective, constraints = list())

## S4 method for signature 'Problem'
objective(object)

## S4 replacement method for signature 'Problem'
objective(object) <- value

## S4 method for signature 'Problem'
constraints(object)

## S4 replacement method for signature 'Problem'
constraints(object) <- value

## S4 method for signature 'Problem'
```

```
value(object)

## S4 replacement method for signature 'Problem'
value(object) <- value

## S4 method for signature 'Problem'
status(object)

## S4 method for signature 'Problem'
is_dcp(object)

## S4 method for signature 'Problem'
is_dgp(object)

## S4 method for signature 'Problem'
is_qp(object)

## S4 method for signature 'Problem'
canonicalize(object)

## S4 method for signature 'Problem'
is_mixed_integer(object)

## S4 method for signature 'Problem'
variables(object)

## S4 method for signature 'Problem'
parameters(object)

## S4 method for signature 'Problem'
constants(object)

## S4 method for signature 'Problem'
atoms(object)

## S4 method for signature 'Problem'
size_metrics(object)

## S4 method for signature 'Problem'
solver_stats(object)

## S4 replacement method for signature 'Problem'
solver_stats(object) <- value

## S4 method for signature 'Problem,character,logical'
get_problem_data(object, solver, gp)

## S4 method for signature 'Problem,character,missing'
```

```
get_problem_data(object, solver, gp)

## S4 method for signature 'Problem'
unpack_results(object, solution, chain, inverse_data)
```

Arguments

`objective`	A Minimize or Maximize object representing the optimization objective.
`constraints`	(Optional) A list of Constraint objects representing constraints on the optimization variables.
`object`	A Problem class.
`value`	A Minimize or Maximize object (objective), list of Constraint objects (constraints), or numeric scalar (value).
`solver`	A string indicating the solver that the problem data is for. Call `installed_solvers()` to see all available.
`gp`	Is the problem a geometric problem?
`solution`	A Solution object.
`chain`	The corresponding solving Chain.
`inverse_data`	A InverseData object or list containing data necessary for the inversion.

Methods (by generic)

- `objective`: The objective of the problem.
- `objective<-`: Set the value of the problem objective.
- `constraints`: A list of the constraints of the problem.
- `constraints<-`: Set the value of the problem constraints.
- `value`: The value from the last time the problem was solved (or NA if not solved).
- `value<-`: Set the value of the optimal objective.
- `status`: The status from the last time the problem was solved.
- `is_dcp`: A logical value indicating whether the problem statisfies DCP rules.
- `is_dgp`: A logical value indicating whether the problem statisfies DGP rules.
- `is_qp`: A logical value indicating whether the problem is a quadratic program.
- `canonicalize`: The graph implementation of the problem.
- `is_mixed_integer`: logical value indicating whether the problem is a mixed integer program.
- `variables`: List of Variable objects in the problem.
- `parameters`: List of Parameter objects in the problem.
- `constants`: List of Constant objects in the problem.
- `atoms`: List of Atom objects in the problem.
- `size_metrics`: Information about the size of the problem.
- `solver_stats`: Additional information returned by the solver.
- `solver_stats<-`: Set the additional information returned by the solver in the problem.

- `get_problem_data`: Get the problem data passed to the specified solver.
- `get_problem_data`: Get the problem data passed to the specified solver.
- `unpack_results`: Parses the output from a solver and updates the problem state, including the status, objective value, and values of the primal and dual variables. Assumes the results are from the given solver.

Slots

`objective` A Minimize or Maximize object representing the optimization objective.

`constraints` (Optional) A list of constraints on the optimization variables.

`value` (Internal) Used internally to hold the value of the optimization objective at the solution.

`status` (Internal) Used internally to hold the status of the problem solution.

`.cached_data` (Internal) Used internally to hold cached matrix data.

`.separable_problems` (Internal) Used internally to hold separable problem data.

`.size_metrics` (Internal) Used internally to hold size metrics.

`.solver_stats` (Internal) Used internally to hold solver statistics.

Examples

```
x <- Variable(2)
p <- Problem(Minimize(p_norm(x, 2)), list(x >= 0))
is_dcp(p)
x <- Variable(2)
A <- matrix(c(1,-1,-1, 1), nrow = 2)
p <- Problem(Minimize(quad_form(x, A)), list(x >= 0))
is_qp(p)
```

`problem-parts` *Parts of a Problem*

Description

Get and set the objective, constraints, or size metrics (get only) of a problem.

Usage

```
objective(object)

objective(object) <- value

constraints(object)

constraints(object) <- value

size_metrics(object)
```

Arguments

`object`	A Problem object.
`value`	The value to assign to the slot.

Value

For getter functions, the requested slot of the object. x <- Variable() prob <- Problem(Minimize(x^2), list(x >= 5)) objective(prob) constraints(prob) size_metrics(prob)

objective(prob) <- Maximize(sqrt(x)) constraints(prob) <- list(x <= 10) objective(prob) constraints(prob)

`ProdEntries-class` *The ProdEntries class.*

Description

The product of the entries in an expression.

Usage

```
ProdEntries(..., axis = NA_real_, keepdims = FALSE)

## S4 method for signature 'ProdEntries'
to_numeric(object, values)

## S4 method for signature 'ProdEntries'
sign_from_args(object)

## S4 method for signature 'ProdEntries'
is_atom_convex(object)

## S4 method for signature 'ProdEntries'
is_atom_concave(object)

## S4 method for signature 'ProdEntries'
is_atom_log_log_convex(object)

## S4 method for signature 'ProdEntries'
is_atom_log_log_concave(object)

## S4 method for signature 'ProdEntries'
is_incr(object, idx)

## S4 method for signature 'ProdEntries'
is_decr(object, idx)

## S4 method for signature 'ProdEntries'
```

```
.column_grad(object, value)

## S4 method for signature 'ProdEntries'
.grad(object, values)
```

Arguments

`...`	Expression objects, vectors, or matrices.
`axis`	(Optional) The dimension across which to apply the function: `1` indicates rows, `2` indicates columns, and `NA` indicates rows and columns. The default is `NA`.
`keepdims`	(Optional) Should dimensions be maintained when applying the atom along an axis? If `FALSE`, result will be collapsed into an $nx1$ column vector. The default is `FALSE`.
`object`	A ProdEntries object.
`values`	A list of numeric values for the arguments
`idx`	An index into the atom.
`value`	A numeric value.

Methods (by generic)

- `to_numeric`: The product of all the entries.
- `sign_from_args`: Returns the sign (is positive, is negative) of the atom.
- `is_atom_convex`: Is the atom convex?
- `is_atom_concave`: Is the atom concave?
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: is the atom log-log concave?
- `is_incr`: Is the atom weakly increasing in the argument `idx`?
- `is_decr`: Is the atom weakly decreasing in the argument `idx`?
- `.column_grad`: Gives the (sub/super)gradient of the atom w.r.t. each column variable
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable

Slots

`expr` An Expression representing a vector or matrix.

`axis` (Optional) The dimension across which to apply the function: `1` indicates rows, `2` indicates columns, and `NA` indicates rows and columns. The default is `NA`.

`prod_entries` *Product of Entries*

Description

The product of entries in a vector or matrix.

Usage

```
prod_entries(..., axis = NA_real_, keepdims = FALSE)

## S3 method for class 'Expression'
prod(..., na.rm = FALSE)
```

Arguments

...	Numeric scalar, vector, matrix, or Expression objects.
axis	(Optional) The dimension across which to apply the function: 1 indicates rows, 2 indicates columns, and NA indicates rows and columns. The default is NA.
keepdims	(Optional) Should dimensions be maintained when applying the atom along an axis? If FALSE, result will be collapsed into an $nx1$ column vector. The default is FALSE.
na.rm	(Unimplemented) A logical value indicating whether missing values should be removed.

Details

This atom is log-log affine, but it is neither convex nor concave.

Value

An Expression representing the product of the entries of the input.

Examples

```
n <- 2
X <- Variable(n, n, pos=TRUE)
obj <- sum(X)
constraints <- list(prod_entries(X) == 4)
prob <- Problem(Minimize(obj), constraints)
result <- solve(prob, gp=TRUE)
result$value
result$getValue(X)

n <- 2
X <- Variable(n, n, pos=TRUE)
obj <- sum(X)
```

```
constraints <- list(prod(X) == 4)
prob <- Problem(Minimize(obj), constraints)
result <- solve(prob, gp=TRUE)
result$value
```

project-methods *Project Value*

Description

Project a value onto the attribute set of a Leaf. A sensible idiom is `value(leaf) = project(leaf,val)`.

Usage

```
project(object, value)

project_and_assign(object, value)
```

Arguments

`object`	A Leaf object.
`value`	The assigned value.

Value

The value rounded to the attribute type.

Promote-class *The Promote class.*

Description

This class represents the promotion of a scalar expression into a vector/matrix.

Usage

```
Promote(expr, promoted_dim)

## S4 method for signature 'Promote'
to_numeric(object, values)

## S4 method for signature 'Promote'
is_symmetric(object)

## S4 method for signature 'Promote'
dim_from_args(object)
```

```
## S4 method for signature 'Promote'
is_atom_log_log_convex(object)

## S4 method for signature 'Promote'
is_atom_log_log_concave(object)

## S4 method for signature 'Promote'
get_data(object)

## S4 method for signature 'Promote'
graph_implementation(object, arg_objs, dim, data = NA_real_)
```

Arguments

`expr`	An Expression or numeric constant.
`promoted_dim`	The desired dimensions.
`object`	A Promote object.
`values`	A list containing the value to promote.
`arg_objs`	A list of linear expressions for each argument.
`dim`	A vector representing the dimensions of the resulting expression.
`data`	A list of additional data required by the atom.

Methods (by generic)

- `to_numeric`: Promotes the value to the new dimensions.
- `is_symmetric`: Is the expression symmetric?
- `dim_from_args`: Returns the (row, col) dimensions of the expression.
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `get_data`: Returns information needed to reconstruct the expression besides the args.
- `graph_implementation`: The graph implementation of the atom.

Slots

`expr` An Expression or numeric constant.

`promoted_dim` The desired dimensions.

`PSDWrap-class` *The PSDWrap class.*

Description

A no-op wrapper to assert the input argument is positive semidefinite.

Usage

```
PSDWrap(arg)

## S4 method for signature 'PSDWrap'
is_psd(object)
```

Arguments

`arg`	A Expression object or matrix.
`object`	A PSDWrap object.

Methods (by generic)

- `is_psd`: Is the atom positive semidefinite?

`psd_coeff_offset` *Given a problem returns a PSD constrain*

Description

Given a problem returns a PSD constrain

Usage

```
psd_coeff_offset(problem, c)
```

Arguments

`problem`	A Problem object.
`c`	A vector of coefficients.

Value

Returns an array G and vector h such that the given constraint is equivalent to G*z <=_PSD h.

psolve *Solve a DCP Problem*

Description

Solve a DCP compliant optimization problem.

Usage

```
psolve(
  object,
  solver = NA,
  ignore_dcp = FALSE,
  warm_start = FALSE,
  verbose = FALSE,
  parallel = FALSE,
  gp = FALSE,
  feastol = NULL,
  reltol = NULL,
  abstol = NULL,
  num_iter = NULL,
  ...
)

## S4 method for signature 'Problem'
psolve(
  object,
  solver = NA,
  ignore_dcp = FALSE,
  warm_start = FALSE,
  verbose = FALSE,
  parallel = FALSE,
  gp = FALSE,
  feastol = NULL,
  reltol = NULL,
  abstol = NULL,
  num_iter = NULL,
  ...
)

## S4 method for signature 'Problem,ANY'
solve(a, b = NA, ...)
```

Arguments

`object, a`	A Problem object.
`solver, b`	(Optional) A string indicating the solver to use. Defaults to "ECOS".

`ignore_dcp`	(Optional) A logical value indicating whether to override the DCP check for a problem.
`warm_start`	(Optional) A logical value indicating whether the previous solver result should be used to warm start.
`verbose`	(Optional) A logical value indicating whether to print additional solver output.
`parallel`	(Optional) A logical value indicating whether to solve in parallel if the problem is separable.
`gp`	(Optional) A logical value indicating whether the problem is a geometric program. Defaults to `FALSE`.
`feastol`	The feasible tolerance on the primal and dual residual.
`reltol`	The relative tolerance on the duality gap.
`abstol`	The absolute tolerance on the duality gap.
`num_iter`	The maximum number of iterations.
`...`	Additional options that will be passed to the specific solver. In general, these options will override any default settings imposed by CVXR.

Value

A list containing the solution to the problem:

`status` The status of the solution. Can be "optimal", "optimal_inaccurate", "infeasible", "infeasible_inaccurate", "unbounded", "unbounded_inaccurate", or "solver_error".

`value` The optimal value of the objective function.

`solver` The name of the solver.

`solve_time` The time (in seconds) it took for the solver to solve the problem.

`setup_time` The time (in seconds) it took for the solver to set up the problem.

`num_iters` The number of iterations the solver had to go through to find a solution.

`getValue` A function that takes a Variable object and retrieves its primal value.

`getDualValue` A function that takes a Constraint object and retrieves its dual value(s).

Examples

```
a <- Variable(name = "a")
prob <- Problem(Minimize(norm_inf(a)), list(a >= 2))
result <- psolve(prob, solver = "ECOS", verbose = TRUE)
result$status
result$value
result$getValue(a)
result$getDualValue(constraints(prob)[[1]])
```

p_norm *P-Norm*

Description

The vector p-norm. If given a matrix variable, p_norm will treat it as a vector and compute the p-norm of the concatenated columns.

Usage

```
p_norm(x, p = 2, axis = NA_real_, keepdims = FALSE, max_denom = 1024)
```

Arguments

x	An Expression, vector, or matrix.
p	A number greater than or equal to 1, or equal to positive infinity.
axis	(Optional) The dimension across which to apply the function: 1 indicates rows, 2 indicates columns, and NA indicates rows and columns. The default is NA.
keepdims	(Optional) Should dimensions be maintained when applying the atom along an axis? If FALSE, result will be collapsed into an $nx1$ column vector. The default is FALSE.
max_denom	(Optional) The maximum denominator considered in forming a rational approximation for p. The default is 1024.

Details

For $p \geq 1$, the p-norm is given by

$$\|x\|_p = \left(\sum_{i=1}^{n} |x_i|^p\right)^{1/p}$$

with domain $x \in \mathbf{R}^n$. For $p < 1, p \neq 0$, the p-norm is given by

$$\|x\|_p = \left(\sum_{i=1}^{n} x_i^p\right)^{1/p}$$

with domain $x \in \mathbf{R}^n_+$.

- Note that the "p-norm" is actually a **norm** only when $p \geq 1$ or $p = +\infty$. For these cases, it is convex.
- The expression is undefined when $p = 0$.
- Otherwise, when $p < 1$, the expression is concave, but not a true norm.

Value

An Expression representing the p-norm of the input.

Examples

```
x <- Variable(3)
prob <- Problem(Minimize(p_norm(x,2)))
result <- solve(prob)
result$value
result$getValue(x)

prob <- Problem(Minimize(p_norm(x,Inf)))
result <- solve(prob)
result$value
result$getValue(x)

## Not run:
  a <- c(1.0, 2, 3)
  prob <- Problem(Minimize(p_norm(x,1.6)), list(t(x) %*% a >= 1))
  result <- solve(prob)
  result$value
  result$getValue(x)

  prob <- Problem(Minimize(sum(abs(x - a))), list(p_norm(x,-1) >= 0))
  result <- solve(prob)
  result$value
  result$getValue(x)

## End(Not run)
```

`Qp2SymbolicQp-class` *The Qp2SymbolicQp class.*

Description

This class reduces a quadratic problem to a problem that consists of affine expressions and symbolic quadratic forms.

`QpMatrixStuffing-class` *The QpMatrixStuffing class.*

Description

This class fills in numeric values for the problem instance and outputs a DCP-compliant minimization problem with an objective of the form

Details

QuadForm(x, p) + t(q)

and Zero/NonPos constraints, both of which exclusively carry affine arguments

QpSolver-class *A QP solver interface.*

Description

A QP solver interface.

Usage

```
## S4 method for signature 'QpSolver,Problem'
accepts(object, problem)

## S4 method for signature 'QpSolver,Problem'
perform(object, problem)
```

Arguments

`object`	A QpSolver object.
`problem`	A Problem object.

Methods (by generic)

- `accepts`: Is this a QP problem?
- `perform`: Constructs a QP problem data stored in a list

QuadForm-class *The QuadForm class.*

Description

This class represents the quadratic form $x^T P x$

Usage

```
QuadForm(x, P)

## S4 method for signature 'QuadForm'
name(x)

## S4 method for signature 'QuadForm'
allow_complex(object)

## S4 method for signature 'QuadForm'
to_numeric(object, values)
```

```
## S4 method for signature 'QuadForm'
validate_args(object)

## S4 method for signature 'QuadForm'
sign_from_args(object)

## S4 method for signature 'QuadForm'
dim_from_args(object)

## S4 method for signature 'QuadForm'
is_atom_convex(object)

## S4 method for signature 'QuadForm'
is_atom_concave(object)

## S4 method for signature 'QuadForm'
is_atom_log_log_convex(object)

## S4 method for signature 'QuadForm'
is_atom_log_log_concave(object)

## S4 method for signature 'QuadForm'
is_incr(object, idx)

## S4 method for signature 'QuadForm'
is_decr(object, idx)

## S4 method for signature 'QuadForm'
is_quadratic(object)

## S4 method for signature 'QuadForm'
is_pwl(object)

## S4 method for signature 'QuadForm'
.grad(object, values)
```

Arguments

`x`	An Expression or numeric vector.
`P`	An Expression, numeric matrix, or vector.
`object`	A QuadForm object.
`values`	A list of numeric values for the arguments
`idx`	An index into the atom.

Methods (by generic)

- `name`: The name and arguments of the atom.
- `allow_complex`: Does the atom handle complex numbers?

- `to_numeric`: Returns the quadratic form.
- `validate_args`: Checks the dimensions of the arguments.
- `sign_from_args`: Returns the sign (is positive, is negative) of the atom.
- `dim_from_args`: The dimensions of the atom.
- `is_atom_convex`: Is the atom convex?
- `is_atom_concave`: Is the atom concave?
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `is_incr`: Is the atom weakly increasing in the argument `idx`?
- `is_decr`: Is the atom weakly decreasing in the argument `idx`?
- `is_quadratic`: Is the atom quadratic?
- `is_pwl`: Is the atom piecewise linear?
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable

Slots

`x` An Expression or numeric vector.

`P` An Expression, numeric matrix, or vector.

`QuadOverLin-class` *The QuadOverLin class.*

Description

This class represents the sum of squared entries in X divided by a scalar y, $\sum_{i,j} X_{i,j}^2 / y$.

Usage

```
QuadOverLin(x, y)

## S4 method for signature 'QuadOverLin'
allow_complex(object)

## S4 method for signature 'QuadOverLin'
to_numeric(object, values)

## S4 method for signature 'QuadOverLin'
validate_args(object)

## S4 method for signature 'QuadOverLin'
dim_from_args(object)

## S4 method for signature 'QuadOverLin'
```

```
sign_from_args(object)

## S4 method for signature 'QuadOverLin'
is_atom_convex(object)

## S4 method for signature 'QuadOverLin'
is_atom_concave(object)

## S4 method for signature 'QuadOverLin'
is_atom_log_log_convex(object)

## S4 method for signature 'QuadOverLin'
is_atom_log_log_concave(object)

## S4 method for signature 'QuadOverLin'
is_incr(object, idx)

## S4 method for signature 'QuadOverLin'
is_decr(object, idx)

## S4 method for signature 'QuadOverLin'
is_quadratic(object)

## S4 method for signature 'QuadOverLin'
is_qpwa(object)

## S4 method for signature 'QuadOverLin'
.domain(object)

## S4 method for signature 'QuadOverLin'
.grad(object, values)
```

Arguments

`x`	An Expression or numeric matrix.
`y`	A scalar Expression or numeric constant.
`object`	A QuadOverLin object.
`values`	A list of numeric values for the arguments
`idx`	An index into the atom.

Methods (by generic)

- `allow_complex`: Does the atom handle complex numbers?
- `to_numeric`: The sum of the entries of `x` squared over `y`.
- `validate_args`: Check the dimensions of the arguments.
- `dim_from_args`: The atom is a scalar.
- `sign_from_args`: The atom is positive.

- `is_atom_convex`: The atom is convex.
- `is_atom_concave`: The atom is not concave.
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `is_incr`: A logical value indicating whether the atom is weakly increasing in argument `idx`.
- `is_decr`: A logical value indicating whether the atom is weakly decreasing in argument `idx`.
- `is_quadratic`: Quadratic if `x` is affine and `y` is constant.
- `is_qpwa`: Quadratic of piecewise affine if `x` is piecewise linear and `y` is constant.
- `.domain`: Returns constraints describing the domain of the node
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable

Slots

`x` An Expression or numeric matrix.

`y` A scalar Expression or numeric constant.

`quad_form` *Quadratic Form*

Description

The quadratic form, $x^T Px$.

Usage

```
quad_form(x, P)
```

Arguments

`x`	An Expression or vector.
`P`	An Expression or matrix.

Value

An Expression representing the quadratic form evaluated at the input.

Examples

```
x <- Variable(2)
P <- rbind(c(4,0), c(0,9))
prob <- Problem(Minimize(quad_form(x,P)), list(x >= 1))
result <- solve(prob)
result$value
result$getValue(x)

A <- Variable(2,2)
c <- c(1,2)
prob <- Problem(Minimize(quad_form(c,A)), list(A >= 1))
result <- solve(prob)
result$value
result$getValue(A)
```

---

quad_over_lin *Quadratic over Linear*

Description

$\sum_{i,j} X_{i,j}^2/y$.

Usage

```
quad_over_lin(x, y)
```

Arguments

x	An Expression, vector, or matrix.
y	A scalar Expression or numeric constant.

Value

An Expression representing the quadratic over linear function value evaluated at the input.

Examples

```
x <- Variable(3,2)
y <- Variable()
val <- cbind(c(-1,2,-2), c(-1,2,-2))
prob <- Problem(Minimize(quad_over_lin(x,y)), list(x == val, y <= 2))
result <- solve(prob)
result$value
result$getValue(x)
result$getValue(y)
```

`Rdict-class` *The Rdict class.*

Description

A simple, internal dictionary composed of a list of keys and a list of values. These keys/values can be any type, including nested lists, S4 objects, etc. Incredibly inefficient hack, but necessary for the geometric mean atom, since it requires mixed numeric/gmp objects.

Usage

```
Rdict(keys = list(), values = list())

## S4 method for signature 'Rdict'
x$name

## S4 method for signature 'Rdict'
length(x)

## S4 method for signature 'ANY,Rdict'
is.element(el, set)

## S4 method for signature 'Rdict,ANY,ANY,ANY'
x[i, j, ..., drop = TRUE]

## S4 replacement method for signature 'Rdict,ANY,ANY,ANY'
x[i, j, ...] <- value
```

Arguments

`keys`	A list of keys.
`values`	A list of values corresponding to the keys.
`x, set`	A Rdict object.
`name`	Either "keys" for a list of keys, "values" for a list of values, or "items" for a list of lists where each nested list is a (key, value) pair.
`el`	The element to search the dictionary of values for.
`i`	A key into the dictionary.
`j, drop, ...`	Unused arguments.
`value`	The value to assign to key `i`.

Slots

`keys` A list of keys.

`values` A list of values corresponding to the keys.

Rdictdefault-class *The Rdictdefault class.*

Description

This is a subclass of Rdict that contains an additional slot for a default function, which assigns a value to an input key. Only partially implemented, but working well enough for the geometric mean. Will be combined with Rdict later.

Usage

```
Rdictdefault(keys = list(), values = list(), default)

## S4 method for signature 'Rdictdefault,ANY,ANY,ANY'
x[i, j, ..., drop = TRUE]
```

Arguments

`keys`	A list of keys.
`values`	A list of values corresponding to the keys.
`default`	A function that takes as input a key and outputs a value to assign to that key.
`x`	A Rdictdefault object.
`i`	A key into the dictionary.
`j, drop, ...`	Unused arguments.

Slots

`keys` A list of keys.

`values` A list of values corresponding to the keys.

`default` A function that takes as input a key and outputs a value to assign to that key.

See Also

Rdict

`Real-class` *The Real class.*

Description

This class represents the real part of an expression.

Usage

```
Real(expr)

## S4 method for signature 'Real'
to_numeric(object, values)

## S4 method for signature 'Real'
dim_from_args(object)

## S4 method for signature 'Real'
is_imag(object)

## S4 method for signature 'Real'
is_complex(object)

## S4 method for signature 'Real'
is_symmetric(object)
```

Arguments

`expr`	An Expression representing a vector or matrix.
`object`	An Real object.
`values`	A list of arguments to the atom.

Methods (by generic)

- `to_numeric`: The imaginary part of the given value.
- `dim_from_args`: The dimensions of the atom.
- `is_imag`: Is the atom imaginary?
- `is_complex`: Is the atom complex valued?
- `is_symmetric`: Is the atom symmetric?

Slots

`expr` An Expression representing a vector or matrix.

reduce *Reduce a Problem*

Description

Reduces the owned problem to an equivalent problem.

Usage

```
reduce(object)
```

Arguments

object	A Reduction object.

Value

An equivalent problem, encoded either as a Problem object or a list.

Reduction-class *The Reduction class.*

Description

This virtual class represents a reduction, an actor that transforms a problem into an equivalent problem. By equivalent, we mean that there exists a mapping between solutions of either problem: if we reduce a problem A to another problem B and then proceed to find a solution to B, we can convert it to a solution of A with at most a moderate amount of effort.

Usage

```
## S4 method for signature 'Reduction,Problem'
accepts(object, problem)

## S4 method for signature 'Reduction'
reduce(object)

## S4 method for signature 'Reduction,Solution'
retrieve(object, solution)

## S4 method for signature 'Reduction,Problem'
perform(object, problem)

## S4 method for signature 'Reduction,Solution,list'
invert(object, solution, inverse_data)
```

Arguments

`object`	A Reduction object.
`problem`	A Problem object.
`solution`	A Solution to a problem that generated the inverse data.
`inverse_data`	The data encoding the original problem.

Details

Every reduction supports three methods: accepts, perform, and invert. The accepts method of a particular reduction codifies the types of problems that it is applicable to, the perform method takes a problem and reduces it to a (new) equivalent form, and the invert method maps solutions from reduced-to problems to their problems of provenance.

Methods (by generic)

- `accepts`: States whether the reduction accepts a problem.
- `reduce`: Reduces the owned problem to an equivalent problem.
- `retrieve`: Retrieves a solution to the owned problem.
- `perform`: Performs the reduction on a problem and returns an equivalent problem.
- `invert`: Returns a solution to the original problem given the inverse data.

`ReductionSolver-class` *The ReductionSolver class.*

Description

The ReductionSolver class.

Usage

```
## S4 method for signature 'ReductionSolver'
mip_capable(solver)

## S4 method for signature 'ReductionSolver'
name(x)

## S4 method for signature 'ReductionSolver'
import_solver(solver)

## S4 method for signature 'ReductionSolver'
is_installed(solver)

## S4 method for signature 'ReductionSolver'
solve_via_data(
  object,
```

```
  data,
  warm_start,
  verbose,
  feastol,
  reltol,
  abstol,
  num_iter,
  solver_opts,
  solver_cache
)

## S4 method for signature 'ReductionSolver,ANY'
reduction_solve(
  object,
  problem,
  warm_start,
  verbose,
  feastol,
  reltol,
  abstol,
  num_iter,
  solver_opts
)

## S4 method for signature 'ECOS'
solve_via_data(
  object,
  data,
  warm_start,
  verbose,
  feastol,
  reltol,
  abstol,
  num_iter,
  solver_opts,
  solver_cache
)
```

Arguments

solver, object, x	A ReductionSolver object.
data	Data generated via an apply call.
warm_start	A boolean of whether to warm start the solver.
verbose	An integer number indicating level of solver verbosity.
feastol	The feasible tolerance on the primal and dual residual.
reltol	The relative tolerance on the duality gap.

abstol	The absolute tolerance on the duality gap.
num_iter	The maximum number of iterations.
solver_opts	A list of Solver specific options
solver_cache	Cache for the solver.
problem	A Problem object.

Methods (by generic)

- mip_capable: Can the solver handle mixed-integer programs?
- name: Returns the name of the solver
- import_solver: Imports the solver
- is_installed: Is the solver installed?
- solve_via_data: Solve a problem represented by data returned from apply.
- reduction_solve: Solve a problem represented by data returned from apply.
- solve_via_data: Solve a problem represented by data returned from apply.

---

resetOptions *Reset Options*

Description

Reset the global package variable .CVXR.options.

Usage

```
resetOptions()
```

Value

The default value of CVXR package global .CVXR.options.

Examples

```
## Not run:
  resetOptions()

## End(Not run)
```

Reshape-class *The Reshape class.*

Description

This class represents the reshaping of an expression. The operator vectorizes the expression, then unvectorizes it into the new dimensions. Entries are stored in column-major order.

Usage

```
Reshape(expr, new_dim)

## S4 method for signature 'Reshape'
to_numeric(object, values)

## S4 method for signature 'Reshape'
validate_args(object)

## S4 method for signature 'Reshape'
dim_from_args(object)

## S4 method for signature 'Reshape'
is_atom_log_log_convex(object)

## S4 method for signature 'Reshape'
is_atom_log_log_concave(object)

## S4 method for signature 'Reshape'
get_data(object)

## S4 method for signature 'Reshape'
graph_implementation(object, arg_objs, dim, data = NA_real_)
```

Arguments

expr	An Expression or numeric matrix.
new_dim	The new dimensions.
object	A Reshape object.
values	A list of arguments to the atom.
arg_objs	A list of linear expressions for each argument.
dim	A vector representing the dimensions of the resulting expression.
data	A list of additional data required by the atom.

Methods (by generic)

- `to_numeric`: Reshape the value into the specified dimensions.
- `validate_args`: Check the new shape has the same number of entries as the old.
- `dim_from_args`: The `c(rows,cols)` dimensions of the new expression.
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `get_data`: Returns a list containing the new shape.
- `graph_implementation`: The graph implementation of the atom.

Slots

`expr` An Expression or numeric matrix.

`new_dim` The new dimensions.

`reshape_expr` *Reshape an Expression*

Description

This function vectorizes an expression, then unvectorizes it into a new shape. Entries are stored in column-major order.

Usage

```
reshape_expr(expr, new_dim)
```

Arguments

`expr`	An Expression, vector, or matrix.
`new_dim`	The new dimensions.

Value

An Expression representing the reshaped input.

Examples

```
x <- Variable(4)
mat <- cbind(c(1,-1), c(2,-2))
vec <- matrix(1:4)
expr <- reshape_expr(x,c(2,2))
obj <- Minimize(sum(mat %*% expr))
prob <- Problem(obj, list(x == vec))
result <- solve(prob)
result$value
```

```
A <- Variable(2,2)
c <- 1:4
expr <- reshape_expr(A,c(4,1))
obj <- Minimize(t(expr) %*% c)
constraints <- list(A == cbind(c(-1,-2), c(3,4)))
prob <- Problem(obj, constraints)
result <- solve(prob)
result$value
result$getValue(expr)
result$getValue(reshape_expr(expr,c(2,2)))

C <- Variable(3,2)
expr <- reshape_expr(C,c(2,3))
mat <- rbind(c(1,-1), c(2,-2))
C_mat <- rbind(c(1,4), c(2,5), c(3,6))
obj <- Minimize(sum(mat %*% expr))
prob <- Problem(obj, list(C == C_mat))
result <- solve(prob)
result$value
result$getValue(expr)

a <- Variable()
c <- cbind(c(1,-1), c(2,-2))
expr <- reshape_expr(c * a,c(1,4))
obj <- Minimize(expr %*% (1:4))
prob <- Problem(obj, list(a == 2))
result <- solve(prob)
result$value
result$getValue(expr)

expr <- reshape_expr(c * a,c(4,1))
obj <- Minimize(t(expr) %*% (1:4))
prob <- Problem(obj, list(a == 2))
result <- solve(prob)
result$value
result$getValue(expr)
```

`residual-methods` *Constraint Residual*

Description

The residual expression of a constraint, i.e. the amount by which it is violated, and the value of that violation. For instance, if our constraint is $g(x) \leq 0$, the residual is $max(g(x), 0)$ applied elementwise.

Usage

```
residual(object)

violation(object)
```

Arguments

`object`	A Constraint object.

Value

A Expression representing the residual, or the value of this expression.

`retrieve` *Retrieve Solution*

Description

Retrieves a solution to the owned problem.

Usage

```
retrieve(object, solution)
```

Arguments

`object`	A Reduction object.
`solution`	A Solution object.

Value

A Solution to the problem emitted by `reduce`.

`scaled_lower_tri` *Utility methods for special handling of semidefinite constraints.*

Description

Utility methods for special handling of semidefinite constraints.

Usage

```
scaled_lower_tri(matrix)
```

Arguments

`matrix`	The matrix to get the lower triangular matrix for

Value

The lower triangular part of the matrix, stacked in column-major order

scalene *Scalene Function*

Description

The elementwise weighted sum of the positive and negative portions of an expression, $\alpha \max(x_i, 0) - \beta \min(x_i, 0)$. This is equivalent to `alpha*pos(x) + beta*neg(x)`.

Usage

```
scalene(x, alpha, beta)
```

Arguments

`x`	An Expression, vector, or matrix.
`alpha`	The weight on the positive portion of `x`.
`beta`	The weight on othe negative portion of `x`.

Value

An Expression representing the scalene function evaluated at the input.

Examples

```
## Not run:
A <- Variable(2,2)
val <- cbind(c(-5,2), c(-3,1))
prob <- Problem(Minimize(scalene(A,2,3)[1,1]), list(A == val))
result <- solve(prob)
result$value
result$getValue(scalene(A, 0.7, 0.3))

## End(Not run)
```

SCS-class *An interface for the SCS solver*

Description

An interface for the SCS solver

Usage

```
SCS()

## S4 method for signature 'SCS'
mip_capable(solver)

## S4 method for signature 'SCS'
status_map(solver, status)

## S4 method for signature 'SCS'
name(x)

## S4 method for signature 'SCS'
import_solver(solver)

## S4 method for signature 'SCS'
reduction_format_constr(object, problem, constr, exp_cone_order)

## S4 method for signature 'SCS,Problem'
perform(object, problem)

## S4 method for signature 'SCS,list,list'
invert(object, solution, inverse_data)

## S4 method for signature 'SCS'
solve_via_data(
  object,
  data,
  warm_start,
  verbose,
  feastol,
  reltol,
  abstol,
  num_iter,
  solver_opts,
  solver_cache
)
```

Arguments

solver, object, x	A SCS object.
status	A status code returned by the solver.
problem	A Problem object.
constr	A Constraint to format.
exp_cone_order	A list indicating how the exponential cone arguments are ordered.
solution	The raw solution returned by the solver.

inverse_data	A list containing data necessary for the inversion.
data	Data generated via an apply call.
warm_start	A boolean of whether to warm start the solver.
verbose	A boolean of whether to enable solver verbosity.
feastol	The feasible tolerance on the primal and dual residual.
reltol	The relative tolerance on the duality gap.
abstol	The absolute tolerance on the duality gap.
num_iter	The maximum number of iterations.
solver_opts	A list of Solver specific options
solver_cache	Cache for the solver.

Methods (by generic)

- `mip_capable`: Can the solver handle mixed-integer programs?
- `status_map`: Converts status returned by SCS solver to its respective CVXPY status.
- `name`: Returns the name of the solver
- `import_solver`: Imports the solver
- `reduction_format_constr`: Return a linear operator to multiply by PSD constraint coefficients.
- `perform`: Returns a new problem and data for inverting the new solution
- `invert`: Returns the solution to the original problem given the inverse_data.
- `solve_via_data`: Solve a problem represented by data returned from apply.

SCS.dims_to_solver_dict

Utility method for formatting a ConeDims instance into a dictionary that can be supplied to SCS.

Description

Utility method for formatting a ConeDims instance into a dictionary that can be supplied to SCS.

Usage

```
SCS.dims_to_solver_dict(cone_dims)
```

Arguments

cone_dims	A ConeDims instance.

Value

The dimensions of the cones.

`SCS.extract_dual_value` *Extracts the dual value for constraint starting at offset.*

Description

Special cases PSD constraints, as per the SCS specification.

Usage

```
SCS.extract_dual_value(result_vec, offset, constraint)
```

Arguments

`result_vec`	The vector to extract dual values from.
`offset`	The starting point of the vector to extract from.
`constraint`	A Constraint object.

Value

The dual values for the corresponding PSD constraints

`setIdCounter` *Set ID Counter*

Description

Set the CVXR variable/constraint identification number counter.

Usage

```
setIdCounter(value = 0L)
```

Arguments

`value`	The value to assign as ID.

Value

the changed value of the package global `.CVXR.options`.

Examples

```
## Not run:
  setIdCounter(value = 0L)

## End(Not run)
```

SigmaMax-class *The SigmaMax class.*

Description

The maximum singular value of a matrix.

Usage

```
SigmaMax(A = A)

## S4 method for signature 'SigmaMax'
to_numeric(object, values)

## S4 method for signature 'SigmaMax'
allow_complex(object)

## S4 method for signature 'SigmaMax'
dim_from_args(object)

## S4 method for signature 'SigmaMax'
sign_from_args(object)

## S4 method for signature 'SigmaMax'
is_atom_convex(object)

## S4 method for signature 'SigmaMax'
is_atom_concave(object)

## S4 method for signature 'SigmaMax'
is_incr(object, idx)

## S4 method for signature 'SigmaMax'
is_decr(object, idx)

## S4 method for signature 'SigmaMax'
.grad(object, values)
```

Arguments

A	An Expression or matrix.
object	A SigmaMax object.
values	A list of numeric values for the arguments
idx	An index into the atom.

Methods (by generic)

- `to_numeric`: The largest singular value of `A`.
- `allow_complex`: Does the atom handle complex numbers?
- `dim_from_args`: The atom is a scalar.
- `sign_from_args`: The atom is positive.
- `is_atom_convex`: The atom is convex.
- `is_atom_concave`: The atom is concave.
- `is_incr`: The atom is not monotonic in any argument.
- `is_decr`: The atom is not monotonic in any argument.
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable

Slots

`A` An Expression or numeric matrix.

`sigma_max` *Maximum Singular Value*

Description

The maximum singular value of a matrix.

Usage

```
sigma_max(A = A)
```

Arguments

`A`	An Expression or matrix.

Value

An Expression representing the maximum singular value.

Examples

```
C <- Variable(3,2)
val <- rbind(c(1,2), c(3,4), c(5,6))
obj <- sigma_max(C)
constr <- list(C == val)
prob <- Problem(Minimize(obj), constr)
result <- solve(prob, solver = "SCS")
result$value
result$getValue(C)
```

sign,Expression-method *Sign of Expression*

Description

The sign of an expression.

Usage

```
## S4 method for signature 'Expression'
sign(x)
```

Arguments

x	An Expression object.

Value

A string indicating the sign of the expression, either "ZERO", "NONNEGATIVE", "NONPOSITIVE", or "UNKNOWN".

sign-methods *Sign Properties*

Description

Determine if an expression is positive, negative, or zero.

Usage

```
is_zero(object)

is_nonneg(object)

is_nonpos(object)
```

Arguments

object	An Expression object.

Value

A logical value.

Examples

```
pos <- Constant(1)
neg <- Constant(-1)
zero <- Constant(0)
unknown <- Variable()

is_zero(pos)
is_zero(-zero)
is_zero(unknown)
is_zero(pos + neg)

is_nonneg(pos + zero)
is_nonneg(pos * neg)
is_nonneg(pos - neg)
is_nonneg(unknown)

is_nonpos(-pos)
is_nonpos(pos + neg)
is_nonpos(neg * zero)
is_nonpos(neg - pos)
```

`sign_from_args` *Atom Sign*

Description

Determine the sign of an atom based on its arguments.

Usage

```
sign_from_args(object)

## S4 method for signature 'Atom'
sign_from_args(object)
```

Arguments

`object`	An Atom object.

Value

A logical vector `c(is positive,is negative)` indicating the sign of the atom.

size *Size of Expression*

Description

The size of an expression.

Usage

```
size(object)

## S4 method for signature 'ListORExpr'
size(object)
```

Arguments

object	An Expression object.

Value

A vector with two elements `c(row,col)` representing the dimensions of the expression.

Examples

```
x <- Variable()
y <- Variable(3)
z <- Variable(3,2)

size(x)
size(y)
size(z)
size(x + y)
size(z - x)
```

size-methods *Size Properties*

Description

Determine if an expression is a scalar, vector, or matrix.

Usage

```
is_scalar(object)

is_vector(object)

is_matrix(object)
```

Arguments

`object`	An Expression object.

Value

A logical value.

Examples

```
x <- Variable()
y <- Variable(3)
z <- Variable(3,2)

is_scalar(x)
is_scalar(y)
is_scalar(x + y)

is_vector(x)
is_vector(y)
is_vector(2*z)

is_matrix(x)
is_matrix(y)
is_matrix(z)
is_matrix(z - x)
```

`SizeMetrics-class` *The SizeMetrics class.*

Description

This class contains various metrics regarding the problem size.

Usage

```
SizeMetrics(problem)
```

Arguments

`problem`	A Problem object.

Slots

`num_scalar_variables` The number of scalar variables in the problem.

`num_scalar_data` The number of constants used across all matrices and vectors in the problem. Some constants are not apparent when the problem is constructed. For example, the `sum_squares` expression is a wrapper for a `quad_over_lin` expression with a constant `1` in the denominator.

`num_scalar_eq_constr` The number of scalar equality constraints in the problem.

`num_scalar_leq_constr` The number of scalar inequality constraints in the problem.

`max_data_dimension` The longest dimension of any data block constraint or parameter.

`max_big_small_squared` The maximum value of (big)(small)^2 over all data blocks of the problem, where (big) is the larger dimension and (small) is the smaller dimension for each data block.

`SOC-class` *The SOC class.*

Description

This class represents a second-order cone constraint, i.e. $\|x\|_2 \leq t$.

Usage

```
SOC(t, X, axis = 2, id = NA_integer_)

## S4 method for signature 'SOC'
as.character(x)

## S4 method for signature 'SOC'
residual(object)

## S4 method for signature 'SOC'
get_data(object)

## S4 method for signature 'SOC'
format_constr(object, eq_constr, leq_constr, dims, solver)

## S4 method for signature 'SOC'
num_cones(object)

## S4 method for signature 'SOC'
size(object)

## S4 method for signature 'SOC'
cone_sizes(object)

## S4 method for signature 'SOC'
is_dcp(object)

## S4 method for signature 'SOC'
is_dgp(object)

## S4 method for signature 'SOC'
canonicalize(object)
```

Arguments

t	The scalar part of the second-order constraint.
X	A matrix whose rows/columns are each a cone.
axis	The dimension along which to slice: 1 indicates rows, and 2 indicates columns. The default is 2.
id	(Optional) A numeric value representing the constraint ID.
x, object	A SOC object.
eq_constr	A list of the equality constraints in the canonical problem.
leq_constr	A list of the inequality constraints in the canonical problem.
dims	A list with the dimensions of the conic constraints.
solver	A string representing the solver to be called.

Methods (by generic)

- `residual`: The residual of the second-order constraint.
- `get_data`: Information needed to reconstruct the object aside from the args.
- `format_constr`: Format SOC constraints as inequalities for the solver.
- `num_cones`: The number of elementwise cones.
- `size`: The number of entries in the combined cones.
- `cone_sizes`: The dimensions of the second-order cones.
- `is_dcp`: An SOC constraint is DCP if each of its arguments is affine.
- `is_dgp`: Is the constraint DGP?
- `canonicalize`: The canonicalization of the constraint.

Slots

`t` The scalar part of the second-order constraint.

`X` A matrix whose rows/columns are each a cone.

`axis` The dimension along which to slice: 1 indicates rows, and 2 indicates columns. The default is 2.

SOCAxis-class *The SOCAxis class.*

Description

This class represents a second-order cone constraint for each row/column. It Assumes t is a vector the same length as X's rows (columns) for axis == 1 (2).

Usage

```
SOCAxis(t, X, axis, id = NA_integer_)

## S4 method for signature 'SOCAxis'
as.character(x)

## S4 method for signature 'SOCAxis'
format_constr(object, eq_constr, leq_constr, dims, solver)

## S4 method for signature 'SOCAxis'
num_cones(object)

## S4 method for signature 'SOCAxis'
cone_sizes(object)

## S4 method for signature 'SOCAxis'
size(object)
```

Arguments

t	The scalar part of the second-order constraint.
X	A matrix whose rows/columns are each a cone.
axis	The dimension across which to take the slice: 1 indicates rows, and 2 indicates columns.
id	(Optional) A numeric value representing the constraint ID.
x, object	A SOCAxis object.
eq_constr	A list of the equality constraints in the canonical problem.
leq_constr	A list of the inequality constraints in the canonical problem.
dims	A list with the dimensions of the conic constraints.
solver	A string representing the solver to be called.

Methods (by generic)

- `format_constr`: Format SOC constraints as inequalities for the solver.
- `num_cones`: The number of elementwise cones.
- `cone_sizes`: The dimensions of a single cone.
- `size`: The dimensions of the (elementwise) second-order cones.

Slots

`t` The scalar part of the second-order constraint.

`x_elems` A list containing `X`, a matrix whose rows/columns are each a cone.

`axis` The dimension across which to take the slice: 1 indicates rows, and 2 indicates columns.

Solution-class *The Solution class.*

Description

This class represents a solution to an optimization problem.

Usage

```
## S4 method for signature 'Solution'
as.character(x)
```

Arguments

x	A Solution object.

SolverStats-class *The SolverStats class.*

Description

This class contains the miscellaneous information that is returned by a solver after solving, but that is not captured directly by the Problem object.

Usage

```
SolverStats(results_dict = list(), solver_name = NA_character_)
```

Arguments

results_dict	A list containing the results returned by the solver.
solver_name	The name of the solver.

Value

A list containing

`solver_name` The name of the solver.

`solve_time` The time (in seconds) it took for the solver to solve the problem.

`setup_time` The time (in seconds) it took for the solver to set up the problem.

`num_iters` The number of iterations the solver had to go through to find a solution.

Slots

solver_name The name of the solver.

solve_time The time (in seconds) it took for the solver to solve the problem.

setup_time The time (in seconds) it took for the solver to set up the problem.

num_iters The number of iterations the solver had to go through to find a solution.

SolvingChain-class *The SolvingChain class.*

Description

This class represents a reduction chain that ends with a solver.

Usage

```
## S4 method for signature 'SolvingChain,Chain'
prepend(object, chain)

## S4 method for signature 'SolvingChain,Problem'
reduction_solve(
  object,
  problem,
  warm_start,
  verbose,
  feastol,
  reltol,
  abstol,
  num_iter,
  solver_opts
)

## S4 method for signature 'SolvingChain'
reduction_solve_via_data(
  object,
  problem,
  data,
  warm_start,
  verbose,
  feastol,
  reltol,
  abstol,
  num_iter,
  solver_opts
)
```

Arguments

object	A SolvingChain object.
chain	A Chain to prepend.
problem	The problem to solve.
warm_start	A boolean of whether to warm start the solver.
verbose	A boolean of whether to enable solver verbosity.
feastol	The feasible tolerance.
reltol	The relative tolerance.
abstol	The absolute tolerance.
num_iter	The maximum number of iterations.
solver_opts	A list of Solver specific options
data	Data for the solver.

Methods (by generic)

- `prepend`: Create and return a new SolvingChain by concatenating chain with this instance.
- `reduction_solve`: Applies each reduction in the chain to the problem, solves it, and then inverts the chain to return a solution of the supplied problem.
- `reduction_solve_via_data`: Solves the problem using the data output by the an apply invocation.

---

sqrt,Expression-method *Square Root*

Description

The elementwise square root.

Usage

```
## S4 method for signature 'Expression'
sqrt(x)
```

Arguments

x	An Expression.

Value

An Expression representing the square root of the input. A <- Variable(2,2) val <- cbind(c(2,4), c(16,1)) prob <- Problem(Maximize(sqrt(A)[1,2]), list(A == val)) result <- solve(prob) result$value `square,Expression-method` *Square*

Description

The elementwise square.

Usage

```
## S4 method for signature 'Expression'
square(x)
```

Arguments

x	An Expression.

Value

An Expression representing the square of the input. A <- Variable(2,2) val <- cbind(c(2,4), c(16,1)) prob <- Problem(Minimize(square(A)[1,2]), list(A == val)) result <- solve(prob) result$value

`SumEntries-class` *The SumEntries class.*

Description

This class represents the sum of all entries in a vector or matrix.

Usage

```
SumEntries(expr, axis = NA_real_, keepdims = FALSE)

## S4 method for signature 'SumEntries'
to_numeric(object, values)

## S4 method for signature 'SumEntries'
is_atom_log_log_convex(object)

## S4 method for signature 'SumEntries'
is_atom_log_log_concave(object)

## S4 method for signature 'SumEntries'
graph_implementation(object, arg_objs, dim, data = NA_real_)
```

Arguments

`expr`	An Expression representing a vector or matrix.
`axis`	(Optional) The dimension across which to apply the function: `1` indicates rows, `2` indicates columns, and `NA` indicates rows and columns. The default is `NA`.
`keepdims`	(Optional) Should dimensions be maintained when applying the atom along an axis? If `FALSE`, result will be collapsed into an $nx1$ column vector. The default is `FALSE`.
`object`	A SumEntries object.
`values`	A list of arguments to the atom.
`arg_objs`	A list of linear expressions for each argument.
`dim`	A vector representing the dimensions of the resulting expression.
`data`	A list of additional data required by the atom.

Methods (by generic)

- `to_numeric`: Sum the entries along the specified axis.
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `graph_implementation`: The graph implementation of the atom.

Slots

`expr` An Expression representing a vector or matrix.

`axis` (Optional) The dimension across which to apply the function: `1` indicates rows, `2` indicates columns, and `NA` indicates rows and columns. The default is `NA`.

`keepdims` (Optional) Should dimensions be maintained when applying the atom along an axis? If `FALSE`, result will be collapsed into an $nx1$ column vector. The default is `FALSE`.

`SumLargest-class` *The SumLargest class.*

Description

The sum of the largest k values of a matrix.

Usage

```
SumLargest(x, k)

## S4 method for signature 'SumLargest'
to_numeric(object, values)

## S4 method for signature 'SumLargest'
```

```
validate_args(object)

## S4 method for signature 'SumLargest'
dim_from_args(object)

## S4 method for signature 'SumLargest'
sign_from_args(object)

## S4 method for signature 'SumLargest'
is_atom_convex(object)

## S4 method for signature 'SumLargest'
is_atom_concave(object)

## S4 method for signature 'SumLargest'
is_incr(object, idx)

## S4 method for signature 'SumLargest'
is_decr(object, idx)

## S4 method for signature 'SumLargest'
get_data(object)

## S4 method for signature 'SumLargest'
.grad(object, values)
```

Arguments

`x`	An Expression or numeric matrix.
`k`	The number of largest values to sum over.
`object`	A SumLargest object.
`values`	A list of numeric values for the arguments
`idx`	An index into the atom.

Methods (by generic)

- `to_numeric`: The sum of the `k` largest entries of the vector or matrix.
- `validate_args`: Check that `k` is a positive integer.
- `dim_from_args`: The atom is a scalar.
- `sign_from_args`: The sign of the atom.
- `is_atom_convex`: The atom is convex.
- `is_atom_concave`: The atom is not concave.
- `is_incr`: The atom is weakly increasing in every argument.
- `is_decr`: The atom is not weakly decreasing in any argument.
- `get_data`: A list containing `k`.
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable

Slots

- `x` An Expression or numeric matrix.
- `k` The number of largest values to sum over.

`SumSmallest` *The SumSmallest atom.*

Description

The sum of the smallest k values of a matrix.

Usage

```
SumSmallest(x, k)
```

Arguments

`x`	An Expression or numeric matrix.
`k`	The number of smallest values to sum over.

Value

Sum of the smlalest k values

`SumSquares` *The SumSquares atom.*

Description

The sum of the squares of the entries.

Usage

```
SumSquares(expr)
```

Arguments

`expr`	An Expression or numeric matrix.

Value

Sum of the squares of the entries in the expression.

sum_entries *Sum of Entries*

Description

The sum of entries in a vector or matrix.

Usage

```
sum_entries(expr, axis = NA_real_, keepdims = FALSE)

## S3 method for class 'Expression'
sum(..., na.rm = FALSE)
```

Arguments

expr	An Expression, vector, or matrix.
axis	(Optional) The dimension across which to apply the function: 1 indicates rows, 2 indicates columns, and NA indicates rows and columns. The default is NA.
keepdims	(Optional) Should dimensions be maintained when applying the atom along an axis? If FALSE, result will be collapsed into an $nx1$ column vector. The default is FALSE.
...	Numeric scalar, vector, matrix, or Expression objects.
na.rm	(Unimplemented) A logical value indicating whether missing values should be removed.

Value

An Expression representing the sum of the entries of the input.

Examples

```
x <- Variable(2)
prob <- Problem(Minimize(sum_entries(x)), list(t(x) >= matrix(c(1,2), nrow = 1, ncol = 2)))
result <- solve(prob)
result$value
result$getValue(x)

C <- Variable(3,2)
prob <- Problem(Maximize(sum_entries(C)), list(C[2:3,] <= 2, C[1,] == 1))
result <- solve(prob)
result$value
result$getValue(C)
x <- Variable(2)
prob <- Problem(Minimize(sum_entries(x)), list(t(x) >= matrix(c(1,2), nrow = 1, ncol = 2)))
result <- solve(prob)
result$value
```

```
result$getValue(x)

C <- Variable(3,2)
prob <- Problem(Maximize(sum_entries(C)), list(C[2:3,] <= 2, C[1,] == 1))
result <- solve(prob)
result$value
result$getValue(C)
```

---

sum_largest *Sum of Largest Values*

Description

The sum of the largest k values of a vector or matrix.

Usage

```
sum_largest(x, k)
```

Arguments

x	An Expression, vector, or matrix.
k	The number of largest values to sum over.

Value

An Expression representing the sum of the largest k values of the input.

Examples

```
set.seed(122)
m <- 300
n <- 9
X <- matrix(stats::rnorm(m*n), nrow = m, ncol = n)
X <- cbind(rep(1,m), X)
b <- c(0, 0.8, 0, 1, 0.2, 0, 0.4, 1, 0, 0.7)
y <- X %*% b + stats::rnorm(m)

beta <- Variable(n+1)
obj <- sum_largest((y - X %*% beta)^2, 100)
prob <- Problem(Minimize(obj))
result <- solve(prob)
result$getValue(beta)
```

sum_smallest *Sum of Smallest Values*

Description

The sum of the smallest k values of a vector or matrix.

Usage

```
sum_smallest(x, k)
```

Arguments

x	An Expression, vector, or matrix.
k	The number of smallest values to sum over.

Value

An Expression representing the sum of the smallest k values of the input.

Examples

```
set.seed(1323)
m <- 300
n <- 9
X <- matrix(stats::rnorm(m*n), nrow = m, ncol = n)
X <- cbind(rep(1,m), X)
b <- c(0, 0.8, 0, 1, 0.2, 0, 0.4, 1, 0, 0.7)
factor <- 2*rbinom(m, size = 1, prob = 0.8) - 1
y <- factor * (X %*% b) + stats::rnorm(m)

beta <- Variable(n+1)
obj <- sum_smallest(y - X %*% beta, 200)
prob <- Problem(Maximize(obj), list(0 <= beta, beta <= 1))
result <- solve(prob)
result$getValue(beta)
```

sum_squares *Sum of Squares*

Description

The sum of the squared entries in a vector or matrix.

Usage

```
sum_squares(expr)
```

Arguments

expr	An Expression, vector, or matrix.

Value

An Expression representing the sum of squares of the input.

Examples

```
set.seed(212)
m <- 30
n <- 20
A <- matrix(stats::rnorm(m*n), nrow = m, ncol = n)
b <- matrix(stats::rnorm(m), nrow = m, ncol = 1)

x <- Variable(n)
obj <- Minimize(sum_squares(A %*% x - b))
constr <- list(0 <= x, x <= 1)
prob <- Problem(obj, constr)
result <- solve(prob)

result$value
result$getValue(x)
result$getDualValue(constr[[1]])
```

SymbolicQuadForm-class *The SymbolicQuadForm class.*

Description

The SymbolicQuadForm class.

Usage

```
SymbolicQuadForm(x, P, expr)

## S4 method for signature 'SymbolicQuadForm'
dim_from_args(object)

## S4 method for signature 'SymbolicQuadForm'
sign_from_args(object)

## S4 method for signature 'SymbolicQuadForm'
get_data(object)

## S4 method for signature 'SymbolicQuadForm'
is_atom_convex(object)
```

```
## S4 method for signature 'SymbolicQuadForm'
is_atom_concave(object)

## S4 method for signature 'SymbolicQuadForm'
is_incr(object, idx)

## S4 method for signature 'SymbolicQuadForm'
is_decr(object, idx)

## S4 method for signature 'SymbolicQuadForm'
is_quadratic(object)

## S4 method for signature 'SymbolicQuadForm'
.grad(object, values)
```

Arguments

`x`	An Expression or numeric vector.
`P`	An Expression, numeric matrix, or vector.
`expr`	The original Expression.
`object`	A SymbolicQuadForm object.
`idx`	An index into the atom.
`values`	A list of numeric values for the arguments

Methods (by generic)

- `dim_from_args`: The dimensions of the atom.
- `sign_from_args`: The sign (is positive, is negative) of the atom.
- `get_data`: The original expression.
- `is_atom_convex`: Is the original expression convex?
- `is_atom_concave`: Is the original expression concave?
- `is_incr`: Is the original expression weakly increasing in argument `idx`?
- `is_decr`: Is the original expression weakly decreasing in argument `idx`?
- `is_quadratic`: The atom is quadratic.
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable

Slots

`x` An Expression or numeric vector.

`P` An Expression, numeric matrix, or vector.

`original_expression` The original Expression.

`t.Expression` *Matrix Transpose*

Description

The transpose of a matrix.

Usage

```
## S3 method for class 'Expression'
t(x)

## S4 method for signature 'Expression'
t(x)
```

Arguments

`x`	An Expression representing a matrix.

Value

An Expression representing the transposed matrix.

Examples

```
x <- Variable(3, 4)
t(x)
```

`TotalVariation` *The TotalVariation atom.*

Description

The total variation of a vector, matrix, or list of matrices. Uses L1 norm of discrete gradients for vectors and L2 norm of discrete gradients for matrices.

Usage

```
TotalVariation(value, ...)
```

Arguments

`value`	An Expression representing the value to take the total variation of.
`...`	Additional matrices extending the third dimension of value.

Value

An expression representing the total variation.

to_numeric *Numeric Value of Atom*

Description

Returns the numeric value of the atom evaluated on the specified arguments.

Usage

```
to_numeric(object, values)
```

Arguments

object	An Atom object.
values	A list of arguments to the atom.

Value

A numeric scalar, vector, or matrix.

Trace-class *The Trace class.*

Description

This class represents the sum of the diagonal entries in a matrix.

Usage

```
Trace(expr)

## S4 method for signature 'Trace'
to_numeric(object, values)

## S4 method for signature 'Trace'
validate_args(object)

## S4 method for signature 'Trace'
dim_from_args(object)

## S4 method for signature 'Trace'
is_atom_log_log_convex(object)

## S4 method for signature 'Trace'
is_atom_log_log_concave(object)

## S4 method for signature 'Trace'
graph_implementation(object, arg_objs, dim, data = NA_real_)
```

Arguments

expr	An Expression representing a matrix.
object	A Trace object.
values	A list of arguments to the atom.
arg_objs	A list of linear expressions for each argument.
dim	A vector representing the dimensions of the resulting expression.
data	A list of additional data required by the atom.

Methods (by generic)

- `to_numeric`: Sum the diagonal entries.
- `validate_args`: Check the argument is a square matrix.
- `dim_from_args`: The atom is a scalar.
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `graph_implementation`: The graph implementation of the atom.

Slots

`expr` An Expression representing a matrix.

`Transpose-class` *The Transpose class.*

Description

This class represents the matrix transpose.

Usage

```
## S4 method for signature 'Transpose'
to_numeric(object, values)

## S4 method for signature 'Transpose'
is_symmetric(object)

## S4 method for signature 'Transpose'
is_hermitian(object)

## S4 method for signature 'Transpose'
dim_from_args(object)

## S4 method for signature 'Transpose'
is_atom_log_log_convex(object)
```

```
## S4 method for signature 'Transpose'
is_atom_log_log_concave(object)

## S4 method for signature 'Transpose'
get_data(object)

## S4 method for signature 'Transpose'
graph_implementation(object, arg_objs, dim, data = NA_real_)
```

Arguments

object	A Transpose object.
values	A list of arguments to the atom.
arg_objs	A list of linear expressions for each argument.
dim	A vector representing the dimensions of the resulting expression.
data	A list of additional data required by the atom.

Methods (by generic)

- `to_numeric`: The transpose of the given value.
- `is_symmetric`: Is the expression symmetric?
- `is_hermitian`: Is the expression hermitian?
- `dim_from_args`: The dimensions of the atom.
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `get_data`: Returns the axes for transposition.
- `graph_implementation`: The graph implementation of the atom.

---

tri_to_full — *Expands lower triangular to full matrix.*

Description

Expands lower triangular to full matrix.

Usage

```
tri_to_full(lower_tri, n)
```

Arguments

lower_tri	A matrix representing the lower triangular part of the matrix, stacked in column-major order
n	The number of rows (columns) in the full square matrix.

Value

A matrix that is the scaled expansion of the lower triangular matrix.

`tv` *Total Variation*

Description

The total variation of a vector, matrix, or list of matrices. Uses L1 norm of discrete gradients for vectors and L2 norm of discrete gradients for matrices.

Usage

```
tv(value, ...)
```

Arguments

`value`	An Expression, vector, or matrix.
`...`	(Optional) Expression objects or numeric constants that extend the third dimension of value.

Value

An Expression representing the total variation of the input.

Examples

```
rows <- 10
cols <- 10
Uorig <- matrix(sample(0:255, size = rows * cols, replace = TRUE), nrow = rows, ncol = cols)

# Known is 1 if the pixel is known, 0 if the pixel was corrupted
Known <- matrix(0, nrow = rows, ncol = cols)
for(i in 1:rows) {
   for(j in 1:cols) {
      if(stats::runif(1) > 0.7)
         Known[i,j] <- 1
   }
}
Ucorr <- Known %*% Uorig

# Recover the original image using total variation in-painting
U <- Variable(rows, cols)
obj <- Minimize(tv(U))
constraints <- list(Known * U == Known * Ucorr)
prob <- Problem(obj, constraints)
result <- solve(prob, solver = "SCS")
result$getValue(U)
```

UnaryOperator-class *The UnaryOperator class.*

Description

This base class represents expressions involving unary operators.

Usage

```
## S4 method for signature 'UnaryOperator'
name(x)

## S4 method for signature 'UnaryOperator'
to_numeric(object, values)
```

Arguments

x, object	A UnaryOperator object.
values	A list of arguments to the atom.

Methods (by generic)

- name: Returns the expression in string form.
- to_numeric: Applies the unary operator to the value.

Slots

expr The Expression that is being operated upon.

op_name A character string indicating the unary operation.

unpack_results *Parse output from a solver and updates problem state*

Description

Updates problem status, problem value, and primal and dual variable values

Usage

```
unpack_results(object, solution, chain, inverse_data)
```

Arguments

`object`	A Problem object.
`solution`	A Solution object.
`chain`	The corresponding solving Chain.
`inverse_data`	A InverseData object or list containing data necessary for the inversion.

Value

A list containing the solution to the problem:

`status` The status of the solution. Can be "optimal", "optimal_inaccurate", "infeasible", "infeasible_inaccurate", "unbounded", "unbounded_inaccurate", or "solver_error".

`value` The optimal value of the objective function.

`solver` The name of the solver.

`solve_time` The time (in seconds) it took for the solver to solve the problem.

`setup_time` The time (in seconds) it took for the solver to set up the problem.

`num_iters` The number of iterations the solver had to go through to find a solution.

`getValue` A function that takes a Variable object and retrieves its primal value.

`getDualValue` A function that takes a Constraint object and retrieves its dual value(s).

Examples

```
## Not run:
x <- Variable(2)
obj <- Minimize(x[1] + cvxr_norm(x, 1))
constraints <- list(x >= 2)
prob1 <- Problem(obj, constraints)
# Solve with ECOS.
ecos_data <- get_problem_data(prob1, "ECOS")
# Call ECOS solver interface directly
ecos_output <- ECOSolveR::ECOS_csolve(
                           c = ecos_data[["c"]],
                           G = ecos_data[["G"]],
                           h = ecos_data[["h"]],
                           dims = ecos_data[["dims"]],
                           A = ecos_data[["A"]],
                           b = ecos_data[["b"]]
                         )
# Unpack raw solver output.
res1 <- unpack_results(prob1, "ECOS", ecos_output)
# Without DCP validation (so be sure of your math), above is equivalent to:
# res1 <- solve(prob1, solver = "ECOS")
X <- Variable(2,2, PSD = TRUE)
Fmat <- rbind(c(1,0), c(0,-1))
obj <- Minimize(sum_squares(X - Fmat))
prob2 <- Problem(obj)
scs_data <- get_problem_data(prob2, "SCS")
scs_output <- scs::scs(
```

```
                    A = scs_data[['A']],
                    b = scs_data[['b']],
                    obj = scs_data[['c']],
                    cone = scs_data[['dims']]
                )
res2 <- unpack_results(prob2, "SCS", scs_output)
# Without DCP validation (so be sure of your math), above is equivalent to:
# res2 <- solve(prob2, solver = "SCS")

## End(Not run)
```

UpperTri-class *The UpperTri class.*

Description

The vectorized strictly upper triagonal entries of a matrix.

Usage

```
UpperTri(expr)

## S4 method for signature 'UpperTri'
to_numeric(object, values)

## S4 method for signature 'UpperTri'
validate_args(object)

## S4 method for signature 'UpperTri'
dim_from_args(object)

## S4 method for signature 'UpperTri'
is_atom_log_log_convex(object)

## S4 method for signature 'UpperTri'
is_atom_log_log_concave(object)

## S4 method for signature 'UpperTri'
graph_implementation(object, arg_objs, dim, data = NA_real_)
```

Arguments

expr	An Expression or numeric matrix.
object	An UpperTri object.
values	A list of arguments to the atom.
arg_objs	A list of linear expressions for each argument.
dim	A vector representing the dimensions of the resulting expression.
data	A list of additional data required by the atom.

Methods (by generic)

- `to_numeric`: Vectorize the upper triagonal entries.
- `validate_args`: Check the argument is a square matrix.
- `dim_from_args`: The dimensions of the atom.
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `graph_implementation`: The graph implementation of the atom.

Slots

`expr` An Expression or numeric matrix.

---

upper_tri *Upper Triangle of a Matrix*

Description

The vectorized strictly upper triangular entries of a matrix.

Usage

```
upper_tri(expr)
```

Arguments

`expr`	An Expression or matrix.

Value

An Expression representing the upper triangle of the input.

Examples

```
C <- Variable(3,3)
val <- cbind(3:5, 6:8, 9:11)
prob <- Problem(Maximize(upper_tri(C)[3,1]), list(C == val))
result <- solve(prob)
result$value
result$getValue(upper_tri(C))
```

validate_args *Validate Arguments*

Description

Validate an atom's arguments, returning an error if any are invalid.

Usage

```
validate_args(object)
```

Arguments

object	An Atom object.

validate_val *Validate Value*

Description

Check that the value satisfies a Leaf's symbolic attributes.

Usage

```
validate_val(object, val)
```

Arguments

object	A Leaf object.
val	The assigned value.

Value

The value converted to proper matrix type.

value-methods *Get or Set Value*

Description

Get or set the value of a variable, parameter, expression, or problem.

Usage

```
value(object)

value(object) <- value
```

Arguments

object	A Variable, Parameter, Expression, or Problem object.
value	A numeric scalar, vector, or matrix to assign to the object.

Value

The numeric value of the variable, parameter, or expression. If any part of the mathematical object is unknown, return NA.

Examples

```
lambda <- Parameter()
value(lambda)

value(lambda) <- 5
value(lambda)
```

Variable-class *The Variable class.*

Description

This class represents an optimization variable.

Usage

```
Variable(rows = NULL, cols = NULL, name = NA_character_, ...)

## S4 method for signature 'Variable'
as.character(x)

## S4 method for signature 'Variable'
```

```
name(x)

## S4 method for signature 'Variable'
value(object)

## S4 method for signature 'Variable'
grad(object)

## S4 method for signature 'Variable'
variables(object)

## S4 method for signature 'Variable'
canonicalize(object)
```

Arguments

`rows`	The number of rows in the variable.
`cols`	The number of columns in the variable.
`name`	(Optional) A character string representing the name of the variable.
`...`	(Optional) Additional attribute arguments. See Leaf for details.
`x, object`	A Variable object.

Methods (by generic)

- `name`: The name of the variable.
- `value`: Get the value of the variable.
- `grad`: The sub/super-gradient of the variable represented as a sparse matrix.
- `variables`: Returns itself as a variable.
- `canonicalize`: The canonical form of the variable.

Slots

`dim` The dimensions of the variable.

`name` (Optional) A character string representing the name of the variable.

Examples

```
x <- Variable(3, name = "x0") ## 3-int variable
y <- Variable(3, 3, name = "y0") # Matrix variable
as.character(y)
id(y)
is_nonneg(x)
is_nonpos(x)
size(y)
name(y)
value(y) <- matrix(1:9, nrow = 3)
value(y)
```

```
grad(y)
variables(y)
canonicalize(y)
```

---

vec *Vectorization of a Matrix*

Description

Flattens a matrix into a vector in column-major order.

Usage

```
vec(X)
```

Arguments

X	An Expression or matrix.

Value

An Expression representing the vectorized matrix.

Examples

```
A <- Variable(2,2)
c <- 1:4
expr <- vec(A)
obj <- Minimize(t(expr) %*% c)
constraints <- list(A == cbind(c(-1,-2), c(3,4)))
prob <- Problem(obj, constraints)
result <- solve(prob)
result$value
result$getValue(expr)
```

---

vectorized_lower_tri_to_mat *Turns symmetric 2D array into a lower triangular matrix*

Description

Turns symmetric 2D array into a lower triangular matrix

Usage

```
vectorized_lower_tri_to_mat(v, dim)
```

Arguments

`v`	A list of length (dim * (dim + 1) / 2).
`dim`	The number of rows (equivalently, columns) in the output array.

Value

Return the symmetric 2D array defined by taking "v" to specify its lower triangular matrix.

---

vstack *Vertical Concatenation*

Description

The vertical concatenation of expressions. This is equivalent to `rbind` when applied to objects with the same number of columns.

Usage

```
vstack(...)
```

Arguments

`...`	Expression objects, vectors, or matrices. All arguments must have the same number of columns.

Value

An Expression representing the concatenated inputs.

Examples

```
x <- Variable(2)
y <- Variable(3)
c <- matrix(1, nrow = 1, ncol = 5)
prob <- Problem(Minimize(c %*% vstack(x, y)), list(x == c(1,2), y == c(3,4,5)))
result <- solve(prob)
result$value

c <- matrix(1, nrow = 1, ncol = 4)
prob <- Problem(Minimize(c %*% vstack(x, x)), list(x == c(1,2)))
result <- solve(prob)
result$value

A <- Variable(2,2)
C <- Variable(3,2)
c <- matrix(1, nrow = 2, ncol = 2)
prob <- Problem(Minimize(sum(vstack(A, C))), list(A >= 2*c, C == -2))
result <- solve(prob)
result$value
```

```
B <- Variable(2,2)
c <- matrix(1, nrow = 1, ncol = 2)
prob <- Problem(Minimize(sum(vstack(c %*% A, c %*% B))), list(A >= 2, B == -2))
result <- solve(prob)
result$value
```

VStack-class *The VStack class.*

Description

Vertical concatenation of values.

Usage

```
VStack(...)

## S4 method for signature 'VStack'
to_numeric(object, values)

## S4 method for signature 'VStack'
validate_args(object)

## S4 method for signature 'VStack'
dim_from_args(object)

## S4 method for signature 'VStack'
is_atom_log_log_convex(object)

## S4 method for signature 'VStack'
is_atom_log_log_concave(object)

## S4 method for signature 'VStack'
graph_implementation(object, arg_objs, dim, data = NA_real_)
```

Arguments

...	Expression objects or matrices. All arguments must have the same number of columns.
object	A VStack object.
values	A list of arguments to the atom.
arg_objs	A list of linear expressions for each argument.
dim	A vector representing the dimensions of the resulting expression.
data	A list of additional data required by the atom.

Methods (by generic)

- `to_numeric`: Vertically concatenate the values using `rbind`.
- `validate_args`: Check all arguments have the same width.
- `dim_from_args`: The dimensions of the atom.
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `graph_implementation`: The graph implementation of the atom.

Slots

`...` Expression objects or matrices. All arguments must have the same number of columns.

`Wrap-class` *The Wrap class.*

Description

This virtual class represents a no-op wrapper to assert properties.

Usage

```
## S4 method for signature 'Wrap'
to_numeric(object, values)

## S4 method for signature 'Wrap'
dim_from_args(object)

## S4 method for signature 'Wrap'
is_atom_log_log_convex(object)

## S4 method for signature 'Wrap'
is_atom_log_log_concave(object)

## S4 method for signature 'Wrap'
graph_implementation(object, arg_objs, dim, data = NA_real_)
```

Arguments

`object`	A Wrap object.
`values`	A list of arguments to the atom.
`arg_objs`	A list of linear expressions for each argument.
`dim`	A vector representing the dimensions of the resulting expression.
`data`	A list of additional data required by the atom.

Methods (by generic)

- `to_numeric`: Returns the input value.
- `dim_from_args`: The dimensions of the atom.
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `graph_implementation`: The graph implementation of the atom.

ZeroConstraint-class *The ZeroConstraint class*

Description

The ZeroConstraint class

Usage

```
## S4 method for signature 'ZeroConstraint'
name(x)

## S4 method for signature 'ZeroConstraint'
dim(x)

## S4 method for signature 'ZeroConstraint'
is_dcp(object)

## S4 method for signature 'ZeroConstraint'
is_dgp(object)

## S4 method for signature 'ZeroConstraint'
residual(object)

## S4 method for signature 'ZeroConstraint'
canonicalize(object)
```

Arguments

`x, object`	A ZeroConstraint object.

Methods (by generic)

- `name`: The string representation of the constraint.
- `dim`: The dimensions of the constrained expression.
- `is_dcp`: Is the constraint DCP?
- `is_dgp`: Is the constraint DGP?
- `residual`: The residual of a constraint
- `canonicalize`: The graph implementation of the object.

`[,Expression,index,missing,ANY-method`
The SpecialIndex class.

Description

This class represents indexing using logical indexing or a list of indices into a matrix.

Usage

```
## S4 method for signature 'Expression,index,missing,ANY'
x[i, j, ..., drop = TRUE]

## S4 method for signature 'Expression,missing,index,ANY'
x[i, j, ..., drop = TRUE]

## S4 method for signature 'Expression,index,index,ANY'
x[i, j, ..., drop = TRUE]

## S4 method for signature 'Expression,matrix,index,ANY'
x[i, j, ..., drop = TRUE]

## S4 method for signature 'Expression,index,matrix,ANY'
x[i, j, ..., drop = TRUE]

## S4 method for signature 'Expression,matrix,matrix,ANY'
x[i, j, ..., drop = TRUE]

## S4 method for signature 'Expression,matrix,missing,ANY'
x[i, j, ..., drop = TRUE]

SpecialIndex(expr, key)

## S4 method for signature 'SpecialIndex'
name(x)

## S4 method for signature 'SpecialIndex'
is_atom_log_log_convex(object)

## S4 method for signature 'SpecialIndex'
is_atom_log_log_concave(object)

## S4 method for signature 'SpecialIndex'
get_data(object)

## S4 method for signature 'SpecialIndex'
.grad(object)
```

Arguments

x, object	An Index object.
i, j	The row and column indices of the slice.
...	(Unimplemented) Optional arguments.
drop	(Unimplemented) A logical value indicating whether the result should be coerced to the lowest possible dimension.
expr	An Expression representing a vector or matrix.
key	A list containing the start index, end index, and step size of the slice.

Methods (by generic)

- name: Returns the index in string form.
- is_atom_log_log_convex: Is the atom log-log convex?
- is_atom_log_log_concave: Is the atom log-log concave?
- get_data: A list containing key.
- .grad: Gives the (sub/super)gradient of the atom w.r.t. each variable

Slots

expr An Expression representing a vector or matrix.

key A list containing the start index, end index, and step size of the slice.

[,Expression,missing,missing,ANY-method
The Index class.

Description

This class represents indexing or slicing into a matrix.

Usage

```
## S4 method for signature 'Expression,missing,missing,ANY'
x[i, j, ..., drop = TRUE]

## S4 method for signature 'Expression,numeric,missing,ANY'
x[i, j, ..., drop = TRUE]

## S4 method for signature 'Expression,missing,numeric,ANY'
x[i, j, ..., drop = TRUE]

## S4 method for signature 'Expression,numeric,numeric,ANY'
x[i, j, ..., drop = TRUE]
```

```
Index(expr, key)

## S4 method for signature 'Index'
to_numeric(object, values)

## S4 method for signature 'Index'
dim_from_args(object)

## S4 method for signature 'Index'
is_atom_log_log_convex(object)

## S4 method for signature 'Index'
is_atom_log_log_concave(object)

## S4 method for signature 'Index'
get_data(object)

## S4 method for signature 'Index'
graph_implementation(object, arg_objs, dim, data = NA_real_)

## S4 method for signature 'SpecialIndex'
to_numeric(object, values)

## S4 method for signature 'SpecialIndex'
dim_from_args(object)
```

Arguments

x	A Expression object.
i, j	The row and column indices of the slice.
...	(Unimplemented) Optional arguments.
drop	(Unimplemented) A logical value indicating whether the result should be coerced to the lowest possible dimension.
expr	An Expression representing a vector or matrix.
key	A list containing the start index, end index, and step size of the slice.
object	An Index object.
values	A list of arguments to the atom.
arg_objs	A list of linear expressions for each argument.
dim	A vector representing the dimensions of the resulting expression.
data	A list of additional data required by the atom.

Methods (by generic)

- `to_numeric`: The index/slice into the given value.
- `dim_from_args`: The dimensions of the atom.

- is_atom_log_log_convex: Is the atom log-log convex?
- is_atom_log_log_concave: Is the atom log-log concave?
- get_data: A list containing key.
- graph_implementation: The graph implementation of the atom.
- to_numeric: The index/slice into the given value.
- dim_from_args: The dimensions of the atom.

Slots

expr An Expression representing a vector or matrix.

key A list containing the start index, end index, and step size of the slice.

%*%,Expression,Expression-method
The MulExpression class.

Description

This class represents the matrix product of two linear expressions. See Multiply for the elementwise product.

Usage

```
## S4 method for signature 'Expression,Expression'
x %*% y

## S4 method for signature 'Expression,ConstVal'
x %*% y

## S4 method for signature 'ConstVal,Expression'
x %*% y

## S4 method for signature 'MulExpression'
to_numeric(object, values)

## S4 method for signature 'MulExpression'
dim_from_args(object)

## S4 method for signature 'MulExpression'
is_atom_convex(object)

## S4 method for signature 'MulExpression'
is_atom_concave(object)

## S4 method for signature 'MulExpression'
```

```
is_atom_log_log_convex(object)

## S4 method for signature 'MulExpression'
is_atom_log_log_concave(object)

## S4 method for signature 'MulExpression'
is_incr(object, idx)

## S4 method for signature 'MulExpression'
is_decr(object, idx)

## S4 method for signature 'MulExpression'
.grad(object, values)

## S4 method for signature 'MulExpression'
graph_implementation(object, arg_objs, dim, data = NA_real_)
```

Arguments

x, y	The Expression objects or numeric constants to multiply.
object	A MulExpression object.
values	A list of numeric values for the arguments
idx	An index into the atom.
arg_objs	A list of linear expressions for each argument.
dim	A vector representing the dimensions of the resulting expression.
data	A list of additional data required by the atom.

Methods (by generic)

- `to_numeric`: Matrix multiplication.
- `dim_from_args`: The (row, col) dimensions of the expression.
- `is_atom_convex`: Multiplication is convex (affine) in its arguments only if one of the arguments is constant.
- `is_atom_concave`: If the multiplication atom is convex, then it is affine.
- `is_atom_log_log_convex`: Is the atom log-log convex?
- `is_atom_log_log_concave`: Is the atom log-log concave?
- `is_incr`: Is the left-hand expression positive?
- `is_decr`: Is the left-hand expression negative?
- `.grad`: Gives the (sub/super)gradient of the atom w.r.t. each variable
- `graph_implementation`: The graph implementation of the expression.

See Also

Multiply

%>>% *The PSDConstraint class.*

Description

This class represents the positive semidefinite constraint, $\frac{1}{2}(X + X^T) \succeq 0$, i.e. $z^T(X + X^T)z \geq 0$ for all z.

Usage

```
e1 %>>% e2

e1 %<<% e2

## S4 method for signature 'Expression,Expression'
e1 %>>% e2

## S4 method for signature 'Expression,ConstVal'
e1 %>>% e2

## S4 method for signature 'ConstVal,Expression'
e1 %>>% e2

## S4 method for signature 'Expression,Expression'
e1 %<<% e2

## S4 method for signature 'Expression,ConstVal'
e1 %<<% e2

## S4 method for signature 'ConstVal,Expression'
e1 %<<% e2

PSDConstraint(expr, id = NA_integer_)

## S4 method for signature 'PSDConstraint'
name(x)

## S4 method for signature 'PSDConstraint'
is_dcp(object)

## S4 method for signature 'PSDConstraint'
is_dgp(object)

## S4 method for signature 'PSDConstraint'
residual(object)

## S4 method for signature 'PSDConstraint'
```

```
canonicalize(object)
```

Arguments

`e1, e2`	The Expression objects or numeric constants to compare.
`expr`	An Expression, numeric element, vector, or matrix representing X.
`id`	(Optional) A numeric value representing the constraint ID.
`x, object`	A PSDConstraint object.

Methods (by generic)

- `name`: The string representation of the constraint.
- `is_dcp`: The constraint is DCP if the left-hand and right-hand expressions are affine.
- `is_dgp`: Is the constraint DGP?
- `residual`: A Expression representing the residual of the constraint.
- `canonicalize`: The graph implementation of the object. Marks the top level constraint as the `dual_holder` so the dual value will be saved to the PSDConstraint.

Slots

`expr` An Expression, numeric element, vector, or matrix representing X.

`^,Expression,numeric-method`

Elementwise Power

Description

Raises each element of the input to the power p. If `expr` is a CVXR expression, then `expr^p` is equivalent to `power(expr,p)`.

Usage

```
## S4 method for signature 'Expression,numeric'
e1 ^ e2

power(x, p, max_denom = 1024)
```

Arguments

`e1`	An Expression object to exponentiate.
`e2`	The power of the exponential. Must be a numeric scalar.
`x`	An Expression, vector, or matrix.
`p`	A scalar value indicating the exponential power.
`max_denom`	The maximum denominator considered in forming a rational approximation of `p`.

Details

For $p = 0$ and $f(x) = 1$, this function is constant and positive. For $p = 1$ and $f(x) = x$, this function is affine, increasing, and the same sign as x. For $p = 2, 4, 8, \ldots$ and $f(x) = |x|^p$, this function is convex, positive, with signed monotonicity. For $p < 0$ and $f(x) =$

- x^p for $x > 0$
- $+\infty x \leq 0$

, this function is convex, decreasing, and positive. For $0 < p < 1$ and $f(x) =$

- x^p for $x \geq 0$
- $-\infty x < 0$

, this function is concave, increasing, and positivea. For $p > 1, p \neq 2, 4, 8, \ldots$ and $f(x) =$

- x^p for $x \geq 0$
- $+\infty x < 0$

, this function is convex, increasing, and positive.

Examples

```
## Not run:
x <- Variable()
prob <- Problem(Minimize(power(x,1.7) + power(x,-2.3) - power(x,0.45)))
result <- solve(prob)
result$value
result$getValue(x)

## End(Not run)
```

Index