Package 'caracas'

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Title Computer Algebra

Maintainer Mikkel Meyer Andersen <mikl@math.aau.dk>

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Description Computer algebra via the 'SymPy' library (<https://www.sympy.org/>).
This makes it possible to solve equations symbolically,
find symbolic integrals, symbolic sums and other important quantities.

Depends R (>= 3.0), methods

Imports reticulate (>= 1.14), Matrix, doBy (>= 4.6.15), magrittr

Suggests Ryacas, testthat (>= 2.1.0), knitr, rmarkdown, tinytex,
magick, pdftools, qpdf

License GPL

SystemRequirements Python (>= 3.6.0)

URL https://github.com/r-cas/caracas

BugReports https://github.com/r-cas/caracas/issues

RoxygenNote 7.2.3

VignetteBuilder knitr

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Author Mikkel Meyer Andersen [aut, cre, cph],
Søren Højsgaard [aut, cph]

Repository CRAN

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R topics documented:

add_prefix *Add prefix to each element of matrix*

Description

Add prefix to each element of matrix

Usage

```
add_prefix(x, prefix = "")
```

Arguments

x	Numeric or symbolic matrix
prefix	A character vector

Examples

```
if (has_sympy()) {
  X <- matrix_sym(2, 3)
  X
  add_prefix(X, "e")

  X <- matrix(1:6, 3, 2)
  X
  add_prefix(X, "e")
}
```

all_vars *All variables*

Description

Return all variables in caracas symbol

Usage

```
all_vars(x)
```

Arguments

x	caracas symbol

Examples

```
if (has_sympy()){
  x <- vector_sym(5)
  all_vars(x)
}
```

---

apart *Partial fraction decomposition on a rational function*

Description

apart() performs a partial fraction decomposition on a rational function

Usage

```
apart(x)
```

Arguments

x	A caracas_symbol

Examples

```
if (has_sympy()){
  def_sym(x)
  expr = (4*x**3 + 21*x**2 + 10*x + 12)/(x**4 + 5*x**3 + 5*x**2 + 4*x)
  apart(expr)
}
```

---

as.character.caracas_symbol *Convert symbol to character*

Description

Convert symbol to character

Usage

```
## S3 method for class 'caracas_symbol'
as.character(x, replace_I = TRUE, ...)
```

Arguments

x	A caracas_symbol
replace_I	Replace constant I (can both be identity and imaginary unit)
...	not used

ask *Ask for a symbol's property*

Description

Ask for a symbol's property

Usage

```
ask(x, property)
```

Arguments

x	symbol
property	property, e.g. 'positive'

Examples

```
if (has_sympy()) {
  x <- symbol("x", positive = TRUE)
  ask(x, "positive")
}
```

as_character *Coerce symbol to character*

Description

Coerce symbol to character

Usage

```
as_character(x)
```

Arguments

x	caracas symbol

as_character_matrix *Get matrix as character matrix*

Description

Get matrix as character matrix

Usage

```
as_character_matrix(x)
```

Arguments

x	caracas symbol

Examples

```
if (has_sympy()) {
  s  <- as_sym("[[r1, r2, r3], [u1, u2, u3]]")
  s2 <- apply(as_character_matrix(s), 2, function(x) (paste("1/(", x, ")")))
  as_sym(s2)
}
```

as_diag *Construct diagonal matrix from vector*

Description

Construct diagonal matrix from vector

Usage

```
as_diag(x)
```

Arguments

x	Matrix with 1 row or 1 column that is the diagonal in a new diagonal matrix

Examples

```
if (has_sympy()) {
  d <- as_sym(c("a", "b", "c"))
  D <- as_diag(d)
  D
}
```

as_expr *Convert caracas object to R*

Description

Potentially calls `doit()`.

Usage

```
as_expr(x, first_doit = TRUE)

## S3 method for class 'caracas_symbol'
as.expression(x, ...)

## S3 method for class 'caracas_solve_sys_sol'
as.expression(x, ...)
```

Arguments

x	caracas_symbol
first_doit	Try doit() first
...	not used

Examples

```
if (has_sympy()) {
  v <- vector_sym(2)
  x <- as_expr(v)
  x
  y <- as.expression(v)
  y
}
```

as_func *Convert expression into function object.*

Description

Convert expression into function object.

Usage

```
as_func(x, order = NULL, vec_arg = FALSE)

## S3 method for class 'caracas_symbol'
as.function(x, ...)
```

Arguments

x	caracas expression.
order	desired order of function argument. Defaults to alphabetical ordering.
vec_arg	should the function take vector valued argument.
...	not used

Examples

```
if (has_sympy()) {
  def_sym(b0, b1, b2, k, x)
  e <- b1 + (b0 - b1)*exp(-k*x) + b2*x

  f1 <- as_func(e)
  f1
  f1(1, 2, 3, 4, 5)
  f1 <- as_func(e, order = sort(all_vars(e)))
  f1(1, 2, 3, 4, 5)
  f2 <- as_func(e, vec_arg = TRUE)
  f2
  f2(c(1, 2, 3, 4, 5))
  f2 <- as_func(e, order = sort(all_vars(e)), vec_arg = TRUE)
  f2
  f2(c(1,2,3,4,5))

  f1a <- as.function(e)
  f1a
  f1a(1, 2, 3, 4, 5)
  f1(1, 2, 3, 4, 5)
}
```

---

as_sym *Convert R object to caracas symbol*

Description

Variables are detected as a character followed by a number of either: character, number or underscore.

Usage

```
as_sym(x, declare_symbols = TRUE)
```

Arguments

x	R object to convert to a symbol
declare_symbols	declare detected symbols automatically

Details

Default is to declare used variables. Alternatively, the user must declare them first, e.g. by `symbol()`.

Note that matrices can be defined by specifying a Python matrix, see below in examples.

Examples

```
if (has_sympy()) {
  x <- symbol("x")
  A <- matrix(c("x", 0, 0, "2*x"), 2, 2)
  A
  B <- as_sym(A)
  B
  2 * B
  dim(B)
  sqrt(B)
  D <- as_sym("[[1, 4, 5], [-5, 8, 9]]")
  D
}
```

---

as_vec *Stacks matrix to vector*

Description

Stacks matrix to vector

Usage

```
as_vec(x)
```

Arguments

x	Matrix

Examples

```
if (has_sympy()) {
  A <- as_sym(matrix(1:9, 3))
  as_vec(A)
}
```

cancel *Put rational function into standard form*

Description

cancel() will take any rational function and put it into the standard canonical form

Usage

```
cancel(x)
```

Arguments

x	A caracas_symbol

Examples

```
if (has_sympy()){
  def_sym(x, y, z)
  expr = cancel((x**2 + 2*x + 1)/(x**2 + x))
  cancel(expr)
  expr = (x*y**2 - 2*x*y*z + x*z**2 + y**2 - 2*y*z + z**2)/(x**2 - 1)
  cancel(expr)
  factor_(expr)
}
```

collect *Collects common powers of a term in an expression*

Description

Collects common powers of a term in an expression

Usage

```
collect(x, a)
```

Arguments

x, a	A caracas_symbol

Examples

```
if (has_sympy()){
  def_sym(x, y, z)
  expr = x*y + x - 3 + 2*x**2 - z*x**2 + x**3
  collect(expr, x)
}
```

colspan *Column space (range) of a symbolic matrix*

Description

Column space (range) of a symbolic matrix

Usage

```
colspan(x)
```

Arguments

x	Symbolic matrix

Examples

```
if (has_sympy()) {
  X1 <- matrix_(paste0("x_",c(1,1,1,1, 2,2,2,2, 3,4,3,4)), nrow = 4)
  X1
  colspan(X1)
  do_la(X1, "columnspace")
  rankMatrix_(X1)

  X2 <- matrix_(paste0("x_",c(1,1,1,1, 0,0,2,2, 3,4,3,4)), nrow = 4)
  X2
  colspan(X2)
  do_la(X2, "columnspace")
  rankMatrix_(X2)
}
```

cumsum.caracas_symbol *Cumulative Sums*

Description

Cumulative Sums

Usage

```
## S3 method for class 'caracas_symbol'
cumsum(x)
```

Arguments

x	Elements to sum

Examples

```
if (has_sympy()) {
  A <- matrix(1:9, 3)
  cumsum(A)
  B <- matrix_sym(3, 3)
  cumsum(B)
  C <- vector_sym(3)
  cumsum(C)
}
```

`def_sym` *Define (invisibly) caracas symbols in global environment*

Description

Define (invisibly) caracas symbols in global environment

Define symbol for components in vector

Usage

```
def_sym(..., charvec = NULL, warn = FALSE, env = parent.frame())

def_sym_vec(x, env = parent.frame())
```

Arguments

`...`	Names for new symbols, also supports non-standard evaluation
`charvec`	Take each element in this character vector and define as caracas symbols
`warn`	Warn if existing variable names are overwritten
`env`	The environment in which the assignment is made.
`x`	Character vector.

Value

Names of declared variables (invisibly)

See Also

`symbol()`, `as_sym()`

Examples

```
if (has_sympy()) {
  ls()
  def_sym(n1, n2, n3)
  ls()
  def_sym("x1", "x2", "x3")
  ls()
  # def_sym("x1", "x2", "x3", warn = TRUE) # Do not run as will cause a warning
  ls()
  def_sym(i, j, charvec = c("x", "y"))
  ls()
}

if (has_sympy()) {
  def_sym(z1, z2, z3)
  u <- paste0("u", seq_len(3))
  ## Creates symbols u1, u2, u3 and binds to names u1, u2, u3 in R.
  def_sym_vec(u)
  ## Same as (but easier than)
  def_sym(u1, u2, u3)
  ## Notice: this creates matrix [u1, u2, u3]
  as_sym(u)
 }
```

---

der *Symbolic differentiation of an expression*

Description

Symbolic differentiation of an expression

Usage

```
der(expr, vars, simplify = TRUE)
```

Arguments

expr	A caracas_symbol
vars	variables to take derivate with respect to
simplify	Simplify result

Examples

```
if (has_sympy()) {
  x <- symbol("x")
  y <- symbol("y")
  f <- 3*x^2 + x*y^2
  der(f, x)
```

```
  g <- der(f, list(x, y))
  g
  dim(g)
  G <- matrify(g)
  G
  dim(G)

  h <- der(g, list(x, y))
  h
  dim(h)
  as.character(h)
  H <- matrify(h)
  H
  dim(H)

  g %>%
    der(list(x, y), simplify = FALSE) %>%
    der(list(x, y), simplify = FALSE) %>%
    der(list(x, y), simplify = FALSE)
}
```

`der2` *Symbolic differentiation of second order of an expression*

Description

Symbolic differentiation of second order of an expression

Usage

```
der2(expr, vars, simplify = TRUE)
```

Arguments

`expr`	A `caracas_symbol`
`vars`	variables to take derivate with respect to
`simplify`	Simplify result

Examples

```
if (has_sympy()) {
  x <- symbol("x")
  y <- symbol("y")
  f <- 3*x^2 + x*y^2
  der2(f, x)
  h <- der2(f, list(x, y))
  h
  dim(h)
```

```
  H <- matrify(h)
  H
  dim(H)
}
```

`diag` *Matrix diagonal*

Description

Matrix diagonal

Usage

```
diag(x, ...)
```

Arguments

`x`	Object `x`
`...`	Passed on

`diag-set` *Replace matrix diagonal*

Description

Replace matrix diagonal

Usage

```
diag(x) <- value
```

Arguments

`x`	Object `x`
`value`	Replacement value

diag.caracas_symbol *Matrix diagonal*

Description

Matrix diagonal

Usage

```
## S3 method for class 'caracas_symbol'
diag(x, ...)
```

Arguments

x	Object x
...	Not used

diag<-.caracas_symbol *Replace diagonal*

Description

Replace diagonal

Usage

```
## S3 replacement method for class 'caracas_symbol'
diag(x) <- value
```

Arguments

x	A caracas_symbol.
value	Replacement value

Examples

```
if (has_sympy()) {
  A <- matrix(c("a", 0, 0, 0, "a", "a", "a", 0, 0), 3, 3)
  B <- as_sym(A)
  B
  diag(B)
  diag(B) <- "b"
  B
  diag(B)
}
```

diag_ *Symbolic diagonal matrix*

Description

Symbolic diagonal matrix

Usage

```
diag_(x, n = 1L, declare_symbols = TRUE, ...)
```

Arguments

x	Character vector with diagonal
n	Number of times x should be repeated
declare_symbols	Passed on to as_sym() when constructing symbolic matrix
...	Passed on to rep(x, n, ...)

Examples

```
if (has_sympy()) {
  diag_(c(1,3,5))
  diag_(c("a", "b", "c"))
  diag_("a", 2)
  diag_(vector_sym(4))
}
```

diff_mat *Difference matrix*

Description

Difference matrix

Usage

```
diff_mat(N, l = "-1", d = 1)
```

Arguments

N	Number of rows (and columns)
l	Value / symbol below main diagonal
d	Value / symbol on main diagonal

Examples

```
if (has_sympy()){
  Dm <- diff_mat(4)
  Dm
  y <- vector_sym(4, "y")
  Dm %*% y
}
```

`dim.caracas_symbol` *Dimensions of a caracas symbol*

Description

Dimensions of a caracas symbol

Usage

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

Arguments

`x`	caracas symbol

`dim<-.caracas_symbol` *Dimensions of a caracas symbol*

Description

Dimensions of a caracas symbol

Usage

```
## S3 replacement method for class 'caracas_symbol'
dim(x) <- value
```

Arguments

`x`	caracas symbol
`value`	new dimension

Examples

```
if (has_sympy()) {
  v <- vector_sym(4)
  v
  dim(v)
  dim(v) <- c(2, 2)
  v
  m <- matrix_sym(2, 2)
  dim(m)
  dim(m) <- c(4, 1)
  m
}
```

`doit` *Perform calculations setup previously*

Description

Perform calculations setup previously

Usage

```
doit(x)
```

Arguments

`x`	A `caracas_symbol`

Examples

```
if (has_sympy()) {
   x <- symbol('x')
   res <- lim(sin(x)/x, "x", 0, doit = FALSE)
   res
   doit(res)
}
```

do_la *Do linear algebra operation*

Description

Do linear algebra operation

Usage

```
do_la(x, slot, ...)
```

Arguments

x	A matrix for which a property is requested
slot	The property requested
...	Auxillary arguments

Value

Returns the requested property of a matrix.

Examples

```
if (has_sympy()) {
  A <- matrix(c("a", "0", "0", "1"), 2, 2) %>% as_sym()

  do_la(A, "QR")
  QRdecomposition(A)

  do_la(A, "LU")
  LUdecomposition(A)

  do_la(A, "cholesky", hermitian = FALSE)
  chol(A, hermitian = FALSE)

  do_la(A, "singular_value_decomposition")
  do_la(A, "svd")
  svd_res <- svd_(A)
  svd_res
  U_expr <- svd_res$U |> as_expr()
  U_expr
  eval(U_expr, list(a = 3+2i))

  b <- symbol("b", real = TRUE)
  B <- matrix(c("b", "0", "0", "1"), 2, 2) %>% as_sym(declare_symbols = FALSE)
  svd_(B)

  do_la(A, "eigenval")
  eigenval(A)
```

```
  do_la(A, "eigenvec")
  eigenvec(A)

  do_la(A, "inv")
  inv(A)

  do_la(A, "trace")
  trace_(A)

  do_la(A, "echelon_form")
  do_la(A, "rank")

  do_la(A, "det") # Determinant
  det(A)
}
```

`drop_remainder` *Remove remainder term*

Description

Remove remainder term

Usage

```
drop_remainder(x)
```

Arguments

x	Expression to remove remainder term from

See Also

`taylor()`

Examples

```
if (has_sympy()) {
  def_sym(x)
  f <- cos(x)
  ft_with_0 <- taylor(f, x0 = 0, n = 4+1)
  ft_with_0
  ft_with_0 %>% drop_remainder() %>% as_expr()
}
```

eval_to_symbol *Create a symbol from a string*

Description

Create a symbol from a string

Usage

```
eval_to_symbol(x)
```

Arguments

x	String to evaluate

Value

A caracas_symbol

Examples

```
if (has_sympy()) {
   x <- symbol('x')
   (1+1)*x^2
   lim(sin(x)/x, "x", 0)
}
```

expand *Expand expression*

Description

Expand expression

Usage

```
expand(x, ...)
```

Arguments

x	A caracas_symbol
...	Pass on to SymPy's expand, e.g. force = TRUE

Examples

```
if (has_sympy()) {
  def_sym(x)
  y <- log(exp(x))
  simplify(y)
  expand(simplify(y))
  expand(simplify(y), force = TRUE)
  expand_log(simplify(y))
}
```

---

expand_func *Expand a function expression*

Description

Expand a function expression

Usage

```
expand_func(x)
```

Arguments

x	A caracas_symbol

---

expand_log *Expand a logarithmic expression*

Description

Note that force as described at https://docs.sympy.org/latest/tutorial/simplification.html#expand-log is used meaning that some assumptions are taken.

Usage

```
expand_log(x)
```

Arguments

x	A caracas_symbol

Examples

```
if (has_sympy()) {
  x <- symbol('x')
  y <- symbol('y')
  z <- log(x*y)
  z
  expand_log(z)
}
```

`expand_trig` *Expand a trigonometric expression*

Description

Expand a trigonometric expression

Usage

```
expand_trig(x)
```

Arguments

x	A `caracas_symbol`

`factor_` *Expand expression*

Description

Expand expression

Usage

```
factor_(x)
```

Arguments

x	A `caracas_symbol`

Examples

```
if (has_sympy()){
  def_sym(x, y, z)
  factor_(x**3 - x**2 + x - 1)
  factor_(x**2*z + 4*x*y*z + 4*y**2*z)
}
```

fraction_parts *Get numerator and denominator of a fraction*

Description

Get numerator and denominator of a fraction

Usage

```
fraction_parts(x)

numerator(x)

denominator(x)
```

Arguments

x	Fraction

Examples

```
if (has_sympy()) {
     x <- as_sym("a/b")
     frac <- fraction_parts(x)
     frac
     frac$numerator
     frac$denominator
 }
```

free_symbols *Get free symbol in expression*

Description

Get free symbol in expression

Usage

```
free_symbols(x)
```

Arguments

x	Expression in which to get the free symbols in

Examples

```
if (has_sympy()) {
  def_sym(a, b)
  x <- (a - b)^4
  free_symbols(x)
}
```

---

generic-matrices *Generate generic vectors and matrices*

Description

Generate generic vectors and matrices.

Usage

```
vector_sym(n, entry = "v")

matrix_sym(nrow, ncol, entry = "v")

matrix_sym_diag(nrow, entry = "v")

matrix_sym_symmetric(nrow, entry = "v")
```

Arguments

n	Length of vector
entry	The symbolic name of each entry.
nrow, ncol	Number of rows and columns

Examples

```
if (has_sympy()) {
  vector_sym(4, "b")
  matrix_sym(3, 2, "a")
  matrix_sym_diag(4, "s")
  matrix_sym_symmetric(4, "s")
}
```

get_basis *Get basis*

Description

Get basis

Usage

```
get_basis(x)
```

Arguments

x	caracas vector / matrix

Examples

```
if (has_sympy()) {
  x <- vector_sym(3)
  get_basis(x)

  W <- matrix(c("r_1", "r_1", "r_2", "r_2", "0", "0", "u_1", "u_2"), nrow=4)
  W <- as_sym(W)
  get_basis(W)
}
```

get_py *Access 'py' object*

Description

Get the 'py' object. Note that it gives you extra responsibilities when you choose to access the 'py' object directly.

Usage

```
get_py()
```

Value

The 'py' object with direct access to the library.

Examples

```
if (has_sympy()) {
  py <- get_py()
}
```

get_sympy *Access 'SymPy' directly*

Description

Get the 'SymPy' object. Note that it gives you extra responsibilities when you choose to access the 'SymPy' object directly.

Usage

```
get_sympy()
```

Value

The 'SymPy' object with direct access to the library.

Examples

```
if (has_sympy()) {
  sympy <- get_sympy()
  sympy$solve("x**2-1", "x")
}
```

has_sympy *Check if 'SymPy' is available*

Description

Check if 'SymPy' is available

Usage

```
has_sympy()
```

Value

`TRUE` if 'SymPy' is available, else `FALSE`

Examples

```
has_sympy()
```

install_sympy *Install 'SymPy'*

Description

Install the 'SymPy' Python package into a virtual environment or Conda environment.

Usage

```
install_sympy(method = "auto", conda = "auto")
```

Arguments

method	Installation method. By default, "auto" automatically finds a method that will work in the local environment. Change the default to force a specific installation method. Note that the "virtualenv" method is not available on Windows.
conda	Path to conda executable (or "auto" to find conda using the PATH and other conventional install locations).

Value

None

int *Integrate a function*

Description

If no limits are provided, the indefinite integral is calculated. Otherwise, if both limits are provided, the definite integral is calculated.

Usage

```
int(f, var, lower, upper, doit = TRUE)
```

Arguments

f	Function to integrate
var	Variable to integrate with respect to (either string or caracas_symbol)
lower	Lower limit
upper	Upper limit
doit	Evaluate the integral immediately (or later with doit())

Examples

```
if (has_sympy()) {
  x <- symbol("x")

  int(1/x, x, 1, 10)
  int(1/x, x, 1, 10, doit = FALSE)
  int(1/x, x)
  int(1/x, x, doit = FALSE)
  int(exp(-x^2/2), x, -Inf, Inf)
  int(exp(-x^2/2), x, -Inf, Inf, doit = FALSE)
}
```

---

is_sym *Is object a caracas symbol*

Description

Is object a caracas symbol

Usage

```
is_sym(x)
```

Arguments

x	object

---

jacobian *Compute Jacobian*

Description

Compute Jacobian

Usage

```
jacobian(expr, vars)
```

Arguments

expr	'caracas expression'.
vars	variables to take derivative with respect to

See Also

score(), hessian() der()

Examples

```
if (has_sympy()) {
  x <- paste0("x", seq_len(3))
  def_sym_vec(x)
  y1 <- x1 + x2
  y2 <- x1^2 + x3
  y <- c(y1, y2)
  jacobian(y, x)
  u <- 2 + 4*x1^2
  jacobian(u, x1)
}
```

---

kronecker,caracas_symbol,caracas_symbol-method

Kronecker product of two matrices

Description

Computes the Kronecker product of two matrices.

Usage

```
## S4 method for signature 'caracas_symbol,caracas_symbol'
kronecker(X, Y, FUN = "*", make.dimnames = FALSE, ...)
```

Arguments

X, Y	matrices as caracas symbols.
FUN	a function; it may be a quoted string.
make.dimnames	Provide dimnames that are the product of the dimnames of 'X' and 'Y'.
...	optional arguments to be passed to 'FUN'.

Value

Kronecker product of A and B.

Examples

```
if (has_sympy()) {
  A <- matrix_sym(2, 2, "a")
  B <- matrix_sym(2, 2, "b")
  II <- matrix_sym_diag(2)
  EE <- eye_sym(2,2)
  JJ <- ones_sym(2,2)

  kronecker(A, B)
  kronecker(A, B, FUN = "+")
  kronecker(II, B)
```

```
  kronecker(EE, B)
  kronecker(JJ, B)
}
```

`lim` *Limit of a function*

Description

Limit of a function

Usage

```
lim(f, var, val, dir = NULL, doit = TRUE)
```

Arguments

`f`	Function to take limit of
`var`	Variable to take limit for (either string or `caracas_symbol`)
`val`	Value for `var` to approach
`dir`	Direction from where `var` should approach `val`: `'+'` or `'-'`
`doit`	Evaluate the limit immediately (or later with `doit()`)

Examples

```
if (has_sympy()) {
  x <- symbol("x")
  lim(sin(x)/x, "x", 0)
  lim(1/x, "x", 0, dir = '+')
  lim(1/x, "x", 0, dir = '-')
}
```

`linalg` *Do linear algebra operation*

Description

Performs various linear algebra operations like finding the inverse, the QR decomposition, the eigenvectors and the eigenvalues.

Usage

```
columnspace(x, matrix = TRUE)

nullspace(x, matrix = TRUE)

rowspace(x, matrix = TRUE)

singular_values(x)

inv(x, method = c("gauss", "lu", "cf", "yac"))

eigenval(x)

eigenvec(x)

GramSchmidt(x)

pinv(x)

rref(x)

QRdecomposition(x)

LUdecomposition(x)

## S3 method for class 'caracas_symbol'
chol(x, ...)

svd_(x, ...)

det(x, ...)

trace_(x)
```

Arguments

x	A matrix for which a property is requested.
matrix	When relevant should a matrix be returned.
method	The default works by Gaussian elimination. The alternatives are LU decomposition (lu), the cofactor method (cf), and Ryacas (yac).
...	Auxillary arguments.

Value

Returns the requested property of a matrix.

See Also

do_la()

Examples

```
if (has_sympy()) {
  A <- matrix(c("a", "0", "0", "1"), 2, 2) |> as_sym()

  QRdecomposition(A)
  LUdecomposition(A)
  #chol(A) # error
  chol(A, hermitian = FALSE)
  eigenval(A)
  eigenvec(A)
  inv(A)
  det(A)

  ## Matrix inversion:
  d <- 3
  m <- matrix_sym(d, d)
  print(system.time(inv(m)))                  ## Gauss elimination
  print(system.time(inv(m, method="cf")))     ## Cofactor
  print(system.time(inv(m, method="lu")))     ## LU decomposition
  if (requireNamespace("Ryacas")){
    print(system.time(inv(m, method="yac")))  ## Use Ryacas
  }

  A <- matrix(c("a", "b", "c", "d"), 2, 2) %>% as_sym()
  evec <- eigenvec(A)
  evec
  evec1 <- evec[[1]]$eigvec
  evec1
  simplify(evec1)

  lapply(evec, function(l) simplify(l$eigvec))

  A <- as_sym("[[1, 2, 3], [4, 5, 6]]")
  pinv(A)
}
```

---

listify *Convert object to list of elements*

Description

Convert object to list of elements

Usage

```
listify(x)
```

Arguments

x	Object

Examples

```
if (has_sympy()) {
  x <- as_sym("Matrix([[b1*x1/(b2 + x1)], [b1*x2/(b2 + x2)], [b1*x3/(b2 + x3)]])")
  listify(x)

  xT <- t(x)
  listify(xT)
}
```

---

ls_sym *List defined symbols*

Description

List defined symbols

Usage

```
ls_sym()
```

Math.caracas_symbol *Math functions*

Description

If x is a matrix, the function is applied component-wise.

Usage

```
## S3 method for class 'caracas_symbol'
Math(x, ...)
```

Arguments

x	caracas_symbol.
...	further arguments passed to methods

matrify *Creates matrix from array symbol*

Description

Creates matrix from array symbol

Usage

```
matrify(x)
```

Arguments

x	Array symbol to convert to matrix

Examples

```
if (has_sympy()) {
  x <- symbol("x")
  y <- symbol("y")
  f <- 3*x^2 + x*y^2
  matrify(f)
  h <- der2(f, list(x, y))
  h
  dim(h)
  H <- matrify(h)
  H
  dim(H)
}
```

matrix-products *Matrix multiplication*

Description

Matrix multiplication

Matrix multiplication

Usage

```
x %*% y

## S3 method for class 'caracas_symbol'
x %*% y
```

Arguments

x	Object x
y	Object y

See Also

base::%*%()

base::%*%()

---

matrix_ *Symbolic matrix*

Description

Symbolic matrix

Usage

```
matrix_(..., declare_symbols = TRUE)
```

Arguments

...	Passed on to matrix()
declare_symbols	Passed on to as_sym() when constructing symbolic matrix

Examples

```
if (has_sympy()) {
  matrix_(1:9, nrow = 3)
  matrix_("a", 2, 2)
}
```

---

matrix_cross_product *Matrix cross product*

Description

Matrix cross product

Usage

```
crossprod_(x, y = NULL)

tcrossprod_(x, y = NULL)
```

Arguments

x, y	caracas matrices

---

mat_pow *Matrix power*

Description

Matrix power

Usage

```
mat_pow(x, pow = "1")
```

Arguments

x	A caracas_symbol, a matrix.
pow	Power to raise matrix x to

Examples

```
if (has_sympy() && sympy_version() >= "1.6") {
  M <- matrix_(c("1", "a", "a", 1), 2, 2)
  M
  mat_pow(M, 1/2)
}
```

N *Numerical evaluation*

Description

Numerical evaluation

Usage

```
N(x, digits = 15)
```

Arguments

x	caracas object
digits	Number of digits

Examples

```
if (has_sympy()) {
  n_2 <- as_sym("2")
  n_pi <- as_sym("pi", declare_symbols = FALSE)
  x <- sqrt(n_2) * n_pi
  x
  N(x)
  N(x, 5)
  N(x, 50)
  as.character(N(x, 50))
}
```

Ops.caracas_symbol *Math operators*

Description

Math operators

Usage

```
## S3 method for class 'caracas_symbol'
Ops(e1, e2)
```

Arguments

e1	A caracas_symbol.
e2	A caracas_symbol.

---

print.caracas_scaled_matrix *Print scaled matrix*

Description

Print scaled matrix

Usage

```
## S3 method for class 'caracas_scaled_matrix'
print(x, ...)
```

Arguments

x	A caracas_scaled_matrix
...	Passed to print.caracas_symbol()

print.caracas_solve_sys_sol *Print solution*

Description

Print solution

Usage

```
## S3 method for class 'caracas_solve_sys_sol'
print(
  x,
  simplify = getOption("caracas.print.sol.simplify", default = TRUE),
  ...
)
```

Arguments

x	A caracas_symbol
simplify	Print solution in a simple format
...	Passed to print.caracas_symbol()

Examples

```
if (has_sympy()) {
  x <- symbol('x')
  solve_sys(x^2, -1, x)

  y <- symbol("y")
  lhs <- cbind(3*x*y - y, x)
  rhs <- cbind(-5*x, y+4)
  sol <- solve_sys(lhs, rhs, list(x, y))
  sol
}
```

print.caracas_symbol *Print symbol*

Description

Print symbol

Usage

```
## S3 method for class 'caracas_symbol'
print(
  x,
  prompt = getOption("caracas.prompt", default = "c: "),
  method = getOption("caracas.print.method", default = "utf8"),
  rowvec = getOption("caracas.print.rowvec", default = TRUE),
  ...
)
```

Arguments

x	A caracas_symbol
prompt	Which prompt/prefix to print (default: 'c: ')
method	What way to print (utf8, prettyascii, ascii, compactascii)
rowvec	FALSE to print column vectors as is
...	not used

---

prod_ *Product of a function*

Description

Product of a function

Usage

```
prod_(f, var, lower, upper, doit = TRUE)
```

Arguments

f	Function to take product of
var	Variable to take product for (either string or caracas_symbol)
lower	Lower limit
upper	Upper limit
doit	Evaluate the product immediately (or later with doit())

Examples

```
if (has_sympy()) {
  x <- symbol("x")
  p <- prod_(1/x, "x", 1, 10)
  p
  as_expr(p)
  prod(1/(1:10))
```

```
  n <- symbol("n")
  prod_(x, x, 1, n)
}
```

`rankMatrix_` *Rank of matrix*

Description

Rank of matrix

Usage

```
rankMatrix_(x)
```

Arguments

`x`	Numeric or symbolic matrix

Examples

```
if (has_sympy()) {
  X <- matrix_(paste0("x_",c(1,1,1,1,2,2,2,2,3,4,3,4)), nrow=4)
  X
  rankMatrix_(X)
  colspan(X)
}
```

`reciprocal_matrix` *Elementwise reciprocal matrix*

Description

Elementwise reciprocal matrix

Usage

```
reciprocal_matrix(x, numerator = 1)
```

Arguments

`x`	Object `x`
`numerator`	The numerator in the result.

Examples

```
if (has_sympy()) {
  s <- as_sym("[[r1, r2, r3], [u1, u2, u3]]")
  reciprocal_matrix(s, numerator = 7)
}
```

`rowSums_colSums` *Form Row and Column Sums*

Description

Form Row and Column Sums

Usage

```
rowSums_(x)

colSums_(x)
```

Arguments

`x`	Symbolic matrix

Examples

```
if (has_sympy()) {
  X <- matrix_(paste0("x_",c(1,1,1,1,2,2,2,2,3,4,3,4)), nrow=4)
  rowSums_(X)
  colSums_(X)
}
```

`scale_matrix` *Create list of factors as in a product*

Description

Create list of factors as in a product

Usage

```
scale_matrix(X, k = NULL, divide = TRUE)
```

Arguments

X	matrix
k	scalar to be factored out
divide	Should X be divided with k before constructing scaled matrix?

Examples

```
if (has_sympy()) {
  V <- matrix_sym(2, 2, "v")
  a <- symbol("a")

  K <- a*V
  scale_matrix(K, a)
  scale_matrix(V, a, divide = FALSE)

  Ks <- scale_matrix(V, a, divide = FALSE)
  Ks
  W <- matrix_sym(2, 2, "w")
  unscale_matrix(Ks) %*% W
  unscale_matrix(Ks) %*% W |> scale_matrix(a)
  Ksi <- unscale_matrix(Ks) |> inv() |> scale_matrix(a/det(unscale_matrix(Ks)))
  (Ksi |> unscale_matrix()) %*% (Ks |> unscale_matrix()) |> simplify()
  tex(Ksi)
}
```

---

score_hessian *Score and Hessian matrix*

Description

Compute column vector of first derivatives and matrix of second derivatives of univariate function.

Usage

```
score(expr, vars, simplify = TRUE)

hessian(expr, vars, simplify = TRUE)
```

Arguments

expr	'caracas expression'.
vars	variables to take derivative with respect to.
simplify	Try to simplify result using `simplify()`; may be time consuming.

See Also

`jacobian()`, `der()`

Examples

```
if (has_sympy()) {
  def_sym(b0, b1, x, x0)
  f <- b0 / (1 + exp(b1*(x-x0)))
  S <- score(f, c(b0, b1))
  S
  H <- hessian(f, c(b0, b1))
  H
}
```

`simplify` *Simplify expression*

Description

Simplify expression

Usage

```
simplify(x)
```

Arguments

x	A caracas_symbol

`solve.caracas_symbol` *Solve a System of Linear Equations*

Description

Solve a System of Linear Equations

Usage

```
## S3 method for class 'caracas_symbol'
solve(a, b, ...)
```

Arguments

a	caracas_symbol
b	If provided, either a caracas_symbol (if not, as_sym() is called on the object)
...	Not used

Examples

```
if (has_sympy()) {
  A <- matrix_sym(2, 2, "a")
  b <- vector_sym(2, "b")
  # Inverse of A:
  solve(A)
  inv(A)
  solve(A) %*% A |> simplify()
  # Find x in Ax = b
  x <- solve(A, b)
  A %*% x |> simplify()
  solve(A, c(2, 1)) |> simplify()
}
```

---

solve_lin *Solve a linear system of equations*

Description

Find x in Ax = b. If b not supplied, the inverse of A is returned.

Usage

```
solve_lin(A, b)
```

Arguments

A	matrix
b	vector

Examples

```
if (has_sympy()) {
  A <- matrix_sym(2, 2, "a")
  b <- vector_sym(2, "b")
  # Inverse of A:
  solve_lin(A) %*% A |> simplify()
  # Find x in Ax = b
  x <- solve_lin(A, b)
  A %*% x |> simplify()
}
```

`solve_sys` *Solves a system of non-linear equations*

Description

If called as `solve_sys(lhs, vars)` the roots are found. If called as `solve_sys(lhs, rhs, vars)` the solutions to `lhs = rhs` for `vars` are found.

Usage

```
solve_sys(lhs, rhs, vars)
```

Arguments

`lhs`	Equation (or equations as row vector/1xn matrix)
`rhs`	Equation (or equations as row vector/1xn matrix)
`vars`	vector of variable names or symbols

Value

A list with solutions (with class `caracas_solve_sys_sol` for compact printing), each element containing a named list of the variables' values.

Examples

```
if (has_sympy()) {
  x <- symbol('x')
  exp1 <- 2*x + 2
  exp2 <- x
  solve_sys(cbind(exp1), cbind(exp2), x)

  x <- symbol("x")
  y <- symbol("y")
  lhs <- cbind(3*x*y - y, x)
  rhs <- cbind(-5*x, y+4)
  sol <- solve_sys(lhs, rhs, list(x, y))
  sol
}
```

special_matrices *Special matrices: zeros_sym, ones_sym, eye_sym*

Description

Special matrices: zeros_sym, ones_sym, eye_sym

Usage

```
zeros_sym(nrow, ncol)

ones_sym(nrow, ncol)

eye_sym(nrow, ncol)
```

Arguments

nrow, ncol	Number of rows and columns of output

See Also

diag_(), matrix_sym(), vector_sym()

Examples

```
if (has_sympy()){
  zeros_sym(3, 4)
  ones_sym(3, 4)
  eye_sym(3, 4)
}
```

subs *Substitute symbol for value*

Description

Substitute symbol for value

Usage

```
subs(sym, nms, vls)
```

Arguments

sym	Expression
nms	Names of symbols (see Details)
vls	Values that nms is substituted with (see Details)

Details

Two different ways to call this function is supported:

1. Supplying nms as a named list and omitting vls. If two components have the same name, the behaviour is undefined.
2. Supplying both nms and vls See Examples.

Examples

```
if (has_sympy()) {
   x <- symbol('x')
   e <- 2*x^2
   e
   subs(e, "x", "2")
   subs(e, x, 2)
   subs(e, list(x = 2))

   A <- matrix_sym(2, 2, "a")
   B <- matrix_sym(2, 2, "b")
   e <- A %*% A
   subs(e, A, B)
}
```

---

sum.caracas_symbol *Summation*

Description

Summation

Usage

```
## S3 method for class 'caracas_symbol'
sum(..., na.rm = FALSE)
```

Arguments

...	Elements to sum
na.rm	Not used

sum_ *Sum of a function*

Description

Sum of a function

Usage

```
sum_(f, var, lower, upper, doit = TRUE)
```

Arguments

f	Function to take sum of
var	Variable to take sum for (either string or caracas_symbol)
lower	Lower limit
upper	Upper limit
doit	Evaluate the sum immediately (or later with doit())

Examples

```
if (has_sympy()) {
  x <- symbol("x")
  s <- sum_(1/x, "x", 1, 10)
  as_expr(s)
  sum(1/(1:10))
  n <- symbol("n")
  simplify(sum_(x, x, 1, n))
}
```

symbol *Create a symbol*

Description

Find available assumptions at https://docs.sympy.org/latest/modules/core.html#module-sympy.core.assumptions.

Usage

```
symbol(x, ...)
```

Arguments

x	Name to turn into symbol
...	Assumptions like positive = TRUE

Value

A caracas_symbol

See Also

as_sym()

Examples

```
if (has_sympy()) {
  x <- symbol("x")
  2*x

  x <- symbol("x", positive = TRUE)
  ask(x, "positive")
}
```

---

symbol_class *Ask type of caracas symbol*

Description

Ask type of caracas symbol

Usage

```
symbol_class(x)
```

Arguments

x	An object, a caracas object is expected

symbol_is_matrix *Check if object is a caracas matrix*

Description

Check if object is a caracas matrix

Usage

```
symbol_is_matrix(x)
```

Arguments

x	An object

Examples

```
if (has_sympy() && sympy_version() >= "1.6") {
  x <- vector_sym(4)
  symbol_is_matrix(x)   ## TRUE
  x2 <- as.character(x) ## "Matrix([[v1], [v2], [v3], [v4]])"
  symbol_is_matrix(x2)  ## TRUE
  x3 <- as_character_matrix(x) ## R matrix
  symbol_is_matrix(x3)  ## FALSE
}
```

sympy_func *Call a SymPy function directly on x*

Description

Extend caracas by calling SymPy functions directly.

Usage

```
sympy_func(x, fun, ...)
```

Arguments

x	Object to call fun on
fun	Function to call
...	Passed on to fun

Examples

```
if (has_sympy()) {
  def_sym(x, a)
  p <- (x-a)^4
  p
  q <- p %>% sympy_func("expand")
  q
  q %>% sympy_func("factor")

  def_sym(x, y, z)
  expr <- x*y + x - 3 + 2*x^2 - z*x^2 + x^3
  expr
  expr %>% sympy_func("collect", x)

  x <- symbol("x")
  y <- gamma(x+3)
  sympy_func(y, "expand_func")
  expand_func(y)
}
```

`sympy_version` *Get 'SymPy' version*

Description

Get 'SymPy' version

Usage

```
sympy_version()
```

Value

The version of the 'SymPy' available

Examples

```
if (has_sympy()) {
  sympy_version()
}
```

sym_class *Ask type of caracas symbol*

Description

Ask type of caracas symbol

Usage

```
sym_class(x)
```

Arguments

x	An object, a caracas object is expected

sym_inherits *Ask if type of caracas symbol is of a requested type*

Description

Ask if type of caracas symbol is of a requested type

Usage

```
sym_inherits(x, what)
```

Arguments

x	An object, a caracas object is expected
what	Requested type (e.g. atomic, vector, list, matrix)

t.caracas_symbol *Transpose of matrix*

Description

Transpose of matrix

Usage

```
## S3 method for class 'caracas_symbol'
t(x)
```

Arguments

x	If caracas_symbol treat as such, else call base::t().

taylor *Taylor expansion*

Description

Taylor expansion

Usage

```
taylor(f, x0 = 0, n = 6)
```

Arguments

f	Function to be expanded
x0	Point to expand around
n	Order of remainder term

See Also

drop_remainder()

Examples

```
if (has_sympy()) {
  def_sym(x)
  f <- cos(x)
  ft_with_O <- taylor(f, x0 = 0, n = 4+1)
  ft_with_O
  ft_with_O %>% drop_remainder() %>% as_expr()
}
```

tex *Export object to TeX*

Description

Export object to TeX

Usage

```
tex(x, zero_as_dot = FALSE, matstr = NULL, ...)
```

Arguments

x	A caracas_symbol
zero_as_dot	Print zero as dots
matstr	Replace \begin{matrix} with another environment, e.g. pmatrix. If vector of length two, the second element is an optional argument.
...	Other arguments passed along

Examples

```
if (has_sympy()) {
S <- matrix_sym_symmetric(3, "s")
S[1, 2] <- "1-x"
S
tex(S)
tex(S, matstr = "pmatrix")
tex(S, matstr = c("pmatrix", "r"))
}
```

---

tex.caracas_scaled_matrix

Export scaled matrix to tex

Description

Export scaled matrix to tex

Usage

```
## S3 method for class 'caracas_scaled_matrix'
tex(x, ...)
```

Arguments

x	scaled matrix
...	Other arguments passed along

texshow *Dump latex representation of sympy object.*

Description

Dump latex representation of sympy object and compile document into pdf.

Usage

```
texshow(x)
```

Arguments

x	An object that can be put in latex format with caracas' tex() function or a character string with tex code (in math mode).

Value

Nothing, but a .tex file and a .pdf file is generated.

Examples

```
if (has_sympy()) {
S <- matrix_sym_symmetric(3, "s")
S
## Not run:
texshow(S)
texshow(paste0("S = ", tex(S)))

## End(Not run)
}
```

to_something *Coerce caracas object*

Description

Coerce caracas object

Usage

```
to_list(x)

to_vector(x)

to_matrix(x)
```

Arguments

x	a caracas object is expected

---

tuplify *Convert object to tuple*

Description

Convert object to tuple

Usage

```
tuplify(x)
```

Arguments

x	Object

Examples

```
if (has_sympy()) {
  x <- as_sym("Matrix([[b1*x1/(b2 + x1)], [b1*x2/(b2 + x2)], [b1*x3/(b2 + x3)]])")
  tuplify(x)
}
```

---

unbracket *Remove inner-most dimension*

Description

Remove inner-most dimension

Usage

```
unbracket(x)
```

Arguments

x	Array symbol to collapse dimension from

Examples

```
if (has_sympy()) {
  x <- as_sym(paste0("x", 1:3))
  y <- as_sym("y")
  l <- list(x, y)
  l
  unbracket(l)
}
```

`unscale_matrix` *Extract matrix from scaled matrix*

Description

Extract matrix from scaled matrix

Usage

```
unscale_matrix(X)
```

Arguments

`X`	scaled matrix created with `scale_matrix()`

Examples

```
if (has_sympy()) {
  V <- matrix_sym(2, 2, "v")
  a <- symbol("a")
  Ks <- scale_matrix(V, a, divide = FALSE)
  Ks
  unscale_matrix(Ks)
  V %*% a
}
```

`vectorfy` *Creates symbol vector from list of caracas symbols*

Description

Creates symbol vector from list of caracas symbols

Usage

```
vectorfy(x)
```

Arguments

x	Symbol to be coerced to vector

[.caracas_symbol *Extract or replace parts of an object*

Description

Extract or replace parts of an object

Usage

```
## S3 method for class 'caracas_symbol'
x[i, j, ..., drop = TRUE]
```

Arguments

x	A caracas_symbol.
i	row indices specifying elements to extract or replace
j	column indices specifying elements to extract or replace
...	Not used
drop	Simplify dimensions of resulting object

Examples

```
if (has_sympy()) {
  A <- matrix(c("a", 0, 0, 0, "a", "a", "a", 0, 0), 3, 3)
  B <- as_sym(A)
  B[1:2, ]
  B[, 2]
  B[2, , drop = FALSE]
}
```

[<-.caracas_symbol *Extract or replace parts of an object*

Description

Extract or replace parts of an object

Usage

```
## S3 replacement method for class 'caracas_symbol'
x[i, j, ...] <- value
```

Arguments

x	A caracas_symbol.
i	row indices specifying elements to extract or replace
j	column indices specifying elements to extract or replace
...	Not used
value	Replacement value

Examples

```
if (has_sympy()) {
  A <- matrix(c("a", 0, 0, 0, "a", "a", "a", 0, 0), 3, 3)
  B <- as_sym(A)
  B[, 2] <- "x"
  B[, 3] <- vector_sym(3)
  B
}
```

%>% *Pipe*

Description

Pipe operator

Arguments

lhs, rhs	specify what lhs and rhs are

Index