Package ‘Matrix’

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Title Sparse and Dense Matrix Classes and Methods
Description A rich hierarchy of sparse and dense matrix classes, including general, symmetric, triangular, and diagonal matrices with numeric, logical, or pattern entries. Efficient methods for operating on such matrices, often wrapping the 'BLAS', 'LAPACK', and 'SuiteSparse' libraries.
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Contact Matrix-authors@R-project.org
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## Index

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Description

The "abIndex" class, short for "Abstract Index Vector", is used for dealing with large index vectors more efficiently, than using integer (or numeric) vectors of the kind 2:1000000 or c(0:1e5, 1000:1e6).

Note that the current implementation details are subject to change, and if you consider working with these classes, please contact the package maintainers (packageDescription("Matrix")$Maintainer).

Objects from the Class

Objects can be created by calls of the form new("abIndex", ...), but more easily and typically either by as(x, "abIndex") where x is an integer (valued) vector, or directly by abIseq() and combination c(...) of such.

Slots

- **kind**: a character string, one of ("int32", "double", "rleDiff"), denoting the internal structure of the abIndex object.
- **x**: Object of class "numLike"; is used (i.e., not of length 0) only iff the object is not compressed, i.e., currently exactly when kind != "rleDiff".
- **rleD**: object of class "rleDiff", used for compression via rle.

Methods

- **as.numeric, as.integer, as.vector** signature(x = "abIndex"): ...
- [ signature(x = "abIndex", i = "index", j = "ANY", drop = "ANY"): ...
- **coerce** signature(from = "numeric", to = "abIndex"): ...
- **coerce** signature(from = "abIndex", to = "numeric"): ...
- **coerce** signature(from = "abIndex", to = "integer"): ...
- **length** signature(x = "abIndex"): ...

**Ops** signature(e1 = "numeric", e2 = "abIndex"): These and the following arithmetic and logic operations are not yet implemented; see Ops for a list of these (S4) group methods.

- **Ops** signature(e1 = "abIndex", e2 = "abIndex"): ...
- **Ops** signature(e1 = "abIndex", e2 = "numeric"): ...

**Summary** signature(x = "abIndex"): ...

- **show** ("abIndex"): simple show method, building on show(<rleDiff>).
- **is.na** ("abIndex"): works analogously to regular vectors.
- **is.finite, is.infinite** ("abIndex"): ditto.
Note

This is currently experimental and not yet used for our own code. Please contact us (packageDescription("Matrix")$Maintainer), if you plan to make use of this class.

Partly builds on ideas and code from Jens Oehlschlaegel, as implemented (around 2008, in the GPL'ed part of) package ff.

See Also

rle (base) which is used here; numeric

Examples

showClass("abIndex")
ii <- c(-3:40, 20:70)
str(ai <- as(ii, "abIndex"))# note
ai # -> show() method

stopifnot(identical(-3:20,
as(abIseq1(-3,20), "vector")))

abIseq

Sequence Generation of "abIndex", Abstract Index Vectors

Description

Generation of abstract index vectors, i.e., objects of class "abIndex".

abIseq() is designed to work entirely like seq, but producing "abIndex" vectors.

abIseq1() is its basic building block, where abIseq1(n,m) corresponds to n:m.

c(x, ...) will return an "abIndex" vector, when x is one.

Usage

abIseq1(from = 1, to = 1)
abIseq (from = 1, to = 1, by = ((to - from)/(length.out - 1)),
       length.out = NULL, along.with = NULL)

## S3 method for class 'abIndex'
c(...)

Arguments

from, to the starting and (maximal) end value of the sequence.

by number: increment of the sequence.
length.out desired length of the sequence. A non-negative number, which for seq and seq.int will be rounded up if fractional.
along.with take the length from the length of this argument.
... in general an arbitrary number of R objects; here, when the first is an "abIndex" vector, these arguments will be concatenated to a new "abIndex" object.

Value
An abstract index vector, i.e., object of class "abIndex".

See Also
the class abIndex documentation; rep2abI() for another constructor; rle (base).

Examples
stopifnot(identical(-3:20,
     as(abIseq1(-3,20), "vector")))

try( ## (arithmetic) not yet implemented
    abIseq(1, 50, by = 3)
  )
Examples

```r
M <- Matrix(1:12 +0, 3,4)
all(M >= 1) # TRUE
any(M < 0 ) # FALSE
MN <- M; MN[2,3] <- NA; MN
all(MN >= 0) # NA
any(MN < 0 ) # NA
any(MN < 0, na.rm = TRUE) # -> FALSE
```

Description

Methods for function `all.equal()` (from R package base) are defined for all `Matrix` classes.

Methods

- target = "Matrix", current = "Matrix"
- target = "ANY", current = "Matrix"
- target = "Matrix", current = "ANY" these three methods are simply using `all.equal.numeric` directly and work via `as.vector()`.

There are more methods, notably also for "sparseVector"'s, see `showMethods("all.equal")`.

Examples

```r
showMethods("all.equal")

(A <- spMatrix(3,3, i= c(1:3,2:1), j=c(3:1,1:2), x = 1:5))
ex <- expand(lu. <- lu(A))
stopifnot( all.equal(as(A[lu.@p + 1L, lu.@q + 1L], "CsparseMatrix"),
            lu.@L %*% lu.@U),
          with(ex, all.equal(as(P %*% A %*% t(Q), "CsparseMatrix"),
                             L %*% U)),
          with(ex, all.equal(as(A, "CsparseMatrix"),
                             t(P) %*% L %*% U %*% Q)))
```
atomicVector-class

Virtual Class "atomicVector" of Atomic Vectors

Description

The class "atomicVector" is a virtual class containing all atomic vector classes of base \( \mathbb{R} \), as also implicitly defined via is.atomic.

Objects from the Class

A virtual Class: No objects may be created from it.

Methods

In the Matrix package, the "atomicVector" is used in signatures where typically “old-style” "matrix" objects can be used and can be substituted by simple vectors.

Extends

The atomic classes "logical", "integer", "double", "numeric", "complex", "raw" and "character" are extended directly. Note that "numeric" already contains "integer" and "double", but we want all of them to be direct subclasses of "atomicVector".

Author(s)

Martin Maechler

See Also

is.atomic, integer, numeric, complex, etc.

Examples

showClass("atomicVector")

band-methods

Extract bands of a matrix

Description

Return the matrix obtained by setting to zero elements below a diagonal (triu), above a diagonal (tril), or outside of a general band (band).
Usage

band(x, k1, k2, ...)
triu(x, k = 0L, ...)
tril(x, k = 0L, ...)  

Arguments

x          a matrix-like object
k,k1,k2    integers specifying the diagonals that are not set to zero. These are interpreted
            relative to the main diagonal, which is k=0. Positive and negative values of k
            indicate diagonals above and below the main diagonal, respectively.
...         optional arguments passed methods (currently unused by package Matrix)

Details

triu(x, k) is equivalent to band(x, k, dim(x)[2]). Similarly, tril(x, k) is equivalent to band(x,
-{-dim(x)[1], k}).

Value

An object of a suitable matrix class, inheriting from triangularMatrix where appropriate. It
inherits from sparseMatrix if and only if x does.

Methods

x = "CsparseMatrix"   method for compressed, sparse, column-oriented matrices.
x = "RsparseMatrix"   method for compressed, sparse, row-oriented matrices.
x = "TsparseMatrix"   method for sparse matrices in triplet format.
x = "diagonalMatrix"  method for diagonal matrices.
x = "denseMatrix"     method for dense matrices in packed or unpacked format.
x = "matrix"         method for traditional matrices of implicit class matrix.

See Also

bandSparse for the construction of a banded sparse matrix directly from its non-zero diagonals.

Examples

## A random sparse matrix :
set.seed(7)
m <- matrix(0, 5, 5)
m[sample(length(m), size = 14)] <- rep(1:9, length=14)
(mm <- as(m, "CsparseMatrix"))

tril(mm)       # lower triangle
tril(mm, -1)   # strict lower triangle
triu(mm, 1)    # strict upper triangle
Construct Sparse Banded Matrix from (Sup-/Super-) Diagonals

Description

Construct a sparse banded matrix by specifying its non-zero sup- and super-diagonals.

Usage

```r
bandSparse(n, m = n, k, diagonals, symmetric = FALSE,
           repr = "C", giveCsparse = (repr == "C"))
```

Arguments

- `n,m` the matrix dimension \((n, m) = (nrow, ncol)\).
- `k` integer vector of “diagonal numbers”, with identical meaning as in `band(*, k)`, i.e., relative to the main diagonal, which is \(k=0\).
- `diagonals` optional list of sub-/super- diagonals; if missing, the result will be a pattern matrix, i.e., inheriting from class `nMatrix`. Diagonals can also be \(n' \times d\) matrix, where \(d <= \text{length}(k)\) and \(n' >= \text{min}(n, m)\). In that case, the sub-/super- diagonals are taken from the columns of diagonals, where only the first several rows will be used (typically) for off-diagonals.
- `symmetric` logical; if true the result will be symmetric (inheriting from class `symmetricMatrix`) and only the upper or lower triangle must be specified (via \(k\) and `diagonals`).
- `repr` character string, one of "C", "T", or "R", specifying the sparse representation to be used for the result, i.e., one from the super classes `CsparseMatrix`, `TsparseMatrix`, or `RsparseMatrix`. 

giveCsparse (deprecated, replaced with repr): logical indicating if the result should be a CsparseMatrix or a TsparseMatrix, where the default was TRUE, and now is determined from repr; very often Csparse matrices are more efficient subsequently, but not always.

Value

A sparse matrix (of class CsparseMatrix) of dimension \( n \times m \) with diagonal “bands” as specified.

See Also

band, for extraction of matrix bands: bdiag, diag, sparseMatrix, Matrix.

Examples

diags <- list(1:30, 10*(1:20), 100*(1:20))
s1 <- bandSparse(13, k = -c(0:2, 6), diag = c(diags, diags[2]), symm=TRUE)
s1
s2 <- bandSparse(13, k = c(0:2, 6), diag = c(diags, diags[2]), symm=TRUE)
stopifnot(identical(s1, t(s2)), is(s1,"dsCMatrix")

## a pattern Matrix of *full* (sub-)diagonals:
bk <- c(0:4, 7,9)
(s3 <- bandSparse(30, k = bk, symm = TRUE))

## If you want a pattern matrix, but with "sparse"-diagonals,
## you currently need to go via logical sparse:
lLis <- lapply(list(rpois(20, 2), rpois(20, 1), rpois(20, 3))[c(1:3, 2:3, 3:2)],
as.logical)
(s4 <- bandSparse(20, k = bk, symm = TRUE, diag = lLis))
(s4. <- as(drop0(s4), "nsparseMatrix")

n <- 1e4
bk <- c(0:5, 7,11)
bMat <- matrix(1:8, n, 8, byrow=TRUE)
bLis <- as.data.frame(bMat)
B <- bandSparse(n, k = bk, diag = bLis)
Bs <- bandSparse(n, k = bk, diag = bLis, symmetric=TRUE)
B [1:15, 1:30]
Bs[1:15, 1:30]

## can use a list *or* a matrix for specifying the diagonals:
stopifnot(identical(B, bandSparse(n, k = bk, diag = bMat)),
identical(Bs, bandSparse(n, k = bk, diag = bMat, symmetric=TRUE))
, inherits(B, "dtCMatrix") # triangular!

)
Construct a Block Diagonal Matrix

Description

Build a block diagonal matrix given several building block matrices.

Usage

bdiag(...)
.bdiag(lst)

Arguments

... individual matrices or a list of matrices.
1st non-empty list of matrices.

Details

For non-trivial argument list, bdiag() calls .bdiag(). The latter maybe useful to programmers.

Value

A sparse matrix obtained by combining the arguments into a block diagonal matrix.

The value of bdiag() inherits from class CsparseMatrix, whereas .bdiag() returns a TsparseMatrix.

Note

This function has been written and is efficient for the case of relatively few block matrices which are typically sparse themselves.

It is currently inefficient for the case of many small dense block matrices. For the case of many dense \( k \times k \) matrices, the bdiag_m() function in the ‘Examples’ is an order of magnitude faster.

Author(s)

Martin Maechler, built on a version posted by Berton Gunter to R-help; earlier versions have been posted by other authors, notably Scott Chasalow to S-news. Doug Bates’s faster implementation builds on TsparseMatrix objects.

See Also

Diagonal for constructing matrices of class diagonalMatrix, or kronecker which also works for "Matrix" inheriting matrices.

bandSparse constructs a banded sparse matrix from its non-zero sub-/super - diagonals.

Note that other CRAN R packages have own versions of bdiag() which return traditional matrices.
Examples

```r
diag(matrix(1:4, 2), diag(3))
## combine "Matrix" class and traditional matrices:
bdia(Diagonal(2), matrix(1:3, 3, 4), diag(3:2))

mlist <- list(1, 2:3, diag(x=5:3), 27, cbind(1,3:6), 100:101)
bdia(mlist)
stopifnot(identical(bdia(mlist),
   bdia(lapply(mlist, as.matrix))))

ml <- c(as(matrix((1:24)%% 11 == 0, 6,4),"nMatrix"),
    rep(list(Diagonal(2, x=TRUE)), 3))
mln <- c(ml, Diagonal(x = 1:3))
stopifnot(is(bdia(ml), "lsparseMatrix"),
   is(bdia(mln),"dsparseMatrix") )

## random (diagonal-)block-triangular matrices:
rblockTri <- function(nb, max.ni, lambda = 3) {
    .bdiag(replicate(nb, {
        n <- sample.int(max.ni, 1)
        tril(Matrix(rpois(n * n, lambda = lambda), n, n)) 
    }))
}
(T4 <- rblockTri(4, 10, lambda = 1))
image(T1 <- rblockTri(12, 20))
```

```r
## Fast version of Matrix :: .bdiag() -- for the case of *many* (k x k) matrices:
## @param lmat list(<mat1>, <mat2>, ..., <mat_N>) where each mat_j is a k x k 'matrix'
## @return a sparse (N*k x N*k) matrix of class \code{\linkS4class{dgCMatrix}}.

```
Description

For boolean or “pattern” matrices, i.e., R objects of class nMatrix, it is natural to allow matrix products using boolean instead of numerical arithmetic.

In package Matrix, we use the binary operator %&% (aka “infix”) function for this and provide methods for all our matrices and the traditional R matrices (see matrix).

Value

a pattern matrix, i.e., inheriting from "nMatrix", or an "ldiMatrix" in case of a diagonal matrix.

Methods

We provide methods for both the “traditional” (R base) matrices and numeric vectors and conceptually all matrices and sparseVectors in package Matrix.

signature(x = "ANY", y = "ANY")
signature(x = "ANY", y = "Matrix")
signature(x = "Matrix", y = "ANY")
signature(x = "mMatrix", y = "mMatrix")
signature(x = "nMatrix", y = "nMatrix")
signature(x = "nMatrix", y = "nsparseMatrix")
signature(x = "nsparseMatrix", y = "nMatrix")
signature(x = "nsparseMatrix", y = "nsparseMatrix")
signature(x = "sparseVector", y = "mMatrix")
signature(x = "mMatrix", y = "sparseVector")
signature(x = "sparseVector", y = "sparseVector")

Note

These boolean arithmetic matrix products had been newly introduced for Matrix 1.2.0 (March 2015). Its implementation has still not been tested extensively.

Originally, it was left unspecified how non-structural zeros, i.e., 0’s as part of the M@x slot should be treated for numeric ("dMatrix") and logical ("lMatrix") sparse matrices. We now specify that boolean matrix products should behave as if applied to drop0(M), i.e., as if dropping such zeros from the matrix before using it.

Equivalently, for all matrices M, boolean arithmetic should work as if applied to M != 0 (or M != FALSE).

The current implementation ends up coercing both x and y to (virtual) class nsparseMatrix which may be quite inefficient for dense matrices. A future implementation may well return a matrix with different class, but the “same” content, i.e., the same matrix entries m_{i,j}. 

boolmatmult-methods

Boolean Arithmetic Matrix Products: %&% and Methods

T12[1:20, 1:20]
See Also

\texttt{%*%}, \texttt{crossprod()}, or \texttt{tcrossprod()}, for (regular) matrix product methods.

Examples

```r
set.seed(7)
L <- Matrix(rnorm(20) > 1, 4,5)
(N <- as(L, "nMatrix"))
L. <- L; L.[1:2,1] <- TRUE; L.@x[1:2] <- FALSE; L. # has "zeros" to drop0()
D <- Matrix(round(rnorm(30)), 5,6) # -> values in -1:1 (for this seed)
L %&% D
stopifnot(identical(L %&% D, N %&% D),
  all(L %&% D == as((L %*% abs(D)) > 0, "sparseMatrix")))
## cross products , possibly with boolArith = TRUE :
crossprod(N) # -> sparse patter'n' (TRUE/FALSE : boolean arithmetic)
crossprod(N +0) # -> numeric Matrix (with same "pattern")
stopifnot(all(crossprod(N) == t(N) %&% N),
  identical(crossprod(N), crossprod(N +0, boolArith=TRUE)),
  identical(crossprod(L), crossprod(N , boolArith=FALSE)))
crossprod(D, boolArith = TRUE) # pattern: "nsCMatrix"
crossprod(L, boolArith = TRUE) # ditto
crossprod(L, boolArith = FALSE) # numeric: "dsCMatrix"
```

Dense Bunch-Kaufman Factorizations

Description

Classes \texttt{BunchKaufman} and \texttt{pBunchKaufman} represent Bunch-Kaufman factorizations of \( n \times n \) real, symmetric matrices \( A \), having the general form

\[ A = U D_U U' = L D_L L' \]

where \( D_U \) and \( D_L \) are symmetric, block diagonal matrices composed of \( b_U \) and \( b_L \) \( 1 \times 1 \) or \( 2 \times 2 \) diagonal blocks; \( U = \prod_{k=1}^{b_U} P_k U_k \) is the product of \( b_U \) row-permuted unit upper triangular matrices, each having nonzero entries above the diagonal in 1 or 2 columns; and \( L = \prod_{k=1}^{b_L} P_k L_k \) is the product of \( b_L \) row-permuted unit lower triangular matrices, each having nonzero entries below the diagonal in 1 or 2 columns.

These classes store the nonzero entries of the \( 2b_U + 1 \) or \( 2b_L + 1 \) factors, which are individually sparse, in a dense format as a vector of length \( nn \) (\texttt{BunchKaufman}) or \( n(n+1)/2 \) (\texttt{pBunchKaufman}), the latter giving the “packed” representation.

Slots

\texttt{Dim}, \texttt{Dimnames} inherited from virtual class \texttt{MatrixFactorization}.
BunchKaufman-class

uplo a string, either "U" or "L", indicating which triangle (upper or lower) of the factorized symmetric matrix was used to compute the factorization and in turn how the x slot is partitioned.

x a numeric vector of length n*n (BunchKaufman) or n*(n+1)/2 (pBunchKaufman), where n=Dim[1]. The details of the representation are specified by the manual for LAPACK routines dsytrf and dsptrf.

perm an integer vector of length n=Dim[1] specifying row and column interchanges as described in the manual for LAPACK routines dsytrf and dsptrf.

Extends

Class BunchKaufmanFactorization, directly. Class MatrixFactorization, by class BunchKaufmanFactorization, distance 2.

Instantiation

Objects can be generated directly by calls of the form new("BunchKaufman", ...) or new("pBunchKaufman", ...), but they are more typically obtained as the value of BunchKaufman(x) for x inheriting from dsyMatrix or dspMatrix.

Methods

coerce signature(from = "BunchKaufman", to = "dtrMatrix"): returns a dtrMatrix, useful for inspecting the internal representation of the factorization; see ‘Note’.

coerce signature(from = "pBunchKaufman", to = "dtpMatrix"): returns a dtpMatrix, useful for inspecting the internal representation of the factorization; see ‘Note’.

determinant signature(from = "p?BunchKaufman", logarithm = "logical"): computes the determinant of the factorized matrix A or its logarithm.

expand1 signature(x = "p?BunchKaufman"): see expand1-methods.

expand2 signature(x = "p?BunchKaufman"): see expand2-methods.

solve signature(a = "p?BunchKaufman", b = .): see solve-methods.

Note

In Matrix < 1.6-0, class BunchKaufman extended dtrMatrix and class pBunchKaufman extended dtpMatrix, reflecting the fact that the internal representation of the factorization is fundamentally triangular: there are n(n + 1)/2 “parameters”, and these can be arranged systematically to form an n x n triangular matrix. Matrix 1.6-0 removed these extensions so that methods would no longer be inherited from dtrMatrix and dtpMatrix. The availability of such methods gave the wrong impression that BunchKaufman and pBunchKaufman represent a (singular) matrix, when in fact they represent an ordered set of matrix factors.

The coercions as(. , "dtrMatrix") and as(. , "dtpMatrix") are provided for users who understand the caveats.
References

The LAPACK source code, including documentation; see https://netlib.org/lapack/double/dsytrf.f and https://netlib.org/lapack/double/dsptrf.f.


See Also

Class dsyMatrix and its packed counterpart.

Generic functions BunchKaufman, expand1, and expand2.

Examples

showClass("BunchKaufman")
set.seed(1)

n <- 6
(A <- forceSymmetric(Matrix(rnorm(n * n), n, n)))

## With dimnames, to see that they are propagated :
dimnames(A) <- rep.int(list(paste0("x", seq_len(n))), 2L)

(bk.A <- BunchKaufman(A))
str(e.bk.A <- expand2(bk.A, complete = FALSE), max.level = 2L)
str(E.bk.A <- expand2(bk.A, complete = TRUE), max.level = 2L)

## Underlying LAPACK representation
(m.bk.A <- as(bk.A, "dtrMatrix"))
stopifnot(identical(as(m.bk.A, "matrix"), 'dim<-'(bk.A@x, bk.A@Dim)))

## Number of factors is 2*b+1, b <= n, which can be nontrivial ...
(b <- (length(E.bk.A) - 1L) %/% 2L)

ae1 <- function(a, b, ...) all.equal(as(a, "matrix"), as(b, "matrix"), ...)
ae2 <- function(a, b, ...) ae1(unname(a), unname(b), ...)

## A ~ U DU U

## Factorization handled as factorized matrix
b <- rnorm(n)
stopifnot(identical(det(A), det(bk.A)), idential(solve(A, b), solve(bk.A, b)))
Methods for Bunch-Kaufman Factorization

Description

Computes the Bunch-Kaufman factorization of an \( n \times n \) real, symmetric matrix \( A \), which has the general form

\[
A = U D_U U' = L D_L L'
\]

where \( D_U \) and \( D_L \) are symmetric, block diagonal matrices composed of \( b_U \) and \( b_L \) \( 1 \times 1 \) or \( 2 \times 2 \) diagonal blocks; \( U = \prod_{k=1}^{b_U} P_k U_k \) is the product of \( b_U \) row-permuted unit upper triangular matrices, each having nonzero entries above the diagonal in 1 or 2 columns; and \( L = \prod_{k=1}^{b_L} P_k L_k \) is the product of \( b_L \) row-permuted unit lower triangular matrices, each having nonzero entries below the diagonal in 1 or 2 columns.

Methods are built on LAPACK routines \texttt{dsytrf} and \texttt{dsptrf}.

Usage

BunchKaufman(x, ...)  
## S4 method for signature 'dsyMatrix'  
BunchKaufman(x, warnSing = TRUE, ...)  
## S4 method for signature 'dspMatrix'  
BunchKaufman(x, warnSing = TRUE, ...)  
## S4 method for signature 'matrix'  
BunchKaufman(x, uplo = "U", ...)

Arguments

- \( x \) a finite symmetric matrix or \texttt{Matrix} to be factorized. If \( x \) is square but not symmetric, then it will be treated as symmetric; see \texttt{uplo}.
- \texttt{warnSing} a logical indicating if a \texttt{warning} should be signaled for singular \( x \).
- \texttt{uplo} a string, either "U" or "L", indicating which triangle of \( x \) should be used to compute the factorization.
- ... further arguments passed to or from methods.

Value

An object representing the factorization, inheriting from virtual class \texttt{BunchKaufmanFactorization}. The specific class is \texttt{BunchKaufman} unless \( x \) inherits from virtual class \texttt{packedMatrix}, in which case it is \texttt{pBunchKaufman}.

References

The LAPACK source code, including documentation; see \url{https://netlib.org/lapack/double/dsytrf.f} and \url{https://netlib.org/lapack/double/dsptrf.f}.

See Also

Classes BunchKaufman and pBunchKaufman and their methods.
Classes dsyMatrix and dspMatrix.

Generic functions expand1 and expand2, for constructing matrix factors from the result.
Generic functions Cholesky, Schur, lu, and qr, for computing other factorizations.

Examples

showMethods("BunchKaufman", inherited = FALSE)
set.seed(0)
data(CAex, package = "Matrix")
class(CAex) # dgCMatrix
isSymmetric(CAex) # symmetric, but not formally

A <- as(CAex, "symmetricMatrix")
class(A) # dsCMatrix

## Have methods for denseMatrix (unpacked and packed),
## but not yet sparseMatrix ...
## Not run:
(bk.A <- BunchKaufman(A))

## End(Not run)
(bk.A <- BunchKaufman(as(A, "unpackedMatrix")))

## A = U DU' in floating point
str(e.bk.A <- expand2(bk.A), max.level = 2L)
stopifnot(all.equal(as(A, "matrix"), as(Reduce("%*%", e.bk.A), "matrix")))

---

CAex  
Albers' example Matrix with "Difficult" Eigen Factorization

Description

An example of a sparse matrix for which eigen() seemed to be difficult, an unscaled version of this has been posted to the web, accompanying an E-mail to R-help (https://stat.ethz.ch/mailman/listinfo/r-help), by Casper J Albers, Open University, UK.

Usage

data(CAex)

Format

This is a 72 × 72 symmetric matrix with 216 non-zero entries in five bands, stored as sparse matrix of class dgCMatrix.
Historical note (2006-03-30): In earlier versions of R, `eigen(CAex)` fell into an infinite loop whereas `eigen(CAex, EISPACK=TRUE)` had been okay.

Examples

data(CAex, package = "Matrix")
str(CAex) # of class "dgCMatrix"

image(CAex)# -> it's a simple band matrix with 5 bands
## and the eigen values are basically 1 (42 times) and 0 (30 x):
## i.e., the matrix is symmetric, hence
zapsmall(ev <- eigen(CAex, only.values=TRUE)$values)
## and
stopifnot(class(sCA) == "dsCMatrix",
  as(sCA, "matrix") == as(CAex, "matrix"))
cbind2-methods

Arguments

... for [c]bind, vector- or matrix-like R objects to be bound together; for [c]bind2, further arguments passed to or from methods; see cbind and cbind2.

deparse.level integer controlling the construction of labels in the case of non-matrix-like arguments; see cbind.

x, y vector- or matrix-like R objects to be bound together.

sparse logical indicating if the result should be formally sparse, i.e., if it should inherit from virtual class sparseMatrix. NA, the default, decides based on the “sparsity” of x and y; see, e.g., selectMethod(cbind2, c("sparseMatrix", "denseMatrix").

Value
typically a ‘matrix-like’ object of a similar class as the first argument in ....

Note that sometimes by default, the result is a sparseMatrix if one of the arguments is (even in the case where this is not efficient). In other cases, the result is chosen to be sparse when there are more zero entries is than non-zero ones (as the default sparse in Matrix()).

Author(s)

Martin Maechler

See Also

cbind, cbind2.

Our class definition help pages mentioning cbind2() and rbind2() methods: "denseMatrix", "diagonalMatrix", "indMatrix".

Examples

(a <- matrix(c(2:1,1:2), 2,2))
(M1 <- cbind(0, rbind(a, 7))) # a traditional matrix
D <- Diagonal(2)
(M2 <- cbind(4, a, D, -1, D, 0)) # a sparse Matrix

stopifnot(validObject(M2), inherits(M2, "sparseMatrix"),
dim(M2) == c(2,9))
**Description**

CHMfactor is the virtual class of sparse Cholesky factorizations of $n \times n$ real, symmetric matrices $A$, having the general form

$$P_1 A P_1' = L_1 D L_1'$$

or (equivalently)

$$A = P_1' L_1 D L_1' P_1$$

where $P_1$ is a permutation matrix, $L_1$ is a unit lower triangular matrix, $D$ is a diagonal matrix, and $L = L_1 \sqrt{D}$. The second equalities hold only for positive semidefinite $A$, for which the diagonal entries of $D$ are non-negative and $\sqrt{D}$ is well-defined.

The implementation of class CHMfactor is based on CHOLMOD's C-level cholmod_factor_struct.

Virtual subclasses CHMsimpl and CHMsuper separate the simplicial and supernodal variants. These have nonvirtual subclasses [dn]CHMsimpl and [dn]CHMsuper, where prefix 'd' and prefix 'n' are reserved for numeric and symbolic factorizations, respectively.

**Usage**

isLDL(x)

**Arguments**

x an object inheriting from virtual class CHMfactor, almost always the result of a call to generic function Cholesky.

**Value**

isLDL(x) returns TRUE or FALSE: TRUE if x stores the lower triangular entries of $L_1 - I + D$, FALSE if x stores the lower triangular entries of $L$.

**Slots**

Of CHMfactor:

- Dim, Dimnames inherited from virtual class MatrixFactorization.

- colcount an integer vector of length Dim[1] giving an estimate of the number of nonzero entries in each column of the lower triangular Cholesky factor. If symbolic analysis was performed prior to factorization, then the estimate is exact.

- perm a 0-based integer vector of length Dim[1] specifying the permutation applied to the rows and columns of the factorized matrix. perm of length 0 is valid and equivalent to the identity permutation, implying no pivoting.
type an integer vector of length 6 specifying details of the factorization. The elements correspond to members ordering, is_ll, is_super, is_monotonic, maxcsize, and maxesize of the original cholmod_factor_struct. Simplicial and supernodal factorizations are distinguished by is_super. Simplicial factorizations do not use maxcsize or maxesize. Supernodal factorizations do not use is_ll or is_monotonic.

Of CHMsimpl (all unused by nCHMsimpl):

nz an integer vector of length Dim[1] giving the number of nonzero entries in each column of the lower triangular Cholesky factor. There is at least one nonzero entry in each column, because the diagonal elements of the factor are stored explicitly.

p an integer vector of length Dim[1]+1. Row indices of nonzero entries in column j of the lower triangular Cholesky factor are obtained as i[p[j]+seq_len(nz[j])+1].

i an integer vector of length greater than or equal to sum(nz) containing the row indices of nonzero entries in the lower triangular Cholesky factor. These are grouped by column and sorted within columns, but the columns themselves need not be ordered monotonically. Columns may be overallocated, i.e., the number of elements of i reserved for column j may exceed nz[j].

prv, nxt integer vectors of length Dim[1]+2 indicating the order in which the columns of the lower triangular Cholesky factor are stored in i and x. Starting from j <- Dim[1]+2, the recursion j <- nxt[j+1]+1 traverses the columns in forward order and terminates when nxt[j+1] = -1. Starting from j <- Dim[1]+1, the recursion j <- prv[j+1]+1 traverses the columns in backward order and terminates when prv[j+1] = -1.

Of dCHMsimpl:

x a numeric vector parallel to i containing the corresponding nonzero entries of the lower triangular Cholesky factor L or (if and only if type[2] is 0) of the lower triangular matrix $L_1 - I + D$

Of CHMsuper:

super, pi, px integer vectors of length nsuper+1, where nsuper is the number of supernodes. super[j]+1 is the index of the leftmost column of supernode j. The row indices of supernode j are obtained as s[pi[j]+seq_len(pi[j+1]-pi[j])+1]. The numeric entries of supernode j are obtained as x[px[j]+seq_len(px[j+1]-px[j])+1] (if slot x is available).

s an integer vector of length greater than or equal to Dim[1] containing the row indices of the supernodes. s may contain duplicates, but not within a supernode, where the row indices must be increasing.

Of dCHMsuper:

x a numeric vector of length less than or equal to prod(Dim) containing the numeric entries of the supernodes.

Extends

Class MatrixFactorization, directly.
**Instantiation**

Objects can be generated directly by calls of the form `new("dCHMsimpl", ...), etc., but `dCHMsimpl` and `dCHMsuper` are more typically obtained as the value of `Cholesky(x, ...) for x inheriting from `sparseMatrix` (often `dsCMatrix`).

There is currently no API outside of calls to `new` for generating `nCHMsimpl` and `nCHMsuper`. These classes are vestigial and may be formally deprecated in a future version of `Matrix`.

**Methods**

**coerce signature** (from = "CHMsimpl", to = "dtCMatrix"): returns a `dtCMatrix` representing
the lower triangular Cholesky factor \(L\) or the lower triangular matrix \(L_1 - I + D\), the latter if and only if `from@type[2]` is 0.

**coerce signature** (from = "CHMsuper", to = "dgCMatrix"): returns a `dgCMatrix` representing
the lower triangular Cholesky factor \(L\). Note that, for supernodes spanning two or more
columns, the supernodal algorithm by design stores non-structural zeros above the main diagonal, hence `dgCMatrix` is indeed more appropriate than `dtCMatrix` as a coercion target.

**determinant signature** (from = "CHMfactor", logarithm = "logical"): behaves according to
an optional argument `sqrt`. If `sqrt = FALSE`, then this method computes the determinant of
the factorized matrix \(A\) or its logarithm. If `sqrt = TRUE`, then this method computes the
determinant of the factor \(L = L_1 sqrt(D)\) or its logarithm, giving NaN for the modulus when
\(D\) has negative diagonal elements. For backwards compatibility, the default value of `sqrt` is
TRUE, but that can be expected change in a future version of `Matrix`, hence defensive code
will always set `sqrt` to TRUE, if the code must remain backwards compatible with `Matrix`
< 1.6-0). Calls to this method not setting `sqrt` may warn about the pending change. The
warnings can be disabled with `options(Matrix.warnSqrtDefault = 0)`.

**diag signature** (x = "CHMfactor"): returns a numeric vector of length \(n\) containing the diagonal
elements of \(D\), which (if they are all non-negative) are the squared diagonal elements of \(L\).

**expand signature** (x = "CHMfactor"): see `expand-methods`.

**expand1 signature** (x = "CHMsimpl"): see `expand1-methods`.

**expand1 signature** (x = "CHMsuper"): see `expand1-methods`.

**expand2 signature** (x = "CHMsimpl"): see `expand2-methods`.

**expand2 signature** (x = "CHMsuper"): see `expand2-methods`.

**image signature** (x = "CHMfactor"): see `image-methods`.

**nnzero signature** (x = "CHMfactor"): see `nnzero-methods`.

**solve signature** (a = "CHMfactor", b = .): see `solve-methods`.

**update signature** (object = "CHMfactor"): returns a copy of object with the same nonzero
pattern but with numeric entries updated according to additional arguments `parent` and `mult`,
where `parent` is (coercible to) a `dsCMatrix` or a `dgCMatrix` and `mult` is a numeric vector of
positive length.

The numeric entries are updated with those of the Cholesky factor of \(F(parent) + mult[1] \ast
I, i.e., \(F\) (parent) plus `mult[1]` times the identity matrix, where \(F = identity\) for symmetric
parent and \(F = tcrossprod\) for other parent. The nonzero pattern of \(F\) (parent) must match
that of \(S\) if `object = Cholesky(S, ...)`.

**updown signature** (update = ., C = ., object = "CHMfactor"): see `updown-methods`.
References
The CHOLMOD source code; see https://github.com/DrTimothyAldenDavis/SuiteSparse, notably the header file ‘CHOLMOD/Include/cholmod.h’ defining cholmod_factor_struct.

See Also
Class dsCMatrix.
Generic functions Cholesky, updown, expand1 and expand2.

Examples

showClass("dCMsimpl")
showClass("dCMsuper")
set.seed(2)

m <- 1000L
n <- 200L
M <- rsparsematrix(m, n, 0.01)
A <- crossprod(M)

## With dimnames, to see that they are propagated :
dimnames(A) <- dn <- rep.int(list(paste0("x", seq_len(n))), 2L)

(ch.A <- Cholesky(A)) # pivoted, by default
str(e.ch.A <- expand2(ch.A, LDL = TRUE), max.level = 2L)
str(E.ch.A <- expand2(ch.A, LDL = FALSE), max.level = 2L)

ae1 <- function(a, b, ...) all.equal(as(a, "matrix"), as(b, "matrix"), ...)
ae2 <- function(a, b, ...) ae1(unname(a), unname(b), ...)

## A ~ P1' L1 D L1' P1 ~ P1' L L' P1 in floating point
stopifnot(exprs = {
  identical(names(e.ch.A), c("P1.", "L1", "D", "L1.", "P1"))
  identical(names(E.ch.A), c("P1.", "L", "L.", "P1"))
  identical(e.ch.A[['P1']],
    new("pMatrix", Dim = c(n, n), Dimnames = c(list(NULL), dn[2L]),
      margin = 2L, perm = invertPerm(ch.A@perm, 0L, 1L)))
  identical(e.ch.A[['P1.']], t(e.ch.A[['P1']]))
  identical(e.ch.A[['L1.']], t(e.ch.A[['L1']]))
  identical(E.ch.A[['L.' ]], t(E.ch.A[['L' ]]))
  identical(e.ch.A[['D']], Diagonal(x = diag(ch.A)))
})
```r
all.equal(E.ch.A[["L"]], with(e.ch.A, L1 %*% sqrt(D)))
ae1(A, with(e.ch.A, P1. %*% L1 %*% D %*% L1. %*% P1))
ae1(A, with(E.ch.A, P1. %*% L %*% L. %*% P1))
ae2(A[ch.ch.A@perm + 1L, ch.ch.A@perm + 1L], with(E.ch.A, L %*% L.))
ae2(A[ch.ch.A@perm + 1L, ch.ch.A@perm + 1L], with(E.ch.A, L %*% L.))
```

## Factorization handled as factorized matrix
## (in some cases only optionally, depending on arguments)
b <- rnorm(n)
stopifnot(identical(det(A), det(ch.A, sqrt = FALSE)),
          identical(solve(A, b), solve(ch.A, b, system = "A")))

u1 <- update(ch.A, A , mult = sqrt(2))
u2 <- update(ch.A, t(M), mult = sqrt(2)) # updating with crossprod(M), not M
stopifnot(all.equal(u1, u2, tolerance = 1e-14))

---

**chol-methods**

Compute the Cholesky Factor of a Matrix

**Description**

Computes the upper triangular Cholesky factor of an \( n \times n \) real, symmetric, positive semidefinite matrix \( A \), optionally after pivoting. That is the factor \( L' \) in

\[
P_1 A P_1' = LL'
\]

or (equivalently)

\[
A = P_1' L L' P_1
\]

where \( P_1 \) is a permutation matrix.

Methods for `denseMatrix` are built on LAPACK routines `dpstrf`, `dpotrf`, and `dpptrf`. The latter two do not permute rows or columns, so that \( P_1 \) is an identity matrix.

Methods for `sparseMatrix` are built on CHOLMOD routines `cholmod_analyze` and `cholmod_factorize_p`.

**Usage**

chol(x, ...)

## S4 method for signature 'dsyMatrix'
chol(x, pivot = FALSE, tol = -1, ...)

## S4 method for signature 'dspMatrix'
chol(x, ...)

## S4 method for signature 'dsCMatrix'
chol(x, pivot = FALSE, ...)

## S4 method for signature 'ddiMatrix'
chol(x, ...)

## S4 method for signature 'generalMatrix'
chol(x, uplo = "U", ...)

## S4 method for signature 'triangularMatrix'
chol(x, uplo = "U", ...)
Arguments

\textit{x} \quad \text{a finite, symmetric, positive semidefinite matrix or Matrix to be factorized. If x is square but not symmetric, then it will be treated as symmetric; see uplo. Methods for dense x require positive definiteness when pivot = FALSE. Methods for sparse (but not diagonal) x require positive definiteness unconditionally.}

\textit{pivot} \quad \text{a logical indicating if the rows and columns of x should be pivoted. Methods for sparse x employ the approximate minimum degree (AMD) algorithm in order to reduce fill-in, i.e., without regard for numerical stability.}

\textit{tol} \quad \text{a finite numeric tolerance, used only if pivot = TRUE. The factorization algorithm stops if the pivot is less than or equal to tol. Negative tol is equivalent to nrow(x) * .Machine$double.eps * max(diag(x)).}

\textit{uplo} \quad \text{a string, either "U" or "L", indicating which triangle of x should be used to compute the factorization. The default is "U", even for lower triangular x, to be consistent with chol from base.}

... further arguments passed to or from methods.

Details

For \textit{x} inheriting from \texttt{diagonalMatrix}, the diagonal result is computed directly and without pivoting, i.e., bypassing CHOLMOD.

For all other \textit{x}, \texttt{chol(x, pivot = value)} calls \texttt{Cholesky(x, perm = value, ...)} under the hood. If you must know the permutation \( P_1 \) in addition to the Cholesky factor \( L' \), then call \texttt{Cholesky} directly, as the result of \texttt{chol(x, pivot = TRUE)} specifies \( L' \) but not \( P_1 \).

Value

A matrix, \texttt{triangularMatrix}, or \texttt{diagonalMatrix} representing the upper triangular Cholesky factor \( L' \). The result is a traditional matrix if \textit{x} is a traditional matrix, dense if \textit{x} is dense, and sparse if \textit{x} is sparse.

References


The CHOLMOD source code; see https://github.com/DrTimothyAldenDavis/SuiteSparse, notably the header file 'CHOLMOD/Include/cholmod.h' defining cholmod_factor_struct.


See Also

The default method from base, chol, called for traditional matrices x.

Generic function Cholesky, for more flexibility notably when computing the Cholesky factorization and not only the factor L'.

Examples

showMethods("chol", inherited = FALSE)
set.seed(0)

## ---- Dense ----------------------------------------------------------
## chol(x, pivot = value) wrapping Cholesky(x, perm = value)
selectMethod("chol", "dsyMatrix")

## Except in packed cases where pivoting is not yet available
selectMethod("chol", "dspMatrix")

## .... Positive definite ..............................................
(A1 <- new("dsyMatrix", Dim = c(2L, 2L), x = c(1, 2, 2, 5)))
(R1.nopivot <- chol(A1))
(R1 <- chol(A1, pivot = TRUE))

## In 2-by-2 cases, we know that the permutation is 1:2 or 2:1,
## even if in general 'chol' does not say ...
stopifnot(exprs = {
  all.equal( A1 , as(crossprod(R1.nopivot), "dsyMatrix"))
  all.equal(t(A1[2:1, 2:1]), as(crossprod(R1), "dsyMatrix"))
  identical(Cholesky(A1)@perm, 2:1) # because 5 > 1
})

## .... Positive semidefinite but not positive definite ................
(A2 <- new("dpoMatrix", Dim = c(2L, 2L), x = c(1, 2, 2, 4)))
try(R2.nopivot <- chol(A2)) # fails as not positive definite
(R2 <- chol(A2, pivot = TRUE)) # returns, with a warning and ...

stopifnot(exprs = {
  all.equal(t(A2[2:1, 2:1]), as(crossprod(R2), "dsyMatrix"))
  identical(Cholesky(A2)@perm, 2:1) # because 4 > 1
})

## .... Not positive semidefinite ......................................
(A3 <- new("dsyMatrix", Dim = c(2L, 2L), x = c(1, 2, 2, 3)))
try(R3.nopivot <- chol(A3)) # fails as not positive definite
(R3 <- chol(A3, pivot = TRUE)) # returns, with a warning and ...

## _Not_ equal: see details and examples in help("Cholesky")
all.equal(t(A3[2:1, 2:1]), as(crossprod(R3), "dsyMatrix"))

## ---- Sparse ---------------------------------------------------------
## chol(x, pivot = value) wrapping
## Cholesky(x, perm = value, LDL = FALSE, super = FALSE)
selectMethod("chol", "dsCMatrix")

## Except in diagonal cases which are handled "directly"
selectMethod("chol", "ddiMatrix")

(A4 <- toeplitz(as(c(10, 0, 1, 0, 3), "sparseVector")))
(ch.A4.nopivot <- Cholesky(A4, perm = FALSE, LDL = FALSE, super = FALSE))
(ch.A4 <- Cholesky(A4, perm = TRUE, LDL = FALSE, super = FALSE))
(R4.nopivot <- chol(A4))
(R4 <- chol(A4, pivot = TRUE))
det4 <- det(A4)
b4 <- rnorm(5L)
x4 <- solve(A4, b4)

stopifnot(exprs = {
    identical(R4.nopivot, expand1(ch.A4.nopivot, "L."))
    identical(R4, expand1(ch.A4, "L."))
    all.equal(A4, crossprod(R4.nopivot))
    all.equal(A4[ch.A4@perm + 1L, ch.A4@perm + 1L], crossprod(R4))
    all.equal(diag(R4.nopivot), sqrt(diag(ch.A4.nopivot)))
    all.equal(diag(R4), sqrt(diag(ch.A4)))
    all.equal(sqrt(det4), det(R4.nopivot))
    all.equal(sqrt(det4), det(R4))
    all.equal(det4, det(ch.A4.nopivot, sqrt = FALSE))
    all.equal(det4, det(ch.A4, sqrt = FALSE))
    all.equal(x4, solve(R4.nopivot, solve(t(R4.nopivot), b4)))
    all.equal(x4, solve(ch.A4.nopivot, b4))
    all.equal(x4, solve(ch.A4, b4))
})

---

chol2inv-methods

Inverse from Cholesky Factor

Description

Given formally upper and lower triangular matrices \( U \) and \( L \), compute \((U'U)^{-1}\) and \((LL')^{-1}\), respectively.

This function can be seen as way to compute the inverse of a symmetric positive definite matrix given its Cholesky factor. Equivalently, it can be seen as a way to compute \((X'X)^{-1}\) given the \( R \) part of the QR factorization of \( X \).
chol2inv-methods

Usage

chol2inv(x, ...)  
## S4 method for signature 'dtrMatrix'
chol2inv(x, ...)  
## S4 method for signature 'dtCMatrix'
chol2inv(x, ...)  
## S4 method for signature 'generalMatrix'
chol2inv(x, uplo = "U", ...)

Arguments

x  
a square matrix or Matrix, typically the result of a call to chol. If x is square but not (formally) triangular, then only the upper or lower triangle is considered, depending on optional argument uplo if x is a Matrix.

uplo  
a string, either "U" or "L", indicating which triangle of x contains the Cholesky factor. The default is "U", to be consistent with chol2inv from base.

...  
further arguments passed to or from methods.

Value

A matrix, symmetricMatrix, or diagonalMatrix representing the inverse of the positive definite matrix whose Cholesky factor is x. The result is a traditional matrix if x is a traditional matrix, dense if x is dense, and sparse if x is sparse.

See Also

The default method from base, chol2inv, called for traditional matrices x.

Generic function chol, for computing the upper triangular Cholesky factor L' of a symmetric positive semidefinite matrix.

Generic function solve, for solving linear systems and (as a corollary) for computing inverses more generally.

Examples

(A <- Matrix(cbind(c(1, 1, 1), c(1, 2, 4), c(1, 4, 16))))  
(R <- chol(A))  
(L <- t(R))  
(R2i <- chol2inv(R))  
(L2i <- chol2inv(R))  
stopifnot(exprs = {  
  all.equal(R2i, tcrossprod(solve(R)))  
  all.equal(L2i, crossprod(solve(L)))  
  all.equal(as(R2i %%*% A, "matrix"), diag(3L)) # the identity  
  all.equal(as(L2i %%*% A, "matrix"), diag(3L)) # ditto  
})
Cholesky-class

Dense Cholesky Factorizations

Description

Classes Cholesky and pCholesky represent dense, pivoted Cholesky factorizations of $n \times n$ real, symmetric, positive semidefinite matrices $A$, having the general form

$$P_1 AP_1' = L_1 DL_1' = LL'$$

or (equivalently)

$$A = P_1'L_1DL_1P_1 = P_1'LL'P_1$$

where $P_1$ is a permutation matrix, $L_1$ is a unit lower triangular matrix, $D$ is a non-negative diagonal matrix, and $L = L_1\sqrt{D}$.

These classes store the entries of the Cholesky factor $L$ or its transpose $L'$ in a dense format as a vector of length $nn$ (Cholesky) or $n(n+1)/2$ (pCholesky), the latter giving the “packed” representation.

Slots

- Dim, Dimnames inherited from virtual class MatrixFactorization.
- uplo a string, either "U" or "L", indicating which triangle (upper or lower) of the factorized symmetric matrix was used to compute the factorization and in turn whether $x$ stores $L'$ or $L$.
- $x$ a numeric vector of length $n*n$ (Cholesky) or $n*(n+1)/2$ (pCholesky), where $n=\text{Dim}[1]$, listing the entries of the Cholesky factor $L$ or its transpose $L'$ in column-major order.
- perm a 1-based integer vector of length $\text{Dim}[1]$ specifying the permutation applied to the rows and columns of the factorized matrix. perm of length 0 is valid and equivalent to the identity permutation, implying no pivoting.

Extends

Class CholeskyFactorization, directly. Class MatrixFactorization, by class CholeskyFactorization, distance 2.

Instantiation

Objects can be generated directly by calls of the form new("Cholesky", ...) or new("pCholesky", ...), but they are more typically obtained as the value of Cholesky(x) for x inheriting from dSyMatrix or dSpMatrix (often the subclasses of those reserved for positive semidefinite matrices, namely dPoMatrix and dPpMatrix).
Methods

coerce signature(from = "Cholesky", to = "dtrMatrix"): returns a dtrMatrix representing the Cholesky factor \( L \) or its transpose \( L' \); see ‘Note’.

coorce signature(from = "pCholesky", to = "dtpMatrix"): returns a dtpMatrix representing the Cholesky factor \( L \) or its transpose \( L' \); see ‘Note’.

determinant signature(from = "p?Cholesky", logarithm = "logical"): computes the determinant of the factorized matrix \( A \) or its logarithm.

diag signature(x = "p?Cholesky"): returns a numeric vector of length \( n \) containing the diagonal elements of \( D \), which are the squared diagonal elements of \( L \).

expand1 signature(x = "p?Cholesky"): see expand1-methods.

expand2 signature(x = "p?Cholesky"): see expand2-methods.

solve signature(a = "p?Cholesky", b = .): see solve-methods.

Note

In Matrix < 1.6-0, class Cholesky extended dtrMatrix and class pCholesky extended dtpMatrix, reflecting the fact that the factor \( L \) is indeed a triangular matrix. Matrix 1.6-0 removed these extensions so that methods would no longer be inherited from dtrMatrix and dtpMatrix. The availability of such methods gave the wrong impression that Cholesky and pCholesky represent a (singular) matrix, when in fact they represent an ordered set of matrix factors.

The coercions as(. , "dtrMatrix") and as(. , "dtpMatrix") are provided for users who understand the caveats.

References


See Also

Class CHMfactor for sparse Cholesky factorizations.

Classes dpoMatrix and dppMatrix.

Generic functions Cholesky, expand1 and expand2.

Examples

    showClass("Cholesky")
    set.seed(1)
    m <- 30L
n <- 6L
(A <- crossprod(Matrix(rnorm(m * n), m, n)))

## With dimnames, to see that they are propagated :
dimnames(A) <- dn <- rep.int(list(paste0("x", seq_len(n))), 2L)

(ch.A <- Cholesky(A)) # pivoted, by default
str(e.ch.A <- expand2(ch.A, LDL = TRUE, max.level = 2L)
str(E.ch.A <- expand2(ch.A, LDL = FALSE, max.level = 2L)

## Underlying LAPACK representation
(m.ch.A <- as(ch.A, "dtrMatrix")) # which is L', not L, because
A@uplo == "U"
stopifnot(identical(as(m.ch.A, "matrix"), 'dim<-'(ch.A@x, ch.A@Dim)))

ae1 <- function(a, b, ...) all.equal(as(a, "matrix"), as(b, "matrix"), ...)
ae2 <- function(a, b, ...) ae1(unname(a), unname(b), ...)

## A ~ P1' L1 D L1 P1 ~ P1' L L P1 in floating point
stopifnot(exprs = {
  identical(names(e.ch.A), c("P1.", "L1", "D", "L1.", "P1"))
  identical(names(E.ch.A), c("P1.", "L" , "L"., "P1"))
  identical(e.ch.A[["P1."]],
            new("pMatrix", Dim = c(n, n), Dimnames = c(list(NULL), dn[2L]),
               margin = 2L, perm = invertPerm(ch.A@perm)))
  identical(e.ch.A[["P1."]], t(e.ch.A[["P1"]]))
  identical(e.ch.A[["L1."]], t(e.ch.A[["L1"]]))
  identical(E.ch.A[["L." ]], t(E.ch.A[["L" ]]))
  identical(e.ch.A[["D." ]], Diagonal(x = diag(ch.A)))
  all.equal(E.ch.A[["L"]], with(e.ch.A, L1 %*% sqrt(D)))
  ae1(A, with(e.ch.A, P1. %*% L1 %*% D %*% L1. %*% P1))
  ae1(A, with(E.ch.A, P1. %*% L  %*% L. %*% P1))
  ae2(A[ch.A@perm, ch.A@perm], with(e.ch.A, L1 %*% D %*% L1.))
  ae2(A[ch.A@perm, ch.A@perm], with(E.ch.A, L %*% L. ))
})

## Factorization handled as factorized matrix
b <- rnorm(n)
all.equal(det(A), det(ch.A), tolerance = 0)
all.equal(solve(A, b), solve(ch.A, b), tolerance = 0)

## For identical results, we need the _unpivoted_ factorization
## computed by det(A) and solve(A, b)
(ch.A.nopivot <- Cholesky(A, perm = FALSE))
stopifnot(identical(det(A), det(ch.A.nopivot)),
          identical(solve(A, b), solve(ch.A.nopivot, b)))

Cholesky-methods

Methods for Cholesky Factorization
Description

Computes the pivoted Cholesky factorization of an \( n \times n \) real, symmetric matrix \( A \), which has the general form

\[
P_1 A P_1' = L_1 D L_1' P_1 D_{jj} \geq 0 LL'
\]

or (equivalently)

\[
A = P_1' L_1 D L_1' P_1 D_{jj} \geq 0 P_1' LL' P_1
\]

where \( P_1 \) is a permutation matrix, \( L_1 \) is a unit lower triangular matrix, \( D \) is a diagonal matrix, and \( L = L_1 \sqrt{D} \). The second equalities hold only for positive semidefinite \( A \), for which the diagonal entries of \( D \) are non-negative and \( \sqrt{D} \) is well-defined.

Methods for \texttt{denseMatrix} are built on LAPACK routines \texttt{dpstrf}, \texttt{dpotrf}, and \texttt{dpptrf}. The latter two do not permute rows or columns, so that \( P_1 \) is an identity matrix.

Methods for \texttt{sparseMatrix} are built on CHOLMOD routines \texttt{cholmod_analyze} and \texttt{cholmod_factorize_p}.

Usage

\begin{verbatim}
Cholesky(A, ...) # S4 method for signature 'dsyMatrix'
Cholesky(A, perm = TRUE, tol = -1, ...) # S4 method for signature 'dspMatrix'
Cholesky(A, ...) # S4 method for signature 'dsCMatrix'
Cholesky(A, perm = TRUE, LDL = !super, super = FALSE, Imult = 0, ...) # S4 method for signature 'ddiMatrix'
Cholesky(A, ...) # S4 method for signature 'generalMatrix'
Cholesky(A, uplo = "U", ...) # S4 method for signature 'triangularMatrix'
Cholesky(A, uplo = "U", ...) # S4 method for signature 'matrix'
Cholesky(A, uplo = "U", ...) # S4 method for signature 'matrix'
\end{verbatim}

Arguments

- \texttt{A} a finite, symmetric matrix or \texttt{Matrix} to be factorized. If \( A \) is square but not symmetric, then it will be treated as symmetric; see \texttt{uplo}. Methods for dense \( A \) require positive definiteness when \texttt{perm = FALSE} and positive semidefiniteness when \texttt{perm = TRUE}. Methods for sparse \( A \) require positive definiteness when \texttt{LDL = TRUE} and nonzero leading principal minors (after pivoting) when \texttt{LDL = FALSE}. Methods for sparse, diagonal \( A \) are an exception, requiring positive semidefiniteness unconditionally.

- \texttt{perm} a logical indicating if the rows and columns of \( A \) should be pivoted. Methods for sparse \( A \) employ the approximate minimum degree (AMD) algorithm in order to reduce fill-in, i.e., without regard for numerical stability. Pivoting for sparsity may introduce nonpositive leading principal minors, causing the factorization to fail, in which case it may be necessary to set \texttt{perm = FALSE}. 

Cholesky-methods

**tol**

A **finite** numeric tolerance, used only if `perm = TRUE`. The factorization algorithm stops if the pivot is less than or equal to `tol`. Negative `tol` is equivalent to `nrow(A) * .Machine$double.eps * max(diag(A))`.

**LDL**

A logical indicating if the simplicial factorization should be computed as $P_1' L_1 D L_1' P_1$, such that the result stores the lower triangular entries of $L_1 - I + D$. The alternative is $P_1' L_L' P_1$, such that the result stores the lower triangular entries of $L = L_1 \sqrt{D}$. This argument is ignored if `super = TRUE` (or if `super = NA` and the supernodal algorithm is chosen), as the supernodal code does not yet support the LDL = TRUE variant.

**super**

A logical indicating if the factorization should use the supernodal algorithm. The alternative is the simplicial algorithm. Setting `super = NA` leaves the choice to a CHOLMOD-internal heuristic.

**Imult**

A **finite** number. The matrix that is factorized is $A + \text{Imult} \times \text{diag}(nrow(A))$, i.e., $A$ plus `Imult` times the identity matrix. This argument is useful for symmetric, indefinite $A$, as $\text{Imult} > \max(\text{rowSums(abs(A))} - \text{diag(abs(A))})$ ensures that $A + \text{Imult} \times \text{diag}(nrow(A))$ is diagonally dominant. (Symmetric, diagonally dominant matrices are positive definite.)

**uplo**

A string, either "U" or "L", indicating which triangle of $A$ should be used to compute the factorization. The default is "U", even for lower triangular $A$, to be consistent with `chol` from `base`.

... further arguments passed to or from methods.

**Details**

Note that the result of a call to `Cholesky` inherits from `CholeskyFactorization` but not `Matrix`. Users who just want a matrix should consider using `chol`, whose methods are simple wrappers around `Cholesky` returning just the upper triangular Cholesky factor $L'$, typically as a `triangularMatrix`. However, a more principled approach would be to construct factors as needed from the `CholeskyFactorization` object, e.g., with `expand1(x, "L")`, if `x` is the object.

The behaviour of `Cholesky(A, perm = TRUE)` for dense $A$ is somewhat exceptional, in that it expects **without** checking that $A$ is positive semidefinite. By construction, if $A$ is positive semidefinite and the exact algorithm encounters a zero pivot, then the unfactorized trailing submatrix is the zero matrix, and there is nothing left to do. Hence when the finite precision algorithm encounters a pivot less than `tol`, it signals a warning instead of an error and zeros the trailing submatrix in order to guarantee that $P' L_L' P$ is positive semidefinite even if $A$ is not. It follows that one way to test for positive semidefiniteness of $A$ in the event of a warning is to analyze the error

$$\frac{\|A - P' L_L' P\|}{\|A\|}.$$ 

See the examples and LAPACK Working Note ("LAWN") 161 for details.

**Value**

An object representing the factorization, inheriting from virtual class `CholeskyFactorization`. For a traditional matrix $A$, the specific class is `Cholesky`. For $A$ inheriting from `unpackedMatrix`, `packedMatrix`, and `sparseMatrix`, the specific class is `Cholesky`, `pCholesky`, and `dCHMsimpl` or `dCHMsuper`, respectively.
References

The LAPACK source code, including documentation; see https://netlib.org/lapack,double/dpstrf.f, https://netlib.org/lapack,double/dpotrf.f, and https://netlib.org/lapack,double/dpotrf.f.

The CHOLMOD source code; see https://github.com/DrTimothyAldenDavis/SuiteSparse, notably the header file ‘CHOLMOD/Include/cholmod.h’ defining cholmod_factor_struct.


See Also

Classes Cholesky, pCholesky, dCHMsimpl and dCHMsuper and their methods.

Classes dpoMatrix, dppMatrix, and dsCMatrix.

Generic function chol, for obtaining the upper triangular Cholesky factor \( L' \) as a matrix or Matrix.

Generic functions expand1 and expand2, for constructing matrix factors from the result.

Generic functions BunchKaufman, Schur, lu, and qr, for computing other factorizations.

Examples

showMethods("Cholesky", inherited = FALSE)
set.seed(0)

## ---- Dense ----------------------------------------------------------
## .... Positive definite ..............................................

n <- 6L
(A1 <- crossprod(Matrix(rnorm(n * n), n, n)))
(ch.A1.nopivot <- Cholesky(A1, perm = FALSE))
(ch.A1 <- Cholesky(A1))
stopifnot(exprs = {
  length(ch.A1@perm) == ncol(A1)
  isPerm(ch.A1@perm)
  is.unsorted(ch.A1@perm) # typically not the identity permutation
  length(ch.A1.nopivot@perm) == 0L
})

## A ~ P1' L D L' P1 ~ P1' L L' P1 in floating point
str(e.ch.A1 <- expand2(ch.A1, LDL = TRUE), max.level = 2L)
str(E.ch.A1 <- expand2(ch.A1, LDL = FALSE), max.level = 2L)
stopifnot(exprs = {
  all.equal(as(A1, "matrix"), as(Reduce("%/%", e.ch.A1), "matrix"))
  all.equal(as(A1, "matrix"), as(Reduce("%/%", E.ch.A1), "matrix"))
})

## .... Positive semidefinite but not positive definite ............
A2 <- A1
A2[1L, ] <- A2[, 1L] <- 0
A2
try(Cholesky(A2, perm = FALSE)) # fails as not positive definite
ch.A2 <- Cholesky(A2) # returns, with a warning and ...
A2.hat <- Reduce("%/%", expand2(ch.A2, LDL = FALSE))
norm(A2 - A2.hat, "2") / norm(A2, "2") # 7.670858e-17

## .... Not positive semidefinite ..................................
A3 <- A1
A3[1L, ] <- A3[, 1L] <- -1
A3
try(Cholesky(A3, perm = FALSE)) # fails as not positive definite
ch.A3 <- Cholesky(A3) # returns, with a warning and ...
A3.hat <- Reduce("%/%", expand2(ch.A3, LDL = FALSE))
norm(A3 - A3.hat, "2") / norm(A3, "2") # 1.781568

## Indeed, 'A3' is not positive semidefinite, but 'A3.hat' _is_
ch.A3.hat <- Cholesky(A3.hat)
A3.hat.hat <- Reduce("%/%", expand(ch.A3.hat, LDL = FALSE))

## ---- Sparse ---------------------------------------------------------
## Really just three cases modulo permutation:
##
## type factorization minors of P1 A P1'
## 1 simplicial P1 A P1' = L1 D L1'  nonzero
## 2 simplicial P1 A P1' = L L'  positive
## 3 supernodal P1 A P2' = L L'  positive

data(KNex, package = "Matrix")
A4 <- crossprod(KNex[["mm"]])
ch.A4 <-
list(pivoted =
  list(simpl1 = Cholesky(A4, perm = TRUE, super = FALSE, LDL = TRUE),
       simpl0 = Cholesky(A4, perm = TRUE, super = FALSE, LDL = FALSE),
       super0 = Cholesky(A4, perm = TRUE, super = TRUE)),
    unpivoted =
  list(simpl1 = Cholesky(A4, perm = FALSE, super = FALSE, LDL = TRUE),
       simpl0 = Cholesky(A4, perm = FALSE, super = FALSE, LDL = FALSE),
       super0 = Cholesky(A4, perm = FALSE, super = TRUE)))
ch.A4

s <- simplify2array
rapply2 <- function(object, f, ...) rapply(object, f, , how = "list", ...)

s(rapply2(ch.A4, isLDL))
s(m.ch.A4 <- rapply2(ch.A4, expand1, "L")) # giving L = L1 sqrt(D)

## By design, the pivoted and simplicial factorizations
## are more sparse than the unpivoted and supernodal ones ...
s(rapply2(m.ch.A4, object.size))

## Which is nicely visualized by lattice-based methods for 'image'
im <- c("pivoted", "unpivoted")
jnm <- c("simpl1", "simpl0", "super0")
for(i in 1:2)
for(j in 1:3)
print(image(m.ch.A4[[c(i, j)]], main = paste(inm[i], jnm[j])),
        split = c(j, i, 3L, 2L), more = i * j < 6L)
simpl1 <- ch.A4[[c("pivoted", "simpl1")]]
stopifnot(exprs = {
    length(simpl1@perm) == ncol(A4)
    isPerm(simpl1@perm, 0L)
    is.unsorted(simpl1@perm) # typically not the identity permutation
})

## One can expand with and without D regardless of isLDL(.),
## but "without" requires L = L1 sqrt(D), which is conditional
## on min(diag(D)) >= 0, hence "with" is the default
isLDL(simpl1)
stopifnot(min(diag(simpl1)) >= 0)
str(e.ch.A4 <- expand2(simpl1, LDL = TRUE), max.level = 2L) # default
str(E.ch.A4 <- expand2(simpl1, LDL = FALSE), max.level = 2L)
stopifnot(exprs = {
    all.equal(E.ch.A4[["L"]], e.ch.A4[["L1"]])
    all.equal(E.ch.A4[["L"]], sqrt(e.ch.A4[["D"]]) %*% e.ch.A4[["L1"]])
    all.equal(A4, as(Reduce("%*%", e.ch.A4), "symmetricMatrix")
    all.equal(A4, as(Reduce("%*%", E.ch.A4), "symmetricMatrix")
})

## The "same" permutation matrix with "alternate" representation
## [i, perm[i]] (margin=1) <-> [invertPerm(perm)[j], j] (margin=2)
alt <- function(P) {
    P@margin <- 1L + !(P@margin - 1L) # 1 <-> 2
    P@perm <- invertPerm(P@perm)
    P
}

## Expansions are elegant but inefficient (transposes are redundant)
## hence programmers should consider methods for 'expand1' and 'diag'
stopifnot(exprs = {
    identical(expand1(simpl1, "P1"), alt(e.ch.A4[["P1"]]))
})
identical(expand1(simpl1, "L"), E.ch.A4[['L']])
identical(Diagonal(x = diag(simpl1)), e.ch.A4[['D']])

## chol(A, pivot = value) is a simple wrapper around
## Cholesky(A, perm = value, LDL = FALSE, super = FALSE),
## returning $L' = \sqrt{D}$ $L_1$ _but_ giving no information
## about the permutation $P_1$
selectMethod("chol", "dsCMatrix")
stopifnot(all.equal(chol(A4, pivot = TRUE), E.ch.A4[['L.']]))

## Now a symmetric matrix with positive _and_ negative eigenvalues,
## hence _not_ positive semidefinite
A5 <- new("dsCMatrix",
      Dim = c(7L, 7L),
      p = c(0:1, 3L, 6:7, 10:11, 15L),
      i = c(0L, 0:1, 0:3, 2:5, 3:6),
      x = c(1, 6, 38, 10, 60, 103, -4, 6, -32, -247, -2, -16, -128, -2, -67))
(ev <- eigen(A5, only.values = TRUE)$values)
(t.ev <- table(factor(sign(ev), -1:1))) # the matrix "inertia"

ch.A5 <- Cholesky(A5)
isLDL(ch.A5)
(d.A5 <- diag(ch.A5)) # diag(D) is partly negative

## Sylvester's law of inertia holds here, but not in general
## in finite precision arithmetic
stopifnot(identical(table(factor(sign(d.A5), -1:1)), t.ev))

try(expand1(ch.A5, "L"))  # unable to compute $L = L_1 \sqrt{D}$
try(expand2(ch.A5, LDL = FALSE))  # ditto
try(chol(A5, pivot = TRUE))  # ditto

## The default expansion is "square root free" and still works here
str(e.ch.A5 <- expand2(ch.A5, LDL = TRUE), max.level = 2L)
stopifnot(all.equal(A5, as(Reduce("%*%", e.ch.A5), "symmetricMatrix")))

## Version of the SuiteSparse library, which includes CHOLMOD
.SuiteSparse_version()

---

**coerce-methods-graph**  Conversions "graph" <=- (sparse) Matrix

---

**Description**

Since 2005, package **Matrix** has supported coercions to and from class **graph** from package **graph**. Since 2013, this functionality has been exposed via functions T2graph and graph2T, which, unlike methods for **as** (from, "<Class>"), support optional arguments.
Usage

\texttt{graph2T(from, use.weights = )}
\texttt{T2graph(from, need.uniq = is_not_uniqT(from), edgemode = NULL)}

Arguments

\texttt{from} \quad \text{for \texttt{graph2T()}, an R object of class "graph";}
\text{for \texttt{T2graph()}, a sparse matrix inheriting from "TsparseMatrix".}

\texttt{use.weights} \quad \text{logical indicating if weights should be used, i.e., equivalently the result will be numeric, i.e. of class \texttt{dgTMatrix}; otherwise the result will be \texttt{ngTMatrix} or \texttt{nsTMatrix}, the latter if the graph is undirected. The default looks if there are weights in the graph, and if any differ from 1, weights are used.}

\texttt{need.uniq} \quad \text{a logical indicating if \texttt{from} may need to be internally “uniqified”; do not set this and hence rather use the default, unless you know what you are doing!}

\texttt{edgemode} \quad \text{one of \texttt{NULL}, "directed", or "undirected". The default \texttt{NULL} looks if the matrix is symmetric and assumes "undirected" in that case.}

Value

For \texttt{graph2T()}, a sparse matrix inheriting from "TsparseMatrix".

For \texttt{T2graph()} an R object of class "graph".

See Also

Package \texttt{igraph}, which provides similar coercions to and from its class \texttt{igraph} via functions \texttt{graph_from_adjacency_matrix} and \texttt{as_adjacency_matrix}.

Examples

\begin{verbatim}
if(requireNamespace("graph")) {
  n4 <- LETTERS[1:4]; dns <- list(n4,n4)
  show(a1 <- sparseMatrix(i= c(1:4), j=c(2:4,1), x = 2, dimnames=dns))
  show(g1 <- as(a1, "graph")) # directed
  unlist(graph::edgeWeights(g1)) # all '2'

  show(a2 <- sparseMatrix(i= c(1:4,4), j=c(2:4,1:2), x = TRUE, dimnames=dns))
  show(g2 <- as(a2, "graph")) # directed
  # now if you want it undirected:
  show(g3 <- T2graph(as(a2,"TsparseMatrix"), edgemode="undirected"))
  show(m3 <- as(g3,"Matrix"))
  show( graph2T(g3) ) # a "pattern Matrix" (nsTMatrix)

  a. <- sparseMatrix(i=4:1, j=1:4, dimnames=list(n4, n4), repr="T") # no 'x'
  show(a.) # "ngTMatrix"
  show(g. <- as(a., "graph"))
}
\end{verbatim}
coerce-methods-SparseM

Sparse Matrix Coercion from and to those from package SparseM

Description

Methods for coercion from and to sparse matrices from package SparseM are provided here, for ease of porting functionality to the Matrix package, and comparing functionality of the two packages. All these work via the usual as(., "<class>") coercion,

\[ \text{as(from, Class)} \]

Methods

\[
\begin{align*}
\text{from} &= \text{"matrix.csr"}, \text{to} = \text{"dgRMatrix"} \\
\text{from} &= \text{"matrix.csc"}, \text{to} = \text{"dgCMatrix"} \\
\text{from} &= \text{"matrix.coo"}, \text{to} = \text{"dgTMatrix"} \\
\text{from} &= \text{"dgRMatrix"}, \text{to} = \text{"matrix.csr"} \\
\text{from} &= \text{"dgCMatrix"}, \text{to} = \text{"matrix.csc"} \\
\text{from} &= \text{"dgTMatrix"}, \text{to} = \text{"matrix.coo"} \\
\text{from} &= \text{"Matrix"}, \text{to} = \text{"matrix.csr"} \\
\text{from} &= \text{"matrix.csr"}, \text{to} = \text{"dgCMatrix"} \\
\text{from} &= \text{"matrix.coo"}, \text{to} = \text{"dgCMatrix"} \\
\text{from} &= \text{"matrix.csr"}, \text{to} = \text{"Matrix"} \\
\text{from} &= \text{"matrix.csc"}, \text{to} = \text{"Matrix"} \\
\text{from} &= \text{"matrix.coo"}, \text{to} = \text{"Matrix"}
\end{align*}
\]

See Also

The documentation in CRAN package SparseM, such as SparseM.ontology, and one important class, matrix.csr.

colSums-methods

Form Row and Column Sums and Means

Description

Form row and column sums and means for objects, for sparseMatrix the result may optionally be sparse (sparseVector), too. Row or column names are kept respectively as for base matrices and colSums methods, when the result is numeric vector.
Usage

```r
colSums(x, na.rm = FALSE, dims = 1L, ...)
rowSums(x, na.rm = FALSE, dims = 1L, ...)
colMeans(x, na.rm = FALSE, dims = 1L, ...)
rowMeans(x, na.rm = FALSE, dims = 1L, ...)
```

## S4 method for signature 'CsparseMatrix'
```r
colSums(x, na.rm = FALSE, dims = 1L, sparseResult = FALSE, ...)
```

## S4 method for signature 'CsparseMatrix'
```r
rowSums(x, na.rm = FALSE, dims = 1L, sparseResult = FALSE, ...)
```

## S4 method for signature 'CsparseMatrix'
```r
colMeans(x, na.rm = FALSE, dims = 1L, sparseResult = FALSE, ...)
```

## S4 method for signature 'CsparseMatrix'
```r
rowMeans(x, na.rm = FALSE, dims = 1L, sparseResult = FALSE, ...)
```

Arguments

- `x`: a Matrix, i.e., inheriting from `Matrix`.
- `na.rm`: logical. Should missing values (including NaN) be omitted from the calculations?
- `dims`: completely ignored by the `Matrix` methods.
- `...`: potentially further arguments, for method `<-` generic compatibility.
- `sparseResult`: logical indicating if the result should be sparse, i.e., inheriting from class `sparseVector`. Only applicable when `x` is inheriting from a `sparseMatrix` class.

Value

returns a numeric vector if `sparseResult` is `FALSE` as per default. Otherwise, returns a `sparseVector`. `dimnames(x)` are only kept (as `names(v)`) when the resulting `v` is numeric, since `sparseVectors` do not have names.

See Also

colSums and the `sparseVector` classes.

Examples

```r
(M <- bdiag(Diagonal(2), matrix(1:3, 3,4), diag(3:2))) # 7 x 8
colSums(M)
d <- Diagonal(10, c(0,0,10,0,2,rep(0,5)))
MM <- kronecker(d, M)
dim(MM) # 70 80
length(MM@x) # 160, but many are '0'; drop those:
MM <- drop0(MM)
length(MM@x) # 32
```
cm <- colSums(MM)
(scm <- colSums(MM, sparseResult = TRUE))
stopifnot(is(scm, "sparseVector"),
    identical(cm, as.numeric(scm)))
rowSums (MM, sparseResult = TRUE) # 14 of 70 are not zero
colMeans(MM, sparseResult = TRUE) # 16 of 80 are not zero
## Since we have no 'NA's, these two are equivalent :
stopifnot(identical(rowMeans(MM, sparseResult = TRUE),
    rowMeans(MM, sparseResult = TRUE, na.rm = TRUE)),
    rowMeans(Diagonal(16)) == 1/16,
    colSums(Diagonal(7)) == 1)

## dimnames(x) --> names( <value> ) :
dimnames(M) <- list(paste0("r", 1:7), paste0("V",1:8))
M
colSums(M)
rowMeans(M)
## Assertions :
stopifnot(exprs = {
    all.equal(colSums(M),
        structure(c(1,1,6,6,6,6,3,2), names = colnames(M))))
    all.equal(rowMeans(M),
        structure(c(1,1,4,8,12,3,2)/8, names = paste0("r", 1:7)))
})

---

compMatrix-class

Class "compMatrix" of Composite (Factorizable) Matrices

Description

Virtual class of composite matrices; i.e., matrices that can be factorized, typically as a product of simpler matrices.

Objects from the Class

A virtual Class: No objects may be created from it.

Slots

factors: Object of class "list" - a list of factorizations of the matrix. Note that this is typically empty, i.e., list(), initially and is updated automatically whenever a matrix factorization is computed.

Dim, Dimnames: inherited from the Matrix class, see there.

Extends

Class "Matrix", directly.
Methods

dimnames<- signature(x = "compMatrix", value = "list"): set the dimnames to a list of length 2, see dimnames<-. The factors slot is currently reset to empty, as the factorization dimnames would have to be adapted, too.

See Also

The matrix factorization classes "MatrixFactorization" and their generators, lu(), qr(), chol() and Cholesky(), BunchKaufman(), Schur().

---

condest

Compute Approximate CONDition number and 1-Norm of (Large) Matrices

Description

“Estimate”, i.e. compute approximately the CONDition number of a (potentially large, often sparse) matrix A. It works by apply a fast randomized approximation of the 1-norm, norm(A,"1"), through onenormest(.).

Usage

condest(A, t = min(n, 5), normA = norm(A, "1"),
   silent = FALSE, quiet = TRUE)

onenormest(A, t = min(n, 5), A.x, At.x, n,
   silent = FALSE, quiet = silent,
   iter.max = 10, eps = 4 * .Machine$double.eps)

Arguments

A a square matrix, optional for onenormest(), where instead of A, A.x and At.x can be specified, see there.

t number of columns to use in the iterations.
normA number; (an estimate of) the 1-norm of A, by default norm(A, "1"); may be replaced by an estimate.
silent logical indicating if warning and (by default) convergence messages should be displayed.
quiet logical indicating if convergence messages should be displayed.
A.x, At.x when A is missing, these two must be given as functions which compute A %*% x, or t(A) %*% x, respectively.
n == nrow(A), only needed when A is not specified.
iter.max maximal number of iterations for the 1-norm estimator.
eps the relative change that is deemed irrelevant.
Details

`condest()` calls `lu(A)`, and subsequently `onenormest(A.x = , At.x = )` to compute an approximate norm of the inverse of A, \( A^{-1} \), in a way which keeps using sparse matrices efficiently when A is sparse.

Note that `onenormest()` uses random vectors and hence both functions’ results are random, i.e., depend on the random seed, see, e.g., `set.seed()`.

Value

Both functions return a list; `condest()` with components,

- `est` a number > 0, the estimated (1-norm) condition number \( \hat{\kappa} \); when \( r := rcond(A) \), \( 1/\hat{\kappa} \approx r \).
- `v` the maximal \( Ax \) column, scaled to \( \|v\| = 1 \). Consequently, \( \| Av \| = \|A\|/est \); when `est` is large, `v` is an approximate null vector.

The function `onenormest()` returns a list with components,

- `est` a number > 0, the estimated \( \|A\| \) \( , "1" \).
- `v` 0-1 integer vector length \( n \), with an 1 at the index \( j \) with maximal column \( A[, , j] \) in \( A \).
- `w` numeric vector, the largest \( Ax \) found.
- `iter` the number of iterations used.

Author(s)

This is based on octave’s `condest()` and `onenormest()` implementations with original author Jason Riedy, U Berkeley; translation to R and adaption by Martin Maechler.

References


See Also

`norm`, `rcond`.

Examples

data(KNex, package = "Matrix")
mtm <- with(KNex, crossprod(mm))
system.time(ce <- condest(mtm))
sum(abs(ce$v)) ## \| v \|_1 == 1
## Prove that \| A v \| = \| A \| / est (as \|v\| = 1):
stopifnot(all.equal(norm(mtm %*% ce$v),
                   norm(mtm) / ce$est))
## reciprocal

```r
1 / ce$est
```

```r
system.time(rc <- rcond(mtm)) # takes ca 3 x longer
```

```r
rc
```

```r
all.equal(rc, 1/ce$est) # TRUE -- the approximation was good
```

```r
one <- onenormest(mtm)
```

```r
str(one) ## est = 12.3
```

```r
## the maximal column:
which(one$v == 1) # mostly 4, rarely 1, depending on random seed
```

---

### CsparseMatrix-class

**Class** "CsparseMatrix" of Sparse Matrices in Column-compressed Form

---

#### Description

The "CsparseMatrix" class is the virtual class of all sparse matrices coded in sorted compressed column-oriented form. Since it is a virtual class, no objects may be created from it. See `showClass("CsparseMatrix")` for its subclasses.

#### Slots

- **i**: Object of class "integer" of length nnzero (number of non-zero elements). These are the 0-based row numbers for each non-zero element in the matrix, i.e., `i` must be in `0:(nrow(.)-1)`.
- **p**: integer vector for providing pointers, one for each column, to the initial (zero-based) index of elements in the column. `.@p` is of length `ncol(.) + 1`, with `p[1] == 0` and `p[length(p)] == nnzero`, such that in fact, `diff(.@p)` are the number of non-zero elements for each column.

  In other words, `m@p[1:ncol(m)]` contains the indices of those elements in `m@x` that are the first elements in the respective column of `m`.

- **Dim, Dimnames**: inherited from the superclass, see the `sparseMatrix` class.

#### Extends

Class "sparseMatrix", directly. Class "Matrix", by class "sparseMatrix".

#### Methods

- Matrix products `%*%`, `crossprod()` and `tcrossprod()`, several `solve` methods, and other matrix methods available:
  ```r
  signature(e1 = "CsparseMatrix", e2 = "numeric"):
  ```

  - **Arith** signature(e1 = "numeric", e2 = "CsparseMatrix"):
  ```r
  ```
  ```r
  ```

  - **Math** signature(x = "CsparseMatrix"):
  ```r
  ```

  - **band** signature(x = "CsparseMatrix"):
  ```r
  ```

  - signature(e1 = "CsparseMatrix", e2 = "numeric"):
  ```r
  ```
- signature(e1 = "numeric", e2 = "CsparseMatrix"): ...
+ signature(e1 = "CsparseMatrix", e2 = "numeric"): ...
+ signature(e1 = "numeric", e2 = "CsparseMatrix"): ...

coerce signature(from = "CsparseMatrix", to = "TsparseMatrix"): ...
coerce signature(from = "CsparseMatrix", to = "denseMatrix"): ...
coerce signature(from = "CsparseMatrix", to = "matrix"): ...
coerce signature(from = "TsparseMatrix", to = "CsparseMatrix"): ...
coerce signature(from = "denseMatrix", to = "CsparseMatrix"): ...
diag signature(x = "CsparseMatrix"): ...
gamma signature(x = "CsparseMatrix"): ...
lgamma signature(x = "CsparseMatrix"): ...
log signature(x = "CsparseMatrix"): ...
t signature(x = "CsparseMatrix"): ...
tril signature(x = "CsparseMatrix"): ...
triu signature(x = "CsparseMatrix"): ...

Note

All classes extending CsparseMatrix have a common validity (see validObject) check function. That function additionally checks the i slot for each column to contain increasing row numbers. In earlier versions of Matrix (< 0.999375-16), validObject automatically re-sorted the entries when necessary, and hence new() calls with somewhat permuted i and x slots worked, as new(...) (with slot arguments) automatically checks the validity.

Now, you have to use sparseMatrix to achieve the same functionality or know how to use .validateCsparse() to do so.

See Also
colSums, kronecker, and other such methods with own help pages.

Further, the super class of CsparseMatrix, sparseMatrix, and, e.g., class dgCMatrix for the links to other classes.

Examples

glass("CsparseMatrix")

## The common validity check function (based on C code):
getValidity(getClass("CsparseMatrix"))
Description

This is the virtual class of all dense numeric (i.e., double, hence “dense”) S4 matrices. Its most important subclass is the dgeMatrix class.

Extends

Class "dMatrix" directly; class "Matrix", by the above.

Slots

the same slots at its subclass dgeMatrix, see there.

Methods

Most methods are implemented via as(*, "generalMatrix") and are mainly used as “fallbacks” when the subclass doesn’t need its own specialized method.

Use showMethods(class = "ddenseMatrix", where = "package:Matrix") for an overview.

See Also

The virtual classes Matrix, dMatrix, and dsparseMatrix.

Examples

showClass("ddenseMatrix")

showMethods(class = "ddenseMatrix", where = "package:Matrix")

ddiMatrix-class

Class "ddiMatrix" of Diagonal Numeric Matrices

Description

The class "ddiMatrix" of numerical diagonal matrices.

Note that diagonal matrices now extend sparseMatrix, whereas they did extend dense matrices earlier.

Objects from the Class

Objects can be created by calls of the form new("ddiMatrix", ...) but typically rather via Diagonal.
Slots

  x: numeric vector. For an \( n \times n \) matrix, the \( x \) slot is of length \( n \) or 0, depending on the diag slot:

  diag: "character" string, either "U" or "N" where "U" denotes unit-diagonal, i.e., identity matrices.

  Dim, Dimnames: matrix dimension and dimnames, see the Matrix class description.

Extends

  Class "diagonalMatrix", directly. Class "dMatrix", directly. Class "sparseMatrix", indirectly, see showClass("ddiMatrix").

Methods

  \%*\% signature(x = "ddiMatrix", y = "ddiMatrix"): ...

See Also

  Class diagonalMatrix and function Diagonal.

Examples

      (d2 <- Diagonal(x = c(10,1)))
      str(d2)
      ## slightly larger in internal size:
      str(as(d2, "sparseMatrix"))

      M <- Matrix(cbind(1,2:4))
      M \%*\% d2 # 'fast' multiplication

      chol(d2) # trivial
      stopifnot(is(cd2 <- chol(d2), "ddiMatrix"),
                all.equal(cd2@x, c(sqrt(10),1)))

---

denseLU-class Dense LU Factorizations

Description

denseLU is the class of dense, row-pivoted LU factorizations of \( m \times n \) real matrices \( A \), having the general form

\[
P_1 A = LU
\]

or (equivalently)

\[
A = P'_1 L U
\]

where \( P_1 \) is an \( m \times m \) permutation matrix, \( L \) is an \( m \times \min(m,n) \) unit lower trapezoidal matrix, and \( U \) is a \( \min(m,n) \times n \) upper trapezoidal matrix. If \( m = n \), then the factors \( L \) and \( U \) are triangular.
denseLU-class

Slots

Dim, Dimnames inherited from virtual class MatrixFactorization.

x a numeric vector of length prod(Dim) storing the triangular L and U factors together in a packed format. The details of the representation are specified by the manual for LAPACK routine dgetrf.

perm an integer vector of length min(Dim) specifying the permutation $P_1$ as a product of transpositions. The corresponding permutation vector can be obtained as asPerm(perm).

Extends

Class LU, directly. Class MatrixFactorization, by class LU, distance 2.

Instantiation

Objects can be generated directly by calls of the form new("denseLU", ...), but they are more typically obtained as the value of lu(x) for x inheriting from denseMatrix (often dgeMatrix).

Methods

coerce signature(from = "denseLU", to = "dgeMatrix"): returns a dgeMatrix with the dimensions of the factorized matrix $A$, equal to $L$ below the diagonal and equal to $U$ on and above the diagonal.

determinant signature(from = "denseLU", logarithm = "logical"): computes the determinant of the factorized matrix $A$ or its logarithm.

expand signature(x = "denseLU"): see expand-methods.

expand1 signature(x = "denseLU"): see expand1-methods.

expand2 signature(x = "denseLU"): see expand2-methods.

solve signature(a = "denseLU", b = "missing"): see solve-methods.

References

The LAPACK source code, including documentation; see https://netlib.org/lapack/double/dgetrf.f.


See Also

Class sparseLU for sparse LU factorizations.

Class dgeMatrix.

Generic functions lu, expand1 and expand2.
Examples

showClass("denseLU")
set.seed(1)

n <- 3L
(A <- Matrix(round(rnorm(n * n), 2L), n, n))

## With dimnames, to see that they are propagated :
dimnames(A) <- dn <- list(paste0("r", seq_len(n)),
paste0("c", seq_len(n)))

(lu.A <- lu(A))
str(e.lu.A <- expand2(lu.A), max.level = 2L)

## Underlying LAPACK representation
(m.lu.A <- as(lu.A, "dgeMatrix")) # which is L and U interlaced
stopifnot(identical(as(m.lu.A, "matrix"), `dim`~(lu.A@x, lu.A@Dim)))
ae1 <- function(a, b, ...) all.equal(as(a, "matrix"), as(b, "matrix"), ...)
ae2 <- function(a, b, ...) ae1(unname(a), unname(b), ...)

## A ~ P1' L U in floating point
stopifnot(exprs = {
  identical(names(e.lu.A), c("P1.", "L", "U"))
  identical(e.lu.A["P1."],
    new("pMatrix", Dim = c(n, n), Dimnames = c(dn[1L], list(NULL)),
    margin = 1L, perm = invertPerm(asPerm(lu.A@perm))))
  identical(e.lu.A["L"],
    new("dtrMatrix", Dim = c(n, n), Dimnames = list(NULL, NULL),
    uplo = "L", diag = "U", x = lu.A@x))
  identical(e.lu.A["U"],
    new("dtrMatrix", Dim = c(n, n), Dimnames = list(NULL, dn[2L]),
    uplo = "U", diag = "N", x = lu.A@x))
  ae1(A, with(e.lu.A, P1. %*% L %*% U))
  ae2(A[asPerm(lu.A@perm), ], with(e.lu.A, L %*% U))
})

## Factorization handled as factorized matrix
b <- rnorm(n)
stopifnot(identical(det(A), det(lu.A)),
  identical(solve(A, b), solve(lu.A, b)))

---

denseMatrix-class  Virtual Class "denseMatrix" of All Dense Matrices

Description

This is the virtual class of all dense (S4) matrices. It partitions into two subclasses packedMatrix and unpackedMatrix. Alternatively into the (currently) three subclasses ddenseMatrix, ldenseMatrix, and ndenseMatrix.
dgCMatrix-class

denseMatrix is (hence) the direct superclass of these \((2 + 3 = 5)\) classes.

**Extends**

class "Matrix" directly.

**Slots**

exactly those of its superclass "Matrix", i.e., "Dim" and "Dimnames".

**Methods**

Use `showMethods(class = "denseMatrix", where = "package:Matrix")` for an overview of methods.

Extraction ("[" methods, see `[methods`.

**See Also**

colSums, kronecker, and other such methods with own help pages.

Its superclass `Matrix`, and main subclasses, `ddenseMatrix` and `sparseMatrix`.

**Examples**

`showClass("denseMatrix")`

---

---

**Description**

The dgCMatrix class is a class of sparse numeric matrices in the compressed, sparse, column-oriented format. In this implementation the non-zero elements in the columns are sorted into increasing row order. dgCMatrix is the "standard" class for sparse numeric matrices in the Matrix package.

**Objects from the Class**

Objects can be created by calls of the form `new("dgCMatrix", ...)`, more typically via `as(*, "CsparseMatrix")` or similar. Often however, more easily via `Matrix(*, sparse = TRUE)`, or most efficiently via `sparseMatrix()`.

**Slots**

x: Object of class "numeric" - the non-zero elements of the matrix.

... all other slots are inherited from the superclass "CsparseMatrix".
Methods

Matrix products (e.g., `crossprod-methods`), and (among other)

- **coerce** signature(from = "matrix", to = "dgCMatrix")
- **diag** signature(x = "dgCMatrix"): returns the diagonal of x
- **dim** signature(x = "dgCMatrix"): returns the dimensions of x
- **image** signature(x = "dgCMatrix"): plots an image of x using the `levelplot` function
- **solve** signature(a = "dgCMatrix", b = "."): see `solve-methods`, notably the extra argument `sparse`.
- **lu** signature(x = "dgCMatrix"): computes the LU decomposition of a square dgCMatrix object

See Also

Classes `dsCMatrix`, `dtCMatrix`, `lu`

Examples

```r
(m <- Matrix(c(0,0,2:0), 3,5))
str(m)
m[,1]
```

---

**dgeMatrix-class**

Class "dgeMatrix" of Dense Numeric (S4 Class) Matrices

Description

A general numeric dense matrix in the S4 Matrix representation. dgeMatrix is the “standard” class for dense numeric matrices in the Matrix package.

Objects from the Class

Objects can be created by calls of the form `new("dgeMatrix", ...)` or, more commonly, by coercion from the Matrix class (see Matrix) or by `Matrix(.)`.

Slots

- **x**: Object of class "numeric" - the numeric values contained in the matrix, in column-major order.
- **Dim**: Object of class "integer" - the dimensions of the matrix - must be an integer vector with exactly two non-negative values.
- **Dimnames**: a list of length two - inherited from class Matrix.
- **factors**: Object of class "list" - a list of factorizations of the matrix.
Methods

The are group methods (see, e.g., *Arith*)

**Arith** signature(e1 = "dgeMatrix", e2 = "dgeMatrix"): ...

**Arith** signature(e1 = "dgeMatrix", e2 = "numeric"): ...

**Arith** signature(e1 = "numeric", e2 = "dgeMatrix"): ...

**Math** signature(x = "dgeMatrix"): ...

**Math2** signature(x = "dgeMatrix", digits = "numeric"): ...

Matrix products `%*%`, `crossprod()` and `tcrossprod()`, several `solve` methods, and other matrix methods available:

**Schur** signature(x = "dgeMatrix", vectors = "logical"): ...

**Schur** signature(x = "dgeMatrix", vectors = "missing"): ...

**chol** signature(x = "dgeMatrix"): see `chol`.

**colMeans** signature(x = "dgeMatrix"): columnwise means (averages)

**colSums** signature(x = "dgeMatrix"): columnwise sums

**diag** signature(x = "dgeMatrix"): ...

**dim** signature(x = "dgeMatrix"): ...

**dimnames** signature(x = "dgeMatrix"): ...

**eigen** signature(x = "dgeMatrix", only.values= "logical"): ...

**eigen** signature(x = "dgeMatrix", only.values= "missing"): ...

**norm** signature(x = "dgeMatrix", type = "character"): ...

**norm** signature(x = "dgeMatrix", type = "missing"): ...

**rcond** signature(x = "dgeMatrix", norm = "character") or norm = "missing": the reciprocal condition number, `rcond()`.

**rowMeans** signature(x = "dgeMatrix"): rowwise means (averages)

**rowSums** signature(x = "dgeMatrix"): rowwise sums

**t** signature(x = "dgeMatrix"): matrix transpose

See Also

Classes `Matrix`, `dtrMatrix`, and `dsyMatrix`.
**dgRMatrix-class**

Sparse Compressed, Row-oriented Numeric Matrices

**Description**

The `dgRMatrix` class is a class of sparse numeric matrices in the compressed, sparse, row-oriented format. In this implementation the non-zero elements in the rows are sorted into increasing column order.

**Note:** The column-oriented sparse classes, e.g., `dgCMatrix`, are preferred and better supported in the `Matrix` package.

**Objects from the Class**

Objects can be created by calls of the form `new("dgRMatrix", ...)`.

**Slots**

- `j`: Object of class "integer" of length `nnzero` (number of non-zero elements). These are the column numbers for each non-zero element in the matrix.
- `p`: Object of class "integer" of pointers, one for each row, to the initial (zero-based) index of elements in the row.
- `x`: Object of class "numeric" - the non-zero elements of the matrix.
- `Dim`: Object of class "integer" - the dimensions of the matrix.

**Methods**

- `diag` signature(x = "dgRMatrix"): returns the diagonal of `x`
- `dim` signature(x = "dgRMatrix"): returns the dimensions of `x`
- `image` signature(x = "dgRMatrix"): plots an image of `x` using the `levelplot` function

**See Also**

the `RsparseMatrix` class, the virtual class of all sparse compressed row-oriented matrices, with its methods. The `dgCMatrix` class (column compressed sparse) is really preferred.
The "dgTMatrix" class is the class of sparse matrices stored as (possibly redundant) triplets. The internal representation is not at all unique, contrary to the one for class dgCMatrix.

Objects from the Class

Objects can be created by calls of the form new("dgTMatrix", ...), but more typically via spMatrix() or sparseMatrix(*, repr = "T").

Slots

i: integer row indices of non-zero entries in 0-base, i.e., must be in 0:(nrow(.)-1).

j: integer column indices of non-zero entries. Must be the same length as slot i and 0-based as well, i.e., in 0:(ncol(.)-1).

x: numeric vector - the (non-zero) entry at position (i,j). Must be the same length as slot i. If an index pair occurs more than once, the corresponding values of slot x are added to form the element of the matrix.

Dim: Object of class "integer" of length 2 - the dimensions of the matrix.

Methods

+ signature(e1 = "dgTMatrix", e2 = "dgTMatrix")

image signature(x = "dgTMatrix"): plots an image of x using the levelplot function

t signature(x = "dgTMatrix"): returns the transpose of x

Note

Triplet matrices are a convenient form in which to construct sparse matrices after which they can be coerced to dgCMatrix objects.

Note that both new(.) and spMatrix constructors for "dgTMatrix" (and other "TsparseMatrix" classes) implicitly add $x_k$'s that belong to identical $(i_k, j_k)$ pairs.

However this means that a matrix typically can be stored in more than one possible "TsparseMatrix" representations. Use uniqTsparse() in order to ensure uniqueness of the internal representation of such a matrix.

See Also

Class dgCMatrix or the superclasses dsparseMatrix and TsparseMatrix; uniqTsparse.
Examples

```r
m <- Matrix(0+1:28, nrow = 4)
m[-3,c(2,4:5,7)] <- m[ 3, 1:4] <- m[1:3, 6] <- 0
(mT <- as(m, "TsparseMatrix"))
str(mT)
str(upperTri(mT))

mT[1,]
mT[4, drop = FALSE]
stopifnot(identical(mT[lower.tri(mT)],
       m[lower.tri(m) ]))

mT[lower.tri(mT, diag=TRUE)] <- 0
mT

## Triplet representation with repeated (i,j) entries
## *adds* the corresponding x's:
T2 <- new("dgTMatrix",
    i = as.integer(c(1,1,0,3,3)),
    j = as.integer(c(2,2,4,0,0)), x=10*1:5, Dim=4:5)
str(T2) # contains (i,j,x) slots exactly as above, but
T2 ## has only three non-zero entries, as for repeated (i,j)'s,
## the corresponding x's are "implicitly" added
stopifnot(nnzero(T2) == 3)
```

Diagonal

Construct a Diagonal Matrix

Description

Construct a formally diagonal Matrix, i.e., an object inheriting from virtual class diagonalMatrix (or, if desired, a mathematically diagonal CsparseMatrix).

Usage

```r
Diagonal(n, x = NULL, names = FALSE)

.sparseDiagonal(n, x = NULL, uplo = "U", shape = "t", unitri = TRUE, kind, cols)
.trDiagonal(n, x = NULL, uplo = "U", unitri = TRUE, kind)
.symDiagonal(n, x = NULL, uplo = "U", kind)
```

Arguments

- **n**: integer indicating the dimension of the (square) matrix. If missing, then length(x) is used.
- **x**: numeric or logical vector listing values for the diagonal entries, to be recycled as necessary. If NULL (the default), then the result is a unit diagonal matrix.

.sparseDiagonal() and friends ignore non-NULL x when kind = "n".
names either logical TRUE or FALSE or then a character vector of length \( n \). If true and \( \text{names}(x) \) is not NULL, use that as both row and column names for the resulting matrix. When a character vector, use it for both dimnames.

uplo one of c("U", "L"), specifying the uplo slot of the result if the result is formally triangular of symmetric.

shape one of c("t", "s", "g"), indicating if the result should be formally triangular, symmetric, or “general”. The result will inherit from virtual class \( \text{triangularMatrix} \), \( \text{symmetricMatrix} \), or \( \text{generalMatrix} \), respectively.

unitri logical indicating if a formally triangular result with ones on the diagonal should be formally unit triangular, i.e., with diag slot equal to "U" rather than "N".

kind one of c("d", "l", "n"), indicating the “mode” of the result: numeric, logical, or pattern. The result will inherit from virtual class \( \text{dsparseMatrix} \), \( \text{lsparseMatrix} \), or \( \text{nsparseMatrix} \), respectively. Values other than "n" are ignored when \( x \) is non-NULL; in that case the mode is determined by typeof(\( x \)).

cols optional integer vector with values in 0:(\( n-1 \)), indexing columns of the specified diagonal matrix. If specified, then the result is (mathematically) \( D[, \text{cols}+1] \) rather than \( D \), where \( D = \text{Diagonal}(n, x) \), and it is always “general” (i.e., shape is ignored).

Value

\( \text{Diagonal()} \) returns an object inheriting from virtual class \( \text{diagonalMatrix} \).

\( \text{.sparseDiagonal()} \) returns a \( \text{CsparseMatrix} \) representation of \( \text{Diagonal}(n, x) \) or, if cols is given, of \( \text{Diagonal}(n, x)[[, \text{cols}+1] \). The precise class of the result depends on shape and kind.

\( \text{.trDiagonal()} \) and \( \text{.symDiagonal()} \) are simple wrappers, for \( \text{.sparseDiagonal}(\text{shape} = "t") \) and \( \text{.sparseDiagonal}(\text{shape} = "s") \), respectively.

\( \text{.sparseDiagonal()} \) exists primarily to leverage efficient C-level methods available for \( \text{CsparseMatrix} \).

Author(s)

Martin Maechler

See Also

the generic function diag for extraction of the diagonal from a matrix works for all “Matrices”. \( \text{bandSparse} \) constructs a banded sparse matrix from its non-zero sub-/super - diagonals. \( \text{band}(A) \) returns a band matrix containing some sub-/super - diagonals of \( A \).

\( \text{Matrix} \) for general matrix construction; further, class \( \text{diagonalMatrix} \).

Examples

\( \text{Diagonal(3)} \)
\( \text{Diagonal(x = 10^(3:1))} \)
\( \text{Diagonal(x = (1:4) >= 2)} \)#-> "ldiMatrix"

## Use \( \text{Diagonal()} \) + \text{kron}

For "repeated-block" matrices:
M1 <- Matrix(0+0:5, 2,3)
(M <- kronecker(Diagonal(3), M1))

(S <- crossprod(Matrix(rbinom(60, size=1, prob=0.1), 10,6)))
(SI <- S + 10*.symDiagonal(6)) # sparse symmetric still
stopifnot(is(SI, "dsCMatrix"))
(I4 <- .sparseDiagonal(4, shape="t"))# now (2012-10) unitriangular
stopifnot(I4@diag == "U", all(I4 == diag(4)))

diagonalMatrix-class  Class "diagonalMatrix" of Diagonal Matrices

Description

Class "diagonalMatrix" is the virtual class of all diagonal matrices.

Objects from the Class

A virtual Class: No objects may be created from it.

Slots

diag: character string, either "U" or "N", where "U" means 'unit-diagonal'.
Dim: matrix dimension, and
Dimnames: the dimnames, a list, see the Matrix class description. Typically list(NULL,NULL)
for diagonal matrices.

Extends

Class "sparseMatrix", directly.

Methods

These are just a subset of the signature for which defined methods. Currently, there are (too) many explicit methods defined in order to ensure efficient methods for diagonal matrices.

coerce signature(from = "matrix", to = "diagonalMatrix"): ...
coerce signature(from = "Matrix", to = "diagonalMatrix"): ...
coerce signature(from = "diagonalMatrix", to = "generalMatrix"): ...
coerce signature(from = "diagonalMatrix", to = "triangularMatrix"): ...
coerce signature(from = "diagonalMatrix", to = "nMatrix"): ...
coerce signature(from = "diagonalMatrix", to = "matrix"): ...
coerce signature(from = "diagonalMatrix", to = "sparseVector"): ...
t signature(x = "diagonalMatrix"): ...
and many more methods
solve signature(a = "diagonalMatrix", b, ...): is trivially implemented, of course; see also solve-methods.

which signature(x = "nMatrix"), semantically equivalent to base function which(x, arr.ind).

"Math" signature(x = "diagonalMatrix"): all these group methods return a "diagonalMatrix", apart from cumsum() etc which return a vector also for base matrix.

* signature(e1 = "ddiMatrix", e2="denseMatrix"): arithmetic and other operators from the Ops group have a few dozen explicit method definitions, in order to keep the results diagonal in many cases, including the following:

/ signature(e1 = "ddiMatrix", e2="denseMatrix"): the result is from class ddiMatrix which is typically very desirable. Note that when e2 contains off-diagonal zeros or NAs, we implicitly use 0/x = 0, hence differing from traditional R arithmetic (where 0/0 ⇔ NaN), in order to preserve sparsity.

summary (object = "diagonalMatrix"): Returns an object of S3 class "diagSummary" which is the summary of the vector object@x plus a simple heading, and an appropriate print method.

See Also

Diagonal() as constructor of these matrices, and isDiagonal. ddiMatrix and ldiMatrix are “actual” classes extending "diagonalMatrix".

Examples

I5 <- Diagonal(5)
D5 <- Diagonal(x = 10*(1:5))
## trivial (but explicitly defined) methods:
stopifnot(identical(crossprod(I5), I5),
          identical(tcrossprod(I5), I5),
          identical(crossprod(I5, D5), D5),
          identical(tcrossprod(D5, I5), D5),
          identical(solve(D5), solve(D5, I5)),
          all.equal(D5, solve(solve(D5)), tolerance = 1e-12))

solve(D5)# efficient as is diagonal

# an unusual way to construct a band matrix:
rbind2(cbind2(I5, D5),
       cbind2(D5, I5))
Description
Transform a triangular matrix \( x \), i.e., of class \texttt{triangularMatrix} from (internally!) unit triangular ("unitriangular") to "general" triangular (\texttt{diagU2N}(x)) or back (\texttt{diagN2U}(x)). Note that the latter, \texttt{diagN2U}(x), also sets the diagonal to one in cases where \texttt{diag}(x) was not all one.

\texttt{.diagU2N}(x) and \texttt{.diagN2U}(x) assume \textit{without} checking that \( x \) is a \texttt{triangularMatrix} with suitable \texttt{diag} slot ("U" and "N", respectively), hence they should be used with care.

Usage
\begin{verbatim}
.diagU2N(x, cl = getClassDef(class(x)), checkDense = FALSE)
.diagN2U(x, cl = getClassDef(class(x)), checkDense = FALSE)
\end{verbatim}

Arguments
\begin{itemize}
  \item \texttt{x} a \texttt{triangularMatrix}, often sparse.
  \item \texttt{cl} (optional, for speedup only:) class (definition) of \( x \).
  \item \texttt{checkDense} logical indicating if dense (see \texttt{denseMatrix}) matrices should be considered at all; i.e., when false, as per default, the result will be sparse even when \( x \) is dense.
\end{itemize}

Details
The concept of unit triangular matrices with a \texttt{diag} slot of "U" stems from LAPACK.

Value
a triangular matrix of the same \texttt{class} but with a different \texttt{diag} slot. For \texttt{diagU2N} (semantically) with identical entries as \( x \), whereas in \texttt{diagN2U}(x), the off-diagonal entries are unchanged and the diagonal is set to all 1 even if it was not previously.

Note
Such internal storage details should rarely be of relevance to the user. Hence, these functions really are rather \textit{internal} utilities.

See Also
"\texttt{triangularMatrix}", "\texttt{dtCMatrix}".

Examples
\begin{verbatim}
(T <- Diagonal(7) + triu(Matrix(rpois(49, 1/4), 7, 7), k = 1))
(uT <- diagN2U(T)) # "unitriangular"
(t.u <- diagN2U(T10*T)) # changes the diagonal!
stopifnot(all(T == uT), diag(t.u) == 1,
  identical(T, diagU2N(uT)))
\end{verbatim}
dimScale

Scale the Rows and Columns of a Matrix

Description

dimScale, rowScale, and colScale implement $D_1 \times x \times D_2$, $D \times x$, and $x \times D$ for diagonal matrices $D_1$, $D_2$, and $D$ with diagonal entries $d_1$, $d_2$, and $d$, respectively. Unlike the explicit products, these functions preserve dimnames(x) and symmetry where appropriate.

Usage

dimScale(x, d1 = sqrt(1/diag(x, names = FALSE)), d2 = d1)
rowScale(x, d)
colScale(x, d)

Arguments

x a matrix, possibly inheriting from virtual class Matrix.
d1, d2, d numeric vectors giving factors by which to scale the rows or columns of x; they are recycled as necessary.

Details

dimScale(x) (with d1 and d2 unset) is only roughly equivalent to cov2cor(x). cov2cor sets the diagonal entries of the result to 1 (exactly); dimScale does not.

Value

The result of scaling x, currently always inheriting from virtual class dMatrix.

It inherits from triangularMatrix if and only if x does. In the special case of dimScale(x, d1, d2) with identical d1 and d2, it inherits from symmetricMatrix if and only if x does.

Author(s)

Mikael Jagan

See Also

cov2cor
Examples

n <- 6L
(x <- forceSymmetric(matrix(1, n, n)))
dimnames(x) <- rep.int(list(letters[seq_len(n)]), 2L)
d <- seq_len(n)
(D <- Diagonal(x = d))

(scx <- dimScale(x, d)) # symmetry and 'dimnames' kept
(mm <- D %*% X %*% D) # symmetry and 'dimnames' lost
stopifnot(identical(unname(as(scx, "generalMatrix")), mm))

rowScale(x, d)
colScale(x, d)

---

dMatrix-class (Virtual) Class "dMatrix" of "double" Matrices

Description

The dMatrix class is a virtual class contained by all actual classes of numeric matrices in the Matrix package. Similarly, all the actual classes of logical matrices inherit from the lMatrix class.

Slots

Common to all matrix object in the package:

Dim: Object of class "integer" - the dimensions of the matrix - must be an integer vector with exactly two non-negative values.

Dimnames: list of length two; each component containing NULL or a character vector length equal the corresponding Dim element.

Methods

There are (relatively simple) group methods (see, e.g., Arith)

Arith signature(e1 = "dMatrix", e2 = "dMatrix"): ...
Arith signature(e1 = "dMatrix", e2 = "numeric"): ...
Arith signature(e1 = "numeric", e2 = "dMatrix"): ...

Math signature(x = "dMatrix"): ...
Math2 signature(x = "dMatrix", digits = "numeric"): this group contains round() and signif().

Compare signature(e1 = "numeric", e2 = "dMatrix"): ...
Compare signature(e1 = "dMatrix", e2 = "numeric"): ...
Compare signature(e1 = "dMatrix", e2 = "dMatrix"): ...

Summary signature(x = "dMatrix"): The "Summary" group contains the seven functions max(), min(), range(), prod(), sum(), any(), and all().
The following methods are also defined for all double matrices:

expm signature(x = "dMatrix"): computes the “*Matrix Exponential*”, see expm.

zapsmall signature(x = "dMatrix"): ...

The following methods are defined for all logical matrices:

which signature(x = "lsparseMatrix") and many other subclasses of "lMatrix": as the base function which(x, arr.ind) returns the indices of the TRUE entries in x; if arr.ind is true, as a 2-column matrix of row and column indices. Since Matrix version 1.2-9, if useNames is true, as by default, with dimnames, the same as base::which.

See Also

The nonzero-pattern matrix class nMatrix, which can be used to store non-NA logical matrices even more compactly.

The numeric matrix classes dgeMatrix, dgCMatrix, and Matrix.

drop0(x, tol=1e-10) is sometimes preferable to (and more efficient than) zapsmall(x, digits=10).

Examples

```r
showClass("dMatrix")

set.seed(101)
round(Matrix(rnorm(28), 4,7), 2)
M <- Matrix(rlnorm(56, sd=10), 4,14)
(M. <- zapsmall(M))
table(as.logical(M. == 0))
```

---

**dmperm**

**Dulmage-Mendelsohn Permutation / Decomposition**

**Description**

For any $n \times m$ (typically) sparse matrix $x$ compute the Dulmage-Mendelsohn row and columns permutations which at first splits the $n$ rows and $m$ columns into coarse partitions each; and then a finer one, reordering rows and columns such that the permutated matrix is “as upper triangular” as possible.

**Usage**

```r
dmperm(x, nAns = 6L, seed = 0L)
```
Arguments

- **x** a typically sparse matrix; internally coerced to either "dgCMatrix" or "dtCMatrix".
- **nAns** an integer specifying the length of the resulting list. Must be 2, 4, or 6.
- **seed** an integer code in -1,0,1; determining the (initial) permutation; by default, seed = 0, no (or the identity) permutation; seed = -1 uses the "reverse" permutation k:1; for seed = 1, it is a random permutation (using R’s RNG, seed, etc).

Details

See the book section by Tim Davis; page 122–127, in the References.

Value

a named **list** with (by default) 6 components,

- **p** integer vector with the permutation p, of length nrow(x).
- **q** integer vector with the permutation q, of length ncol(x).
- **r** integer vector of length nb+1, where block k is rows r[k] to r[k+1]-1 in A[p,q].
- **s** integer vector of length nb+1, where block k is cols s[k] to s[k+1]-1 in A[p,q].
- **rr5** integer vector of length 5, defining the coarse row decomposition.
- **cc5** integer vector of length 5, defining the coarse column decomposition.

Author(s)

Martin Maechler, with a lot of “encouragement” by Mauricio Vargas.

References


See Also

**Schur**, the class of permutation matrices; "**pMatrix**".

Examples

```r
set.seed(17)
(S9 <- rsparsematrix(9, 9, nnz = 10, symmetric=TRUE)) # dsCMatrix
str( dm9 <- dmperm(S9) )
(S9p <- with(dm9, S9[p, q]))
## looks good, but *not* quite upper triangular; these, too:
str( dm9.0 <- dmperm(S9, seed=-1)) # non-random too.
str( dm9_1 <- dmperm(S9, seed= 1)) # a random one
## The last two permutations differ, but have the same effect!
(S9p0 <- with(dm9.0, S9[p, q])) # .. hmm ..
```
dpoMatrix-class

Positive Semi-definite Dense (Packed \ Non-packed) Numeric Matrices

Description

- The "dpoMatrix" class is the class of positive-semidefinite symmetric matrices in nonpacked storage.
- The "dppMatrix" class is the same except in packed storage. Only the upper triangle or the lower triangle is required to be available.
- The "corMatrix" and "pcorMatrix" classes represent correlation matrices. They extend "dpoMatrix" and "dppMatrix", respectively, with an additional slot sd allowing restoration of the original covariance matrix.

Objects from the Class

Objects can be created by calls of the form `new("dpoMatrix", ...)` or from `crossprod` applied to an "dgeMatrix" object.

Slots

- `uplo`: Object of class "character". Must be either "U", for upper triangular, and "L", for lower triangular.
- `x`: Object of class "numeric". The numeric values that constitute the matrix, stored in column-major order.
- `Dim`: Object of class "integer". The dimensions of the matrix which must be a two-element vector of non-negative integers.
Dimnames: inherited from class "Matrix"

factors: Object of class "list". A named list of factorizations that have been computed for the matrix.

sd: (for "corMatrix" and "pcorMatrix") a numeric vector of length n containing the (original) \(\sqrt{\text{var}()}\) entries which allow reconstruction of a covariance matrix from the correlation matrix.

Extends

Class "dsyMatrix", directly.
Classes "dgeMatrix", "symmetricMatrix", and many more by class "dsyMatrix".

Methods

- **chol** signature(x = "dpoMatrix"): Returns (and stores) the Cholesky decomposition of x, see chol.

- **determinant** signature(x = "dpoMatrix"): Returns the determinant of x, via chol(x), see above.

- **rcond** signature(x = "dpoMatrix", norm = "character"): Returns (and stores) the reciprocal of the condition number of x. The norm can be "O" for the one-norm (the default) or "I" for the infinity-norm. For symmetric matrices the result does not depend on the norm.

- **solve** signature(a = "dpoMatrix", b = "...."), and

- **solve** signature(a = "dpoMatrix", b = "....") work via the Cholesky composition, see also the Matrix solve-methods.

- **Arith** signature(e1 = "dpoMatrix", e2 = "numeric") (and quite a few other signatures): The result of ("elementwise" defined) arithmetic operations is typically not positive-definite anymore. The only exceptions, currently, are multiplications, divisions or additions with positive length(.) == 1 numbers (or logicals).

Note

Currently the validity methods for these classes such as getValidity(getClass("dpoMatrix")) for efficiency reasons only check the diagonal entries of the matrix – they may not be negative. This is only necessary but not sufficient for a symmetric matrix to be positive semi-definite.

A more reliable (but often more expensive) check for positive semi-definiteness would look at the signs of diag(BunchKaufman(.)) (with some tolerance for very small negative values), and for (strict) positive definiteness at something like !inherits(tryCatch(chol(.), error=identity), "error"). Indeed, when coercing to these classes, a version of Cholesky() or chol() is typically used, e.g., see selectMethod("coerce", c(from="dsyMatrix", to="dpoMatrix")).

See Also

Classes dsyMatrix and dgeMatrix; further, Matrix, rcond, chol, solve, crossprod.
Examples

```r
h6 <- Hilbert(6)
rcond(h6)
str(h6)
h6 * 27720 # is `integer'
solve(h6)
str(hp6 <- as(h6, "dppMatrix"))
```

```r
### Note that as(*, "corMatrix") *scales* the matrix
(ch6 <- as(h6, "corMatrix"))
stopifnot(all.equal(h6 * 27720, round(27720 * h6), tolerance = 1e-14),
          all.equal(ch6@sd^(-2), 2*(1:6)-1, tolerance = 1e-12))
chch <- Cholesky(ch6, perm = FALSE)
stopifnot(identical(chch, ch6@factors$Cholesky),
          all(abs(crossprod(as(chch, "dtrMatrix")) - ch6) < 1e-10))
```

---

**drop0**

*Drop Non-Structural Zeros from a Sparse Matrix*

**Description**

Deletes “non-structural” zeros (i.e., zeros stored explicitly, in memory) from a sparse matrix and returns the result.

**Usage**

```r
drop0(x, tol = 0, is.Csparse = NA, give.Csparse = TRUE)
```

**Arguments**

- `x` a *Matrix*, typically inheriting from virtual class `sparseMatrix`. `denseMatrix` and traditional vectors and matrices are coerced to `CsparseMatrix`, with zeros dropped automatically, hence users passing such `x` should consider `as(x, "CsparseMatrix")` instead, notably in the `tol = 0` case.
- `tol` a non-negative number. If `x` is numeric, then entries less than or equal to `tol` in absolute value are deleted.
- `is.Csparse` a logical used only if `give.Csparse` is TRUE, indicating if `x` already inherits from virtual class `CsparseMatrix`, in which case coercion is not attempted, permitting some (typically small) speed-up.
- `give.Csparse` a logical indicating if the result must inherit from virtual class `CsparseMatrix`. If FALSE and `x` inherits from `RsparseMatrix`, `TsparseMatrix`, or `indMatrix`, then the result preserves the class of `x`. The default value is TRUE only for backwards compatibility.

**Value**

A `sparseMatrix`, the result of deleting non-structural zeros from `x`, possibly after coercion.
dsCMatrix-class

Note

drop0 is sometimes called in conjunction with zapsmall, e.g., when dealing with sparse matrix products; see the example.

See Also

Function sparseMatrix, for constructing objects inheriting from virtual class sparseMatrix; nnzero.

Examples

```r
(m <- sparseMatrix(i = 1:8, j = 2:9, x = c(0:2, 3:-1),
         dims = c(10L, 20L)))
drop0(m)
## A larger example:
t5 <- new("dtCMatrix", Dim = c(5L, 5L), uplo = "L",
     x = c(10, 1, 3, 10, 1, 10, 1, 10, 10),
     i = c(0L,2L,4L, 1L, 3L,2L,4L, 3L, 4L),
     p = c(0L, 3L, 5L, 7:9))
TT <- kronecker(t5, kronecker(kronecker(t5, t5), t5))
IT <- solve(TT)
I. <- TT %*% IT ; nnzero(I.) # 697 ( == 625 + 72 )
I.0 <- drop0(zapsmall(I.))
## which actually can be more efficiently achieved by
I.. <- drop0(I., tol = 1e-15)
stopifnot(all(I.0 == Diagonal(625)), nnzero(I..) == 625)
```

dsCMatrix-class Numeric Symmetric Sparse (column compressed) Matrices

Description

The dsCMatrix class is a class of symmetric, sparse numeric matrices in the compressed, column-oriented format. In this implementation the non-zero elements in the columns are sorted into increasing row order.

The dsTMatrix class is the class of symmetric, sparse numeric matrices in triplet format.

Objects from the Class

Objects can be created by calls of the form new("dsCMatrix",...) or new("dsTMatrix",...), or automatically via e.g., as(*, "symmetricMatrix"), or (for dsCMatrix) also from Matrix(.).

Creation “from scratch” most efficiently happens via sparseMatrix(*, symmetric=TRUE).
Slots

uplo: A character object indicating if the upper triangle ("U") or the lower triangle ("L") is stored.

i: Object of class "integer" of length nnZ (half number of non-zero elements). These are the row numbers for each non-zero element in the lower triangle of the matrix.

p: (only in class "dsCMatrix"): an integer vector for providing pointers, one for each column, see the detailed description in CsparseMatrix.

j: (only in class "dsTMatrix"): Object of class "integer" of length nnZ (as i). These are the column numbers for each non-zero element in the lower triangle of the matrix.

x: Object of class "numeric" of length nnZ – the non-zero elements of the matrix (to be duplicated for full matrix).

factors: Object of class "list" - a list of factorizations of the matrix.

Dim: Object of class "integer" - the dimensions of the matrix - must be an integer vector with exactly two non-negative values.

Extends

Both classes extend classes and symmetricMatrix dsparseMatrix directly; dsCMatrix further directly extends CsparseMatrix, where dsTMatrix does TsparseMatrix.

Methods

solve signature(a = "dsCMatrix", b = "...."): x <- solve(a,b) solves Ax = b for x; see solve-methods.

chol signature(x = "dsCMatrix", pivot = "logical"): Returns (and stores) the Cholesky decomposition of x, see chol.

Cholesky signature(A = "dsCMatrix", ...): Computes more flexibly Cholesky decompositions, see Cholesky.

determinant signature(x = "dsCMatrix", logarithm = "missing"): Evaluate the determinant of x on the logarithm scale. This creates and stores the Cholesky factorization.

determinant signature(x = "dsCMatrix", logarithm = "logical"): Evaluate the determinant of x on the logarithm scale or not, according to the logarithm argument. This creates and stores the Cholesky factorization.

t signature(x = "dsCMatrix"): Transpose. As for all symmetric matrices, a matrix for which the upper triangle is stored produces a matrix for which the lower triangle is stored and vice versa, i.e., the uplo slot is swapped, and the row and column indices are interchanged.

t signature(x = "dsTMatrix"): Transpose. The uplo slot is swapped from "U" to "L" or vice versa, as for a "dsCMatrix", see above.

See Also

Classes dgCMat, dgTMat, dgeMat and those mentioned above.
Examples

```r
mm <- Matrix(toeplitz(c(10, 0, 1, 0, 3)), sparse = TRUE)
mm # automatically dsCMatrix
str(mm)

mT <- as(as(mm, "generalMatrix"), "TsparseMatrix")

## Either
(symM <- as(mT, "symmetricMatrix")) # dsT
(symC <- as(symM, "CsparseMatrix")) # dsC
## or
sT <- Matrix(mT, sparse=TRUE, forceCheck=TRUE) # dsT

sym2 <- as(symC, "TsparseMatrix")
## --> the same as 'symM', a "dsTMatrix"
```

dsparseMatrix-class  Virtual Class "dsparseMatrix" of Numeric Sparse Matrices

Description

The Class "dsparseMatrix" is the virtual (super) class of all numeric sparse matrices.

Slots

- **Dim**: the matrix dimension, see class "Matrix".
- **Dimnames**: see the "Matrix" class.
- **x**: a numeric vector containing the (non-zero) matrix entries.

Extends

Class "dMatrix" and "sparseMatrix", directly.
Class "Matrix", by the above classes.

See Also

the documentation of the (non virtual) sub classes, see `showClass("dsparseMatrix")`; in particular, `dgTMatrix`, `dgCMatrix`, and `dgRMatrix`.

Examples

```r
showClass("dsparseMatrix")
```
Description

The dsRMatrix class is a class of symmetric, sparse matrices in the compressed, row-oriented format. In this implementation the non-zero elements in the rows are sorted into increasing column order.

Objects from the Class

These "..RMATRIX" classes are currently still mostly unimplemented!

Objects can be created by calls of the form new("dsRMatrix", ...).

Slots

uplo: A character object indicating if the upper triangle ("U") or the lower triangle ("L") is stored. At present only the lower triangle form is allowed.

j: Object of class "integer" of length nnzero (number of non-zero elements). These are the row numbers for each non-zero element in the matrix.

p: Object of class "integer" of pointers, one for each row, to the initial (zero-based) index of elements in the row.

factors: Object of class "list" - a list of factorizations of the matrix.

x: Object of class "numeric" - the non-zero elements of the matrix.

Dim: Object of class "integer" - the dimensions of the matrix - must be an integer vector with exactly two non-negative values.

Dimnames: List of length two, see Matrix.

Extends

Classes RsparseMatrix, dsparseMatrix and symmetricMatrix, directly.

Class "dMatrix", by class "dsparseMatrix", class "sparseMatrix", by class "dsparseMatrix" or "RsparseMatrix": class "compMatrix" by class "symmetricMatrix" and of course, class "Matrix".

Methods

forceSymmetric signature(x = "dsRMatrix", uplo = "missing"): a trivial method just returning x

forceSymmetric signature(x = "dsRMatrix", uplo = "character"): if uplo == x@uplo, this trivially returns x; otherwise t(x).

See Also

the classes dgCMatrix, dgTMatrix, and dgeMatrix.
Examples

```r
(m0 <- new("dsRMMatrix"))
m2 <- new("dsRMMatrix", Dim = c(2L,2L),
         x = c(3,1), j = c(1L,1L), p = 0:2)
m2
stopifnot(colSums(as(m2, "TsparseMatrix")) == 3:4)
str(m2)
(ds2 <- forceSymmetric(diag(2))) # dsy*
dR <- as(ds2, "RsparseMatrix")
dR # dsRMMatrix
```

dsyMatrix-class

Symmetric Dense (Packed or Unpacked) Numeric Matrices

Description

- The "dsyMatrix" class is the class of symmetric, dense matrices in non-packed storage and
- "dspMatrix" is the class of symmetric dense matrices in packed storage, see `pack()`. Only the upper triangle or the lower triangle is stored.

Objects from the Class

Objects can be created by calls of the form `new("dsyMatrix", ...)` or `new("dspMatrix", ...)`, respectively.

Slots

- `uplo`: Object of class "character". Must be either "U", for upper triangular, and "L", for lower triangular.
- `x`: Object of class "numeric". The numeric values that constitute the matrix, stored in column-major order.
- `Dim`, `Dimnames`: The dimension (a length-2 "integer") and corresponding names (or NULL), see the `Matrix`
- `factors`: Object of class "list". A named list of factorizations that have been computed for the matrix.

Extends

"dsyMatrix" extends class "dgeMatrix", directly, whereas
"dspMatrix" extends class "ddenseMatrix", directly.

Both extend class "symmetricMatrix", directly, and class "Matrix" and others, indirectly, use `showClass("dsyMatrix")`, e.g., for details.
Methods

- **norm**
  signature(x = "dspMatrix", type = "character"), or x = "dsyMatrix" or type = "missing":
  Computes the matrix norm of the desired type, see, norm.

- **rcond**
  signature(x = "dspMatrix", type = "character"), or x = "dsyMatrix" or type = "missing":
  Computes the reciprocal condition number, rcond().

- **solve**
  signature(a = "dspMatrix", b = "...."), and
  signature(a = "dsyMatrix", b = "...."): x <- solve(a, b) solves Ax = b for x; see
  solve-methods.

- **t**
  signature(x = "dsyMatrix"): Transpose: swaps from upper triangular to lower triangular storage, i.e., the uplo slot from "U" to "L" or vice versa, the same as for all symmetric matrices.

See Also

The positive (Semi-)definite dense (packed or non-packed numeric matrix classes dpoMatrix, dppMatrix and corMatrix,
Classes dgeMatrix and Matrix: solve, norm, rcond, t

Examples

```r
## Only upper triangular part matters (when uplo == "U" as per default)
(sy2 <- new("dsyMatrix", Dim = as.integer(c(2,2)), x = c(14, NA, 32, 77)))
str(t(sy2)) # uplo = "L", and the lower tri. (i.e. NA is replaced).

chol(sy2) #-> "Cholesky" matrix
(sp2 <- pack(sy2)) # a "dspMatrix"

## Coercing to dpoMatrix gives invalid object:
sy3 <- new("dsyMatrix", Dim = as.integer(c(2,2)), x = c(14, -1, 2, -7))
try(as(sy3, "dpoMatrix")) # -> error: not positive definite

## 4x4 example
m <- matrix(0,4,4); m[upper.tri(m)] <- 1:6
(sym <- m+t(m)+diag(11:14, 4))
(S1 <- pack(sym))
(S2 <- t(S1))
stopifnot(all(S1 == S2)) # equal "seen as matrix", but differ internally :
str(S1)
S2@x
```
Description

The "dtCMatrix" class is a class of triangular, sparse matrices in the compressed, column-oriented format. In this implementation the non-zero elements in the columns are sorted into increasing row order.

The "dtTMatrix" class is a class of triangular, sparse matrices in triplet format.

Objects from the Class

Objects can be created by calls of the form new("dtCMatrix", ...) or calls of the form new("dtTMatrix", ...), but more typically automatically via Matrix() or coercions such as as(x, "triangularMatrix").

Slots

uplo: Object of class "character". Must be either "U", for upper triangular, and "L", for lower triangular.

diag: Object of class "character". Must be either "U", for unit triangular (diagonal is all ones), or "N"; see triangularMatrix.

p: (only present in "dtCMatrix"): an integer vector for providing pointers, one for each column, see the detailed description in CsparseMatrix.

i: Object of class "integer" of length nnzero (number of non-zero elements). These are the row numbers for each non-zero element in the matrix.

j: Object of class "integer" of length nnzero (number of non-zero elements). These are the column numbers for each non-zero element in the matrix. (Only present in the dtTMatrix class.)

x: Object of class "numeric" - the non-zero elements of the matrix.

Dim,Dimnames: The dimension (a length-2 "integer") and corresponding names (or NULL), inherited from the Matrix, see there.

Extends

Class "dgCMatrix", directly. Class "triangularMatrix", directly. Class "dMatrix", "sparseMatrix", and more by class "dgCMatrix" etc, see the examples.

Methods

solve signature(a = "dtCMatrix", b = "..."): sparse triangular solve (aka “backsolve” or “forwardsolve”), see solve-methods.

t signature(x = "dtCMatrix"): returns the transpose of x

t signature(x = "dtTMatrix"): returns the transpose of x

See Also

Classes dgCMatrix, dgTMatrix, dgeMatrix, and dtrMatrix.
Examples

```
showClass("dtCMatrix")
showClass("dtTMatrix")
t1 <- new("dtTMatrix", x= c(3,7), i= 0:1, j=3:2, Dim= as.integer(c(4,4)))
t1
## from 0-diagonal to unit-diagonal (low-level step):
tu <- t1 ; tu@diag <- "U"
tu
(cu <- as(tu, "CsparseMatrix"))
str(cu)# only two entries in @i and @x
stopifnot(cu@i == 1:0,
         all(2 * symmpart(cu) == Diagonal(4) + forceSymmetric(cu)))
t1[1,2:3] <- -1:-2
diag(t1) <- 10*c(1:2,3:2)
t1 # still triangular
(it1 <- solve(t1))
t1. <- solve(it1)
all(abs(t1 - t1.) < 10 * .Machine$double.eps)
```

## 2nd example

```
U5 <- new("dtCMatrix", i= c(1L, 0:3), p=c(0L,0L,0:2, 5L), Dim = c(5L, 5L),
        x = rep(1, 5), diag = "U")
U5
(iu <- solve(U5)) # contains one '0'
validObject(iu2 <- solve(U5, Diagonal(5)))# failed in earlier versions
I5 <- iu %*% U5 # should equal the identity matrix
i5 <- iu2 %*% U5
m53 <- matrix(1:15, 5,3, dimnames=list(NULL,letters[1:3]))
asDiag <- function(M) as(drop0(M), "diagonalMatrix")
stopifnot(
    all.equal(Diagonal(5), asDiag(I5), tolerance=1e-14) ,
    all.equal(Diagonal(5), asDiag(i5), tolerance=1e-14) ,
    identical(list(NULL, dimnames(m53)[[2]]), dimnames(solve(U5, m53)))
)
```

---

dtpMatrix-class

Packed Triangular Dense Matrices - "dtpMatrix"

dtpMatrix-class

Description

The "dtpMatrix" class is the class of triangular, dense, numeric matrices in packed storage. The "dtrMatrix" class is the same except in nonpacked storage.

Objects from the Class

Objects can be created by calls of the form `new("dtpMatrix", ...)` or by coercion from other classes of matrices.
Slots

uplo: Object of class "character". Must be either "U", for upper triangular, and "L", for lower triangular.

diag: Object of class "character". Must be either "U", for unit triangular (diagonal is all ones), or "N"; see triangularMatrix.

x: Object of class "numeric". The numeric values that constitute the matrix, stored in column-major order. For a packed square matrix of dimension $d \times d$, length(x) is of length $d(d+1)/2$ (also when diag == "U"!).

Dim, Dimnames: The dimension (a length-2 "integer") and corresponding names (or NULL), inherited from the Matrix, see there.

Extends

Class "ddenseMatrix", directly. Class "triangularMatrix", directly. Class "dMatrix" and more by class "ddenseMatrix" etc, see the examples.

Methods

%*% signature(x = "dtpMatrix", y = "dgeMatrix"): Matrix multiplication; ditto for several other signature combinations, see showMethods("%*%", class = "dtpMatrix").

determinant signature(x = "dtpMatrix", logarithm = "logical"): the determinant(x) trivially is prod(diag(x)), but computed on log scale to prevent over- and underflow.

diag signature(x = "dtpMatrix"): ...

norm signature(x = "dtpMatrix", type = "character"): ...

rcond signature(x = "dtpMatrix", norm = "character"): ...

solve signature(a = "dtpMatrix", b = ".."): efficiently using internal backsolve or forward-solve, see solve-methods.

t signature(x = "dtpMatrix"): t(x) remains a "dtpMatrix", lower triangular if x is upper triangular, and vice versa.

See Also

Class dtrMatrix

Examples

dtpMatrix-class

showClass("dtrMatrix")

dtpMatrix-class

dtpMatrix-class
### dtRMatrix-class

Triangular Sparse Compressed Row Matrices

#### Description

The `dtRMatrix` class is a class of triangular, sparse matrices in the compressed, row-oriented format. In this implementation the non-zero elements in the rows are sorted into increasing column order.

#### Objects from the Class

This class is currently still mostly unimplemented!

Objects can be created by calls of the form `new("dtRMatrix", ...)`. 

#### Slots

- **uplo**: Object of class "character". Must be either "U", for upper triangular, and "L", for lower triangular. At present only the lower triangle form is allowed.
- **diag**: Object of class "character". Must be either "U", for unit triangular (diagonal is all ones), or "N"; see `triangularMatrix`.
- **j**: Object of class "integer" of length `nnzero(.)` (number of non-zero elements). These are the row numbers for each non-zero element in the matrix.
- **p**: Object of class "integer" of pointers, one for each row, to the initial (zero-based) index of elements in the row. (Only present in the `dsRMatrix` class.)
- **x**: Object of class "numeric" - the non-zero elements of the matrix.
- **Dim**: The dimension (a length-2 "integer")
- **Dimnames**: corresponding names (or `NULL`), inherited from the `Matrix`, see there.

#### Extends

Class "dgRMatrix", directly. Class "dsparseMatrix", by class "dgRMatrix". Class "dMatrix", by class "dgRMatrix". Class "sparseMatrix", by class "dgRMatrix". Class "Matrix", by class "dgRMatrix".

#### Methods

No methods currently with class "dsRMatrix" in the signature.

#### See Also

Classes `dgCMatrix`, `dgTMatrix`, `dgeMatrix`
dtrMatrix-class

Examples

(m0 <- new("dtRMatrix"))
(m2 <- new("dtRMatrix", Dim = c(2L,2L),
           x = c(5, 1:2), p = c(0L,2:3), j= c(0:1,1L)))
str(m2)
(m3 <- as(Diagonal(2), "RsparseMatrix"))# --> dtRMatrix

---

**dtrMatrix-class**

Triangular, dense, numeric matrices

---

**Description**

The "dtrMatrix" class is the class of triangular, dense, numeric matrices in nonpacked storage. The "dtpMatrix" class is the same except in packed storage, see `pack()`.

**Objects from the Class**

Objects can be created by calls of the form `new("dtrMatrix", ...)`.

**Slots**

- **uplo**: Object of class "character". Must be either "U", for upper triangular, and "L", for lower triangular.
- **diag**: Object of class "character". Must be either "U", for unit triangular (diagonal is all ones), or "N"; see `triangularMatrix`.
- **x**: Object of class "numeric". The numeric values that constitute the matrix, stored in column-major order.
- **Dim**: Object of class "integer". The dimensions of the matrix which must be a two-element vector of non-negative integers.

**Extends**

Class "ddenseMatrix", directly. Class "triangularMatrix", directly. Class "Matrix" and others, by class "ddenseMatrix".

**Methods**

Among others (such as matrix products, e.g. ?crossprod-methods),

- **norm** signature(x = "dtrMatrix", type = "character")
- **rcond** signature(x = "dtrMatrix", norm = "character")
- **solve** signature(a = "dtrMatrix", b = "....") efficiently use a "forwardsolve" or "backsolve" for a lower or upper triangular matrix, respectively, see also `solve-methods`.

All the `Ops` group methods are available. When applied to two triangular matrices, these return a triangular matrix when easily possible.
See Also

Classes `ddenseMatrix`, `dtpMatrix`, `triangularMatrix`

Examples

```r
(m <- rbind(2:3, 0:-1))
(M <- as(m, "generalMatrix"))

(T <- as(M, "triangularMatrix")) # formally upper triangular
(T2 <- as(t(M), "triangularMatrix"))
stopifnot(T@uplo == "U", T2@uplo == "L", identical(T2, t(T)))

m <- matrix(0,4,4); m[upper.tri(m)] <- 1:6
(t1 <- Matrix(m+diag(4)))
str(t1p <- pack(t1))
(t1pu <- diagN2U(t1p))
stopifnot(exprs = {
  inherits(t1 , "dtrMatrix"); validObject(t1)
  inherits(t1p, "dtpMatrix"); validObject(t1p)
  inherits(t1pu,"dtCMatrix"); validObject(t1pu)
  t1pu@x == 1:6
  all(t1pu == t1p)
  identical((t1pu - t1)x, numeric())# sparse all-0
})
```

Description

`expand1` and `expand2` construct matrix factors from objects specifying matrix factorizations. Such objects typically do not store the factors explicitly, employing instead a compact representation to save memory.

Usage

```r
expand1(x, which, ...)  
expand2(x, ...)  
expand (x, ...)
```

Arguments

- `x`  
a matrix factorization, typically inheriting from virtual class `MatrixFactorization`.  
- `which`  
a character string indicating a matrix factor.  
- `...`  
further arguments passed to or from methods.
Details

Methods for expand are retained only for backwards compatibility with \textbf{Matrix} \textless{} 1.6-0. New code should use expand1 and expand2, whose methods provide more control and behave more consistently. Notably, expand2 obeys the rule that the product of the matrix factors in the returned list should reproduce (within some tolerance) the factorized matrix, \textit{including} its dimnames.

Hence if \(x\) is a matrix and \(y\) is its factorization, then

\[
\text{all.equal(as(x, "matrix"), as(Reduce(\%\%\%, expand2(y)), "matrix"))}
\]

should in most cases return \text{TRUE}.

Value

expand1 returns an object inheriting from virtual class \textbf{Matrix}, representing the factor indicated by \textit{which}, always without row and column names.

expand2 returns a list of factors, typically with names using conventional notation, as in \text{list(L=, U=)}. The first and last factors get the row and column names of the factorized matrix, which are preserved in the \textit{Dimnames} slot of \(x\).

Methods

The following table lists methods for expand1 together with allowed values of argument \textit{which}.

<table>
<thead>
<tr>
<th>class(x)</th>
<th>which</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schur</td>
<td>c(&quot;Q&quot;, &quot;T&quot;, &quot;Q.&quot; )</td>
</tr>
<tr>
<td>denseLU</td>
<td>c(&quot;P1&quot;, &quot;P1.&quot;, &quot;L&quot;, &quot;U&quot;)</td>
</tr>
<tr>
<td>sparseLU</td>
<td>c(&quot;P1&quot;, &quot;P1.&quot;, &quot;P2.&quot;, &quot;L&quot;, &quot;U&quot;)</td>
</tr>
<tr>
<td>sparseQR</td>
<td>c(&quot;P1&quot;, &quot;P1.&quot;, &quot;P2.&quot;, &quot;Q&quot;, &quot;Q1&quot;, &quot;R&quot;, &quot;R1&quot;)</td>
</tr>
<tr>
<td>BunchKaufman, pBunchKaufman</td>
<td>c(&quot;U&quot;, &quot;DU&quot;, &quot;U.&quot;, &quot;L&quot;, &quot;DL&quot;, &quot;L.&quot;)</td>
</tr>
<tr>
<td>Cholesky, pCholesky</td>
<td>c(&quot;P1&quot;, &quot;P1.&quot;, &quot;L1&quot;, &quot;D&quot;, &quot;L1.&quot;, &quot;L&quot;, &quot;L.&quot;)</td>
</tr>
<tr>
<td>CHMsimpl, CHMsimpl</td>
<td>c(&quot;P1&quot;, &quot;P1.&quot;, &quot;L1&quot;, &quot;D&quot;, &quot;L1.&quot;, &quot;L&quot;, &quot;L.&quot;)</td>
</tr>
</tbody>
</table>

Methods for expand2 and expand are described below. Factor names and classes apply also to expand1.

expand2 signature\((x = \text{"CHMsimpl"})\): expands the factorization \(A = P_1^T L_1 D L_1^T P_1 = P_1^T L L' P_1\) as \text{list(P1., L1, D, L1., P1)} (the default) or as \text{list(P1., L1., L, P1)}, depending on optional logical argument LDL. \(P_1\) and \(P_1\) are \texttt{pMatrix}, \texttt{L1}, \texttt{L1.}, \texttt{L}, and \(\texttt{L}\) are \texttt{dtCMatrix}, and \(D\) is a \texttt{ddiMatrix}.

expand2 signature\((x = \text{"CHMsuper"})\): as CHMsimpl, but the triangular factors are stored as \texttt{dgCMatrix}.

expand2 signature\((x = \text{"p?Cholesky"})\): expands the factorization \(A = L_1 D L_1' = L L'\) as \text{list(L1, D, L1.)} (the default) or as \text{list(L, L.)}, depending on optional logical argument LDL. \(L_1\), \texttt{L1.}, \texttt{L}, and \(\texttt{L}\) are \texttt{dtrMatrix} or \texttt{dtpMatrix}, and \(D\) is a \texttt{ddiMatrix}.

expand2 signature\((x = \text{"p?BunchKaufman"})\): expands the factorization \(A = U D U' = L D L'\) where \(U = \bigotimes_{k=1}^{b_U} P_k U_k\) and \(L = \bigotimes_{k=1}^{b_L} P_k L_k\) as \text{list(U, DU, U.)} or \text{list(L, DL, L.)}, depending on \texttt{x@uplo}. If optional argument complete is \texttt{TRUE}, then an unnamed list giving the full expansion with \(2b_U + 1\) or \(2b_L + 1\) matrix factors is returned instead. \(P_k\) are represented...
as `pMatrix`. $U_k$ and $L_k$ are represented as `dtCMatrix`, and $D_U$ and $D_L$ are represented as `dsCMatrix`.

**expand2 signature**($x = \text{"Schur"}$): expands the factorization $A = QTQ'$ as `list(Q, T, Q.)`. $Q$ and $Q.$ are $x@Q$ and $t(x@Q)$ modulo Dimnames, and $T$ is $x@T$.

**expand2 signature**($x = \text{"sparseLU"}$): expands the factorization $A = P_1^T L U P_2$ as `list(P1., L, U, P2.)`. $P_1.$ and $P_2.$ are `pMatrix`, and $L$ and $U$ are `dtCMatrix`.

**expand2 signature**($x = \text{"denseLU"}$): expands the factorization $A = P_1^T L U$ as `list(P1., L, U)`. $P_1.$ is a `pMatrix`, and $L$ and $U$ are `dtrMatrix` if square and `dgeMatrix` otherwise.

**expand2 signature**($x = \text{"sparseQR"}$): expands the factorization $A = P_1^T Q R P_2$ as `list(P1., Q, R, P2.)` or `list(P1., Q1, R1, P2.)` depending on optional logical argument `complete`. $P_1.$ and $P_2.$ are `pMatrix`, $Q$ and $Q1$ are `dgeMatrix`, $R$ is a `dgCMatrix`, and $R1$ is a `dtCMatrix`.

**expand signature**($x = \text{"CHMfactor"}$): as `expand2`, but returning `list(P, L)`.

`expand(x)[[\"P\"]` and `expand2(x)[[\"P1\"]` represent the same permutation matrix $P_1$ but have opposite margin slots and inverted perm slots. The components of `expand(x)` do not preserve $x@\text{Dimnames}$.

**expand signature**($x = \text{"sparseLU"}$): as `expand2`, but returning `list(P, L, U, Q)`.

`expand(x)[[\"Q\"]` and `expand2(x)[[\"P2\"]` represent the same permutation matrix $P_2$ but have opposite margin slots and inverted perm slots. `expand(x)[[\"P\"]` represents the permutation matrix $P_1$ rather than its transpose $P_1'$; it is `expand2(x)[[\"P1\"]` with an inverted perm slot. `expand(x)[[\"L\"]` and `expand2(x)[[\"L\"]` represent the same unit lower triangular matrix $L$, but with diag slot equal to "N" and "U", respectively. `expand(x)[[\"L\"]` and `expand(x)[[\"U\"]` store the permuted first and second components of $x@\text{Dimnames}$ in their Dimnames slots.

**expand signature**($x = \text{"denseLU"}$): as `expand2`, but returning `list(L, U, P)`.

`expand(x)[[\"P\"]` and `expand2(x)[[\"P1\"]` are identical modulo Dimnames. The components of `expand(x)` do not preserve $x@\text{Dimnames}$.

**See Also**

The virtual class `compMatrix` of factorizable matrices.

The virtual class `MatrixFactorization` of matrix factorizations.

Generic functions `Cholesky`, `BunchKaufman`, `Schur`, `lu`, and `qr` for computing factorizations.

**Examples**

```r
showMethods("expand1", inherited = FALSE)
showMethods("expand2", inherited = FALSE)
set.seed(0)

(A <- Matrix(rnorm(9L, 0, 10), 3L, 3L))
(lu.A <- lu(A))
(e.lu.A <- expand2(lu.A))
stopifnot(exprs = {
  is.list(e.lu.A)
  identical(names(e.lu.A), c("P1.", "L", "U"))
  all(sapply(e.lu.A, is, "Matrix"))
  all.equal(as(A, "matrix"), as(Reduce("%*%", e.lu.A), "matrix"))
})
```
expm-methods

Matrix Exponential

Description

Compute the exponential of a matrix.

Usage

expm(x)

Arguments

x

a matrix, typically inheriting from the dMatrix class.

Details

The exponential of a matrix is defined as the infinite Taylor series $\expm(A) = I + A + A^2/2! + A^3/3! + \ldots$ (although this is definitely not the way to compute it). The method for the dgeMatrix class uses Ward's diagonal Padé approximation with three step preconditioning, a recommendation from Moler & Van Loan (1978) "Nineteen dubious ways... ."

Value

The matrix exponential of x.

Author(s)

This is a translation of the implementation of the corresponding Octave function contributed to the Octave project by A. Scottedward Hodel <A.S.Hodel@Eng.Auburn.EDU>. A bug in there has been fixed by Martin Maechler.
References

https://en.wikipedia.org/wiki/Matrix_exponential


for historical reference mostly:


See Also

Package **expm**, which provides newer (in some cases faster, more accurate) algorithms for computing the matrix exponential via its own (non-generic) function `expm()`. **expm** also implements `logm()`, `sqrtm()`, etc.

Generic function **Schur**.

Examples

```r
(m1 <- Matrix(c(1,0,1,1), ncol = 2))
(e1 <- expm(m1)) ; e <- exp(1)
stopifnot(all.equal(e1@x, c(e,0,e,e), tolerance = 1e-15))
(m2 <- Matrix(c(-49, -64, 24, 31), ncol = 2))
(e2 <- expm(m2))
(m3 <- Matrix(cbind(0,rbind(6*diag(3),0)))# sparse!
(e3 <- expm(m3)) # upper triangular
```

---

**externalFormats**

*Read and write external matrix formats*

**Description**

Read matrices stored in the Harwell-Boeing or MatrixMarket formats or write `sparseMatrix` objects to one of these formats.

**Usage**

```r
readHB(file)
readMM(file)
writeMM(obj, file, ...)
```
Arguments

obj       a real sparse matrix
file     for writeMM - the name of the file to be written. For readHB and readMM the
          name of the file to read, as a character scalar. The names of files storing matrices
          in the Harwell-Boeing format usually end in ".rua" or ".rsa". Those storing
          matrices in the MatrixMarket format usually end in ".mtx".
          Alternatively, readHB and readMM accept connection objects.
...       optional additional arguments. Currently none are used in any methods.

Value

The readHB and readMM functions return an object that inherits from the "Matrix" class. Methods
for the writeMM generic functions usually return NULL and, as a side effect, the matrix obj is written
to file in the MatrixMarket format (writeMM).

Note

The Harwell-Boeing format is older and less flexible than the MatrixMarket format. The function
writeHB was deprecated and has now been removed. Please use writeMM instead.
Note that these formats do not know anything about dimnames, hence these are dropped by writeMM().

A very simple way to export small sparse matrices S, is to use summary(S) which returns a data.frame
with columns i, j, and possibly x, see summary in sparseMatrix-class, and an example below.

References

https://math.nist.gov/MatrixMarket/
https://sparse.tamu.edu/

Examples

str(pores <- readMM(system.file("external/pores_1.mtx", package = "Matrix")))
str(utm <- readHB(system.file("external/utm300.rua", package = "Matrix")))
str(lundA <- readMM(system.file("external/lund_a.mtx", package = "Matrix")))
str(lundA <- readHB(system.file("external/lund_a.rsa", package = "Matrix")))
## https://math.nist.gov/MatrixMarket/data/Harwell-Boeing/counterx/counterx.htm
str(jgl <- readMM(system.file("external/jgl009.mtx", package = "Matrix")))

## NOTE: The following examples take quite some time
## ---- even on a fast internet connection:
if(FALSE) {
## The URL has been corrected, but we need an untar step:
u. <- url("https://www.cise.ufl.edu/research/sparse/RB/Boeing/msc00726.tar.gz")
str(sm <- readHB(gzcon(u.)))
}

data(KNex, package = "Matrix")
## Store as MatrixMarket (".mtx") file, here inside temporary dir./folder:
(MMfile <- file.path(tempdir(), "mmMM.mtx"))
writeMM(KNex$mm, file=MMfile)  
file.info(MMfile)[,c("size", "ctime")] # (some confirmation of the file's)

## very simple export - in triplet format - to text file:
data(CAex, package = "Matrix")  
s.CA <- summary(CAex)  
s.CA # shows (i, j, x) [columns of a data frame]  
message("writing to ", outf <- tempfile())  
write.table(s.CA, file = outf, row.names=FALSE)  
## and read it back -- showing off sparseMatrix():  
str(dd <- read.table(outf, header=TRUE))  
## has columns (i, j, x) -> we can use via do.call() as arguments to sparseMatrix():  
mm <- do.call(sparseMatrix, dd)  
stopifnot(all.equal(mm, CAex, tolerance=1e-15))

facmul-methods

Multiplication by Factors from Matrix Factorizations

Description

Multiplies a matrix or vector on the left or right by a factor from a matrix factorization or its transpose.

Usage

facmul(x, factor, y, trans = FALSE, left = TRUE, ...)

Arguments

x

a MatrixFactorization object.

factor

a character string indicating a factor in the factorization represented by x, typically an element of names(expand2(x, ...)).

y

a matrix or vector to be multiplied on the left or right by the factor or its transpose.

trans

a logical indicating if the transpose of the factor should be used, rather than the factor itself.

left

a logical indicating if the y should be multiplied on the left by the factor, rather than on the right.

...

further arguments passed to or from methods.

Details

facmul is experimental and currently no methods are exported from Matrix.

Value

The value of op(M) %*% y or y %*% op(M), depending on left, where M is the factor (always without dimnames) and op(M) is M or t(M), depending on trans.
Examples

```r
## Conceptually, methods for `facmul` _would_ behave as follows ...
## Not run:
n <- 3L
x <- lu(Matrix(rnorm(n * n), n, n))
y <- rnorm(n)
L <- unname(expand2(x)[[nm <- "L"]])
stopifnot(exprs = {
  all.equal(facmul(x, nm, y, trans = FALSE, left = TRUE), L %*% y)
  all.equal(facmul(x, nm, y, trans = FALSE, left = FALSE), y %*% L)
  all.equal(facmul(x, nm, y, trans = TRUE, left = TRUE), crossprod(L, y))
  all.equal(facmul(x, nm, y, trans = TRUE, left = FALSE), tcrossprod(y, L))
})
## End(Not run)
```

---

fastMisc

"Low Level" Coercions and Methods

Description

"Semi-API" functions used internally by Matrix, often to bypass S4 dispatch and avoid the associated overhead. These are exported to provide this capability to expert users. Typical users should continue to rely on S4 generic functions to dispatch suitable methods, by calling, e.g., `as(., <class>)` for coercions.

Usage

```
.M2kind(from, kind = ".", sparse = NA)
.M2gen(from, kind = ".")
.M2sym(from, ...)
.M2tri(from, ...)
.M2diag(from)

.M2v(from)
.M2m(from)
.M2unpacked(from)
.M2packed(from)
.M2C(from)
.M2R(from)
.M2T(from)

.sparse2dense(from, packed = FALSE)
.diag2dense(from, shape = "t", packed = FALSE, uplo = "U")
.ind2dense(from, kind = "n")
.m2dense(from, class, uplo = "U", diag = "N")
```
`.dense2sparse(from, repr = "C")`
`.diag2sparse(from, shape = "t", repr = "C", uplo = "U")`
`.ind2sparse(from, kind = "n", repr = ".")`
`.m2sparse(from, class, uplo = "U", diag = "N")`

`.tCRT(x, lazy = TRUE)`
`.diag.dsC(x, Chx = Cholesky(x, LDL = TRUE), res.kind = "diag")`

`.solve.dgC.lu (a, b, tol = .Machine$double.eps, check = TRUE)`
`.solve.dgC.qr (a, b, order = 3L, check = TRUE)`
`.solve.dgC.chol(a, b, check = TRUE)`

`.updateCHMfactor(object, parent, mult = 0)`

**Arguments**

*from, x, a, b*  
a Matrix, matrix, or vector.

*kind*  
a string (".", "n", "l", or "d") specifying the "kind" of the result. "." indicates that the kind of from should be preserved. "n" indicates that the result should inherit from `nMatrix` (and so on).

*shape*  
a string (".", "g", "s", or "t") specifying the "shape" of the result. "." indicates that the shape of from should be preserved. "g" indicates that the result should inherit from `generalMatrix` (and so on).

*repr*  
a string (".", "C", "R", or "T") specifying the sparse representation of the result. "." is accepted only by `.ind2sparse` and indicates the most efficient representation, which is "C" ("R") for margin = 2 (1). "C" indicates that the result should inherit from `CsparseMatrix` (and so on).

*packed*  
a logical indicating if the result should inherit from `packedMatrix` rather than from `unpackedMatrix`. It is ignored for `from` inheriting from `generalMatrix`.

*sparse*  
a logical indicating if the result should inherit from `sparseMatrix` rather than from `denseMatrix`. If NA, then the result will be formally sparse if and only if `from` is.

*uplo*  
a string ("U" or "L") indicating whether the result (if symmetric or triangular) should store the upper or lower triangle of `from`. The elements of `from` in the opposite triangle are ignored.

*diag*  
a string ("N" or "U") indicating whether the result (if triangular) should be formally nonunit or unit triangular. In the unit triangular case, the diagonal elements of `from` are ignored.

*class*  
a string whose first three characters specify the class of the result. It should match the pattern "^[.nld](ge|sy|tr|sp|tp)" for `m2dense` and "^[.nld][gst][CRT]" for `m2sparse`, where "." in the first position is equivalent to "l" for logical arguments and "d" for numeric arguments.

*...*  
optional arguments passed to `isSymmetric` or `isTriangular`.
lazy

a logical indicating if the transpose should be constructed with minimal allocation, but possibly without preserving representation.

Chx

optionally, the Cholesky(x, ...) factorization of x. If supplied, then x is unused.

res.kind

a string in c("trace", "sumLog", "prod", "min", "max", "range", "diag", "diagBack").

tol

see lu-methods.

order

see qr-methods.

check

a logical indicating if the first argument should be tested for inheritance from dgCMatrix and coerced if necessary. Set to FALSE for speed only if it is known to already inherit from dgCMatrix.

object

a Cholesky factorization inheriting from virtual class CHMfactor, almost always the result of a call to generic function Cholesky.

parent

an object of class dsCMatrix or class dgCMatrix.

mult

a numeric vector of positive length. Only the first element is used, and that must be finite.

Details

Functions with names of the form .<A>2<B> implement coercions from virtual class A to the “nearest” non-virtual subclass of virtual class B, where the virtual classes are abbreviated as follows:

M Matrix m matrix or vector v vector dense denseMatrix unpacked unpackedMatrix packed packedMatrix sparse CsparseMatrix, RsparseMatrix, or TsparseMatrix C CsparseMatrix R RsparseMatrix T T sparse Matrix gen generalMatrix sym symmetricMatrix tri triangularMatrix diag diagonalMatrix ind indMatrix

Abbreviations should be seen as a guide, rather than as an exact description of behaviour. For example, .m2dense and .m2sparse accept vectors in addition to matrices.

.tCRT(x): If lazy = TRUE, then .tCRT constructs the transpose of x using the most efficient representation, which for ‘CRT’ is ‘RCT’. If lazy = FALSE, then .tCRT preserves the representation of x, behaving as the corresponding methods for generic function t.
.diag.dsC(x): \text{.diag.dsC computes (or uses if Chx is supplied) the Cholesky factorization of} x \text{ as } LDL' \text{ in order to calculate one of several possible statistics from the diagonal entries of } D. \text{ See res.kind under 'Arguments'.}

.solve.dgC.(a, b): \text{.solve.dgC.lu(a, b) needs a square matrix } a. \text{ .solve.dgC.qr(a, b) needs a "long" matrix } a, \text{ with nrow(a) } \geq \text{ ncol(a). .solve.dgC.chol(a, b) needs a "wide" matrix } a, \text{ with nrow(a) } \leq \text{ ncol(a).}

\text{All three may be used to solve sparse linear systems directly. Only .solve.dgC.qr and .solve.dgC.chol be used to solve sparse least squares problems.}

.updateCHMfactor(object, parent, mult): \text{.updateCHMfactor updates object with the result of Cholesky factorizing } F(parent) + \text{mult[1] * diag(nrow(parent))}, i.e., F(parent) \text{ plus mult[1] times the identity matrix, where } F = \text{identity if parent is a dsCMatrix and } F = \text{tcrossprod if parent is a dgCMatrix. The nonzero pattern of } F(parent) \text{ must match that of } S \text{ if object = Cholesky(S, ...).}

\textbf{Examples}

\begin{verbatim}
D. <- diag(x = c(1, 1, 2, 3, 5, 8))
D.0 <- Diagonal(x = c(0, 0, 0, 3, 5, 8))
S. <- toeplitz(as.double(1:6))
C. <- new("dgCMatrix", Dim = c(3L, 4L),
p = c(0L, 1L, 1L, 1L, 3L), i = c(1L, 0L, 2L), x = c(-8, 2, 3))
stopifnot(exprs = {
  identical(.M2tri (D.), as(D., "triangularMatrix"))
  identical(.M2sym (D.), as(D., "symmetricMatrix"))
  identical(.M2diag(D.), as(D., "diagonalMatrix"))
  identical(.M2kind(C., "l"),
    as(C., "LMatrix"))
  identical(.M2kind(.sparse2dense(C.), "l"),
    as(as(C., "denseMatrix"), "lMatrix"))
  identical(.diag2sparse(D.0, "t", "C"),
    dense2sparse(.diag2dense(D.0, "t", TRUE), "C"))
  identical(.M2gen(.diag2dense(D.0, "s", FALSE)),
    .sparse2dense(.M2gen(.diag2sparse(D.0, "s", "T"))))
  identical(S.,
    .M2m(.m2sparse(S., ".sR")))
  identical(S. * lower.tri(S.) + diag(1, 6L),
    .M2m(.m2dense (S., ".tr", "L", "U")))
  identical(.M2R(C.), .M2R(.M2T(C.)))
  identical(.tCRT(C.), .M2R(t(C.)))
})

A <- tcrossprod(C.)/6 + Diagonal(3, 1/3); A[1,2] <- 3; A
stopifnot(exprs = {
  is.numeric( x. <- c(2.2, 0, -1.2 )
  all.equal(x., .solve.dgC.lu(A, c(1,0), check=FALSE))
  all.equal(x., .solve.dgC.qr(A, c(1,0), check=FALSE))
})
\end{verbatim}
## Solving sparse least squares:

\[
X \leftarrow \text{rbind}(A, \text{Diagonal}(3)) \quad \# \text{design matrix } X \text{ (for L.S.)}
\]

\[
Xt \leftarrow \text{t}(X) \quad \# \text{*transposed* } X \text{ (for L.S.)}
\]

\[
(y \leftarrow \text{drop}((\text{crossprod}(Xt, 1:3)) + c(-1,1)/1000) \# \text{small rand.err.}
\]

\[
\text{str}(\text{solveCh} <- \text{.solve.dgC.chol}(Xt, y, \text{check=FALSE})) \quad \# Xt \text{ *is* dgC.}
\]

\[
\text{stopifnot} (\text{exprs} = {
    \begin{align*}
    \text{all.equal}(\text{solveCh}\text{\$coef}, 1:3, \text{tol} = 1e-3) & \# \text{rel.err - 1e-4} \\
    \text{all.equal}(\text{solveCh}\text{\$coef}, \text{drop}(\text{solve}(\text{tcrossprod}(Xt), Xt \%\% y))) & \\
    \text{all.equal}(\text{solveCh}\text{\$coef}, \text{.solve.dgC.qr}(X, y, \text{check=FALSE})) & \\
    \end{align*}
})
\]

---

**forceSymmetric**-methods

### Force a Matrix to ‘symmetricMatrix’ Without Symmetry Checks

#### Description

Force a square matrix `x` to a `symmetricMatrix`, **without** a symmetry check as it would be applied for `as(x, "symmetricMatrix")`.

#### Usage

`forceSymmetric(x, uplo)`

#### Arguments

- `x` any square matrix (of numbers), either “"traditional"" (`matrix`) or inheriting from `Matrix`.
- `uplo` optional string, "U" or "L" indicating which “triangle” half of `x` should determine the result. The default is "U" unless `x` already has a `uplo` slot (i.e., when it is `symmetricMatrix`, or `triangularMatrix`), where the default will be `x@uplo`.

#### Value

a square matrix inheriting from class `symmetricMatrix`.

#### See Also

- `symmpart` for the symmetric part of a matrix, or the coercions `as(x, <symmetricMatrix class>)`.

#### Examples

### Hilbert matrix

\[
i \leftarrow 1:6
\]

\[
h6 \leftarrow 1/\text{outer}(i - 1L, i, "+")
\]

\[
sd <- \sqrt{\text{diag}(h6)}
\]

\[
hh <- \text{t}(h6/sd)/sd \quad \# \text{theoretically symmetric}
\]

\[
\text{isSymmetric}(hh, \text{tol=0}) \quad \# \text{FALSE; hence}
\]
try( as(hh, "symmetricMatrix") ) # fails, but this works fine:
H6 <- forceSymmetric(hh)

## result can be pretty surprising:
(M <- Matrix(1:36, 6))
forceSymmetric(M) # symmetric, hence very different in lower triangle
(tm <- tril(M))
forceSymmetric(tm)

formatSparseM

Formatting Sparse Numeric Matrices Utilities

Description

Utilities for formatting sparse numeric matrices in a flexible way. These functions are used by the format and print methods for sparse matrices and can be applied as well to standard R matrices. Note that all arguments but the first are optional.

formatSparseM() is the main “workhorse” of formatSpMatrix, the format method for sparse matrices.

.formatSparseSimple() is a simple helper function, also dealing with (short/empty) column names construction.

Usage

formatSparseM(x, zero.print = ".", align = c("fancy", "right"),
m = as(x,"matrix"), asLogical=FALSE, uniDiag=FALSE, digits=NULL, cx, iN0, dn = dimnames(m))

.formatSparseSimple(m, asLogical=FALSE, digits=NULL, col.names, note.dropping.colnames = TRUE, dn=dimnames(m))

Arguments

x an R object inheriting from class sparseMatrix.
zero.print character which should be used for structural zeroes. The default "." may occasionally be replaced by " " (blank); using "0" would look almost like print()ing of non-sparse matrices.
align a string specifying how the zero.print codes should be aligned, see formatSpMatrix.
m (optional) a (standard R) matrix version of x.
asLogical should the matrix be formatted as a logical matrix (or rather as a numeric one); mostly for formatSparseM().
uniDiag logical indicating if the diagonal entries of a sparse unit triangular or unit-diagonal matrix should be formatted as "I" instead of "1" (to emphasize that the 1's are "structural").
digits significant digits to use for printing, see `print.default`.
cx (optional) character matrix; a formatted version of x, still with strings such as 
"0.00" for the zeros.
iN0 (optional) integer vector, specifying the location of the non-zeroes of x.
col.names, `note.dropping.colnames` see `formatSpMatrix`.
dn `dimnames` to be used; a list (of length two) with row and column names (or NULL).

Value

a character matrix like cx, where the zeros have been replaced with (padded versions of) `zero.print`. As this is a dense matrix, do not use these functions for really large (really) sparse matrices!

Author(s)

Martin Maechler

See Also

`formatSpMatrix` which calls `formatSparseM()` and is the `format` method for sparse matrices. 
`printSpMatrix` which is used by the (typically implicitly called) `show` and `print` methods for sparse matrices.

Examples

```r
m <- suppressWarnings(matrix(c(0, 3.2, 0,0, 11,0,0,0,0,-7,0), 4,9))
fm <- formatSparseM(m)
noquote(fm)
## nice, but this is nicer (with "units" vertically aligned):
print(fm, quote=FALSE, right=TRUE)
## and "the same" as :
Matrix(m)

## align = "right" is cheaper --> the "." are not aligned:
noquote(f2 <- formatSparseM(m,align="r"))
stopifnot(f2 == fm | m == 0, dim(f2) == dim(m),
          (f2 == ".") == (m == 0))
```

---

generalMatrix-class

**Class** "generalMatrix" of General Matrices

Description

Virtual class of “general” matrices; i.e., matrices that do not have a known property such as symmetric, triangular, or diagonal.
Objects from the Class

A virtual Class: No objects may be created from it.

Slots

factors,
Dim,
Dimnames: all slots inherited from compMatrix; see its description.

Extends

Class "compMatrix", directly. Class "Matrix", by class "compMatrix".

See Also

Classes compMatrix, and the non-general virtual classes: symmetricMatrix, triangularMatrix, diagonalMatrix.

---

Hilbert Generate a Hilbert matrix

Description

Generate the n by n symmetric Hilbert matrix. Because these matrices are ill-conditioned for moderate to large n, they are often used for testing numerical linear algebra code.

Usage

Hilbert(n)

Arguments

n a non-negative integer.

Value

the n by n symmetric Hilbert matrix as a "dpoMatrix" object.

See Also

the class dpoMatrix

Examples

Hilbert(6)
Description

Methods for function image in package Matrix. An image of a matrix simply color codes all matrix entries and draws the $n \times m$ matrix using an $n \times m$ grid of (colored) rectangles.

The Matrix package image methods are based on levelplot() from package lattice; hence these methods return an “object” of class “trellis”, producing a graphic when (auto-) print()ed.

Usage

```r
## S4 method for signature 'dgTMatrix'
image(x,
    xlim = c(1, di[2]),
    ylim = c(di[1], 1), aspect = "iso",
    sub = sprintf("Dimensions: %d x %d", di[1], di[2]),
    xlab = "Column", ylab = "Row", cuts = 15,
    useRaster = FALSE,
    useAbs = NULL, colorkey = !useAbs,
    col.regions = NULL,
    lwd = NULL, border.col = NULL, ...)
```

Arguments

- **x**: a Matrix object, i.e., fulfilling is(x, "Matrix").
- **xlim, ylim**: x- and y-axis limits; may be used to “zoom into” matrix. Note that $x, y$ “feel reversed”: ylim is for the rows (= 1st index) and xlim for the columns (= 2nd index). For convenience, when the limits are integer valued, they are both extended by 0.5; also, ylim is always used decreasingly.
- **aspect**: aspect ratio specified as number (y/x) or string; see levelplot.
- **sub, xlab, ylab**: axis annotation with sensible defaults; see plot.default.
- **cuts**: number of levels the range of matrix values would be divided into.
- **useRaster**: logical indicating if raster graphics should be used (instead of the tradition rectangle vector drawing). If true, panel.levelplot.raster (from lattice package) is used, and the colorkey is also done via rasters, see also levelplot and possibly grid.raster.

Note that using raster graphics may often be faster, but can be slower, depending on the matrix dimensions and the graphics device (dimensions).

- **useAbs**: logical indicating if abs(x) should be shown; if TRUE, the former (implicit) default, the default col.regions will be grey colors (and no colorkey drawn). The default is FALSE unless the matrix has no negative entries.
colorkey  logical indicating if a color key aka `legend` should be produced. Default is to draw one, unless `useAbs` is true. You can also specify a list, see `levelplot`, such as `list(raster=TRUE)` in the case of rastering.

col.regions vector of gradually varying colors; see `levelplot`.

lwd (only used when `useRaster` is false:) non-negative number or NULL (default), specifying the line-width of the rectangles of each non-zero matrix entry (drawn by `grid.rect`). The default depends on the matrix dimension and the device size.

border.col color for the border of each rectangle. NA means no border is drawn. When NULL as by default, `border.col <- if(lwd < .01) NA else NULL` is used. Consider using an opaque color instead of NULL which corresponds to `grid::get.gpar("col")`.

... further arguments passed to methods and `levelplot`, notably `at` for specifying (possibly non equidistant) cut values for dividing the matrix values (superseding `cuts` above).

Value

as all `lattice` graphics functions, `image(<Matrix>)` returns a "trellis" object, effectively the result of `levelplot()`.

Methods

All methods currently end up calling the method for the `dgTMatrix` class. Use `showMethods(image)` to list them all.

See Also

`levelplot`, and `print.trellis` from package `lattice`.

Examples

```r
showMethods(image)  ## And if you want to see the method definitions:
showMethods(image, includeDefs = TRUE, inherited = FALSE)

data(CAex, package = "Matrix")
image(CAex, main = "image(CAex)") -> imgC; imgC
stopifnot(!is.null(img <- imgC$legend), is.list(img$right))  # failed for 2 days ..
image(CAex, useAbs=TRUE, main = "image(CAex, useAbs=TRUE)")

cCA <- Cholesky(crossprod(CAex), Imult = .01)
## See ?print.trellis --- place two image() plots side by side:
print(image(cCA, main="Cholesky(crossprod(CAex), Imult = .01)"),
split=c(x=1,y=1,nx=2, ny=1), more=TRUE)
print(image(cCA, useAbs=TRUE),
split=c(x=2,y=1,nx=2, ny=1))

data(USCounties, package = "Matrix")
image(USCounties)# huge
```
image(sign(USCounties))## just the pattern
   # how the result looks, may depend heavily on
   # the device, screen resolution, antialiasing etc
   # e.g. x11(type="Xlib") may show very differently than cairo-based

## Drawing borders around each rectangle;
   # again, viewing depends very much on the device:
image(USCounties[1:400,1:200], lwd=.1)
## Using (xlim,ylim) has advantage : matrix dimension and (col/row) indices:
image(USCounties, c(1,200), c(1,400), lwd=.1)
image(USCounties, c(1,200), c(1,200), lwd=.5)
image(USCounties, c(1,300), c(1,200), lwd=.01)
## These 3 are all equivalent :
(I1 <- image(USCounties, c(1,100), c(1,100), useAbs=FALSE))
I2 <- image(USCounties, c(1,100), c(1,100), useAbs=FALSE, border.col=NA)
I3 <- image(USCounties, c(1,100), c(1,100), useAbs=FALSE, lwd=2, border.col=NA)
stopifnot(all.equal(I1, I2, check.environment=FALSE),
         all.equal(I2, I3, check.environment=FALSE))
## using an opaque border color
image(USCounties, c(1,100), c(1,100), useAbs=FALSE, lwd=3, border.col = adjustcolor("skyblue", 1/2))

if(interactive() || nzchar(Sys.getenv("R_MATRIX_CHECK_EXTRA"))) {
   ## Using raster graphics: For PDF this would give a 77 MB file,
   ## however, for such a large matrix, this is typically considerably
   ## *slower* (than vector graphics rectangles) in most cases :
   if(doPNG <- !dev.interactive())
      png("image-USCounties-raster.png", width=3200, height=3200)
   image(USCounties, useRaster = TRUE) # should not suffer from anti-aliasing
   if(doPNG)
      dev.off()
   ## and now look at the *.png image in a viewer you can easily zoom in and out
}#only if(doExtras)

---

## index-class

Virtual Class "index" - Simple Class for Matrix Indices

**Description**

The class "index" is a virtual class used for indices (in signatures) for matrix indexing and sub-assignment of Matrix matrices.

In fact, it is currently implemented as a simple class union (setClassUnion) of "numeric", "logical" and "character".

**Objects from the Class**

Since it is a virtual Class, no objects may be created from it.

**See Also**

[-methods, and
Subassign-methods, also for examples.]
Examples

```r
showClass("index")
```

### Description

The `indMatrix` class is the class of row and column index matrices, stored as 1-based integer index vectors. A row (column) index matrix is a matrix whose rows (columns) are standard unit vectors. Such matrices are useful when mapping observations to discrete sets of covariate values.

Multiplying a matrix on the left by a row index matrix is equivalent to indexing its rows, i.e., sampling the rows “with replacement”. Analogously, multiplying a matrix on the right by a column index matrix is equivalent to indexing its columns. Indeed, such products are implemented in `Matrix` as indexing operations; see ‘Details’ below.

A matrix whose rows and columns are standard unit vectors is called a permutation matrix. This special case is designated by the `pMatrix` class, a direct subclass of `indMatrix`.

### Details

The transpose of an index matrix is an index matrix with identical `perm` but opposite `margin`. Hence the transpose of a row index matrix is a column index matrix, and vice versa.

The cross product of a row index matrix `R` and itself is a diagonal matrix whose diagonal entries are the number of entries in each column of `R`.

Given a row index matrix `R` with `perm` slot `p`, a column index matrix `C` with `perm` slot `q`, and a matrix `M` with conformable dimensions, we have

\[
RM = R \times M = M[p, ]
\]

\[
MC = M \times C = M[, q]
\]

\[
C' M = \text{crossprod}(C, M) = M[q, ]
\]

\[
MR' = \text{tcrossprod}(M, R) = M[, p]
\]

\[
R'R = \text{crossprod}(R) = \text{Diagonal}(x=\text{tabulate}(p, \text{ncol}(R)))
\]

\[
CC' = \text{tcrossprod}(C) = \text{Diagonal}(x=\text{tabulate}(q, \text{nrow}(C)))
\]

Operations on index matrices that result in index matrices will accordingly return an `indMatrix`. These include products of two column index matrices and (equivalently) column-indexing of a column index matrix (when dimensions are not dropped). Most other operations on `indMatrix` treat them as sparse nonzero pattern matrices (i.e., inheriting from virtual class `nsparseMatrix`). Hence vector-valued subsets of `indMatrix`, such as those given by `diag`, are always of type "logical".

### Objects from the Class

Objects can be created explicitly with calls of the form `new("indMatrix", ...)`, but they are more commonly created by coercing 1-based integer index vectors, with calls of the form `as(. , "indMatrix")`; see ‘Methods’ below.
Slots

margin an integer, either 1 or 2, specifying whether the matrix is a row (1) or column (2) index.

perm a 1-based integer index vector, i.e., a vector of length Dim[margin] with elements taken from 1:Dim[1+margin%%2].

Dim,Dimnames inherited from virtual superclass Matrix.

Extends

Classes "sparseMatrix" and "generalMatrix", directly.

Methods

%*% signature(x = "indMatrix", y = "Matrix") and others listed by showMethods("%*%", classes = "indMatrix"): matrix products implemented where appropriate as indexing operations.

coerce signature(from = "numeric", to = "indMatrix"): supporting typical indMatrix construction from a vector of positive integers. Row indexing is assumed.

coerce signature(from = "list", to = "indMatrix"): supporting indMatrix construction for row and column indexing, including index vectors of length 0 and index vectors whose maximum is less than the number of rows or columns being indexed.

coerce signature(from = "indMatrix", to = "matrix"): coercion to a traditional matrix of logical type, with FALSE and TRUE in place of 0 and 1.

t signature(x = "indMatrix"): the transpose, which is an indMatrix with identical perm but opposite margin.

rowSums,rowMeans, colSums, colMeans signature(x = "indMatrix"): row and column sums and means.

rbind2,cbind2 signature(x = "indMatrix", y = "indMatrix"): row-wise catenation of two row index matrices with equal numbers of columns and column-wise catenation of two column index matrices with equal numbers of rows.

kronecker signature(X = "indMatrix", Y = "indMatrix"): Kronecker product of two row index matrices or two column index matrices, giving the row or column index matrix corresponding to their “interaction”.

Author(s)

Fabian Scheipl and Uni Muenchen, building on the existing class pMatrix after a nice hike’s conversation with Martin Maechler. Methods for crossprod(x, y) and kronecker(x, y) with both arguments inheriting from indMatrix were made considerably faster thanks to a suggestion by Boris Vaillant. Diverse tweaks by Martin Maechler and Mikael Jagan, notably the latter’s implementation of margin, prior to which the indMatrix class was designated only for row index matrices.

See Also

Subclass pMatrix of permutation matrices, a special case of index matrices; virtual class nMatrix of nonzero pattern matrices, and its subclasses.
Examples

```r
# Examples for invertPerm utility

p1 <- as(c(2,3,1), "pMatrix")
(sm1 <- as(rep(c(2,3,1), e=3), "indMatrix"))
stopifnot(all(sm1 == p1[rep(1:3, each=3),]))

## row-indexing of a <pMatrix> turns it into an <indMatrix>:
class(p1[rep(1:3, each=3),])

set.seed(12) # so we know '10' is in sample
## random index matrix for 30 observations and 10 unique values:
(s10 <- as(sample(1:10, 30, replace=TRUE), "indMatrix"))

## Sample rows of a numeric matrix:
(mm <- matrix(1:10, nrow=10, ncol=3))
s10 %*% mm

set.seed(27)
IM1 <- as(sample(1:20, 100, replace=TRUE), "indMatrix")
IM2 <- as(sample(1:18, 100, replace=TRUE), "indMatrix")
(c12 <- crossprod(IM1,IM2))
## same as cross-tabulation of the two index vectors:
stopifnot(all(c12 - unclass(table(IM1@perm, IM2@perm)) == 0))

# 3 observations, 4 implied values, first does not occur in sample:
as(2:4, "indMatrix")
# 3 observations, 5 values, first and last do not occur in sample:
as(list(2:4, 5), "indMatrix")

as(sm1, "nMatrix")
s10[1:7, 1:4] # gives an "ngTMatrix" (most economic!)
s10[1:4, ] # preserves "indMatrix"-class

I1 <- as(c(5:1,6:4:7:3), "indMatrix")
I2 <- as(7:1, "pMatrix")
(I12 <- rbind(I1, I2))
stopifnot(is(I12, "indMatrix"),
          identical(I12, rbind(I1, I2)),
          colSums(I12) == c(2L,2:4:4:2))
```

invertPerm

Utilities for Permutation Vectors

Description

invertPerm and signPerm compute the inverse and sign of a length-n permutation vector. isPerm tests if a length-n integer vector is a valid permutation vector. asPerm coerces a length-m transposition vector to a length-n permutation vector, where m <= n.
Usage

invertPerm(p, off = 1L, ioff = 1L)
signPerm(p, off = 1L)
isPerm(p, off = 1L)
asPerm(pivot, off = 1L, ioff = 1L, n = length(pivot))

invPerm(p, zero.p = FALSE, zero.res = FALSE)

Arguments

p an integer vector of length n.
pivot an integer vector of length m.
off an integer offset, indicating that p is a permutation of off+0:(n-1) or that pivot contains m values sampled with replacement from off+0:(n-1).
ioff an integer offset, indicating that the result should be a permutation of ioff+0:(n-1).
n a integer greater than or equal to m, indicating the length of the result. Transpositions are applied to a permutation vector vector initialized as seq_len(n).
zero.p a logical. Equivalent to off=0 if TRUE and off=1 if FALSE.
zero.res a logical. Equivalent to ioff=0 if TRUE and ioff=1 if FALSE.

Details

invertPerm(p, off, ioff=1) is equivalent to order(p) or sort.list(p) for all values of off. For the default value off=1, it returns the value of p after p[p] <- seq_along(p).

invPerm is a simple wrapper around invertPerm, retained for backwards compatibility.

Value

By default, i.e., with off=1 and ioff=1:

invertPerm(p) returns an integer vector of length length(p) such that p[invertPerm(p)] and invertPerm(p)[p] are both seq_along(p), i.e., the identity permutation.
signPerm(p) returns 1 if p is an even permutation and -1 otherwise (i.e., if p is odd).
isPerm(p) returns TRUE if p is a permutation of seq_along(p) and FALSE otherwise.
asPerm(pivot) returns the result of transposing elements i and pivot[i] of a permutation vector initialized as seq_len(n), for i in seq_along(pivot).

See Also

Class pMatrix of permutation matrices.

Examples

p <- sample(10L) # a random permutation vector
ip <- invertPerm(p)
s <- signPerm(p)
## 'p' and 'ip' are indeed inverses:

```r
stopifnot(exprs = {
  isPerm(p)
  isPerm(ip)
  identical(s, 1L) || identical(s, -1L)
  identical(s, signPerm(ip))
  identical(p[ip], 1:10)
  identical(ip[p], 1:10)
  identical(invertPerm(ip), p)
})
```

## Product of transpositions (1 2)(2 1)(4 3)(6 8)(10 1) = (3 4)(6 8)(1 10)

```r
pivot <- c(2L, 1L, 3L, 3L, 5L, 8L, 7L, 8L, 9L, 1L)
q <- asPerm(pivot)
stopifnot(exprs = {
  identical(q, c(10L, 2L, 4L, 3L, 5L, 8L, 7L, 6L, 9L, 1L))
  identical(q[q], seq_len(10L)) # because the permutation is odd:
  signPerm(q) == -1L
})
```

invPerm # a less general version of 'invertPerm'

---

### is.na-methods is.na(), is.finite() Methods for 'Matrix' Objects

#### Description

Methods for generic functions `is.na()`, `is.nan()`, `is.finite()`, `is.infinite()`, and `anyNA()`, for objects inheriting from virtual class `Matrix` or `sparseVector`.

#### Usage

```r
## S4 method for signature 'dsparseMatrix'
is.na(x)
## S4 method for signature 'dsparseMatrix'
is.nan(x)
## S4 method for signature 'dsparseMatrix'
is.finite(x)
## S4 method for signature 'dsparseMatrix'
is.infinite(x)
## S4 method for signature 'dsparseMatrix'
anyNA(x)
## ...  
## and for other classes
```

#### Arguments

- `x` an R object, here a sparse or dense matrix or vector.
Value

For `is.*()`, an `nMatrix` or `nsparseVector` matching the dimensions of `x` and specifying the positions in `x` of (some subset of) `NA`, `NaN`, `Inf`, and `-Inf`. For `anyNA()`, `TRUE` if `x` contains `NA` or `NaN` and `FALSE` otherwise.

See Also

`NA`, `NaN`, `Inf`

Examples

```r
(M <- Matrix(1:6, nrow = 4, ncol = 3,
             dimnames = list(letters[1:4], LETTERS[1:3])))
stopifnot(!anyNA(M), !any(is.na(M)))

M[2:3, 2] <- NA
(inM <- is.na(M))
stopifnot(anyNA(M), sum(inM) == 2)

(A <- spMatrix(nrow = 10, ncol = 20,
               i = c(1, 3:8), j = c(2, 9, 6:10), x = 7 * (1:7)))
stopifnot(!anyNA(A), !any(is.na(A)))

(inA <- is.na(A))
stopifnot(anyNA(A), sum(inA) == 1 + 1 + 5)
```

Description

Are the dimnames `dn` NULL-like?

`is.null.DN(dn)` is less strict than `is.null(dn)`, because it is also true (`TRUE`) when the dimnames `dn` are “like” NULL, or `list(NULL,NULL)`, as they can easily be for the traditional R matrices (`matrix`) which have no formal `class` definition, and hence much freedom in how their `dimnames` look like.

Usage

`is.null.DN(dn)`

Arguments

dn

dimnames() of a matrix-like R object.

Value

`logical` `TRUE` or `FALSE`.

Note

This function is really to be used on “traditional” matrices rather than those inheriting from `Matrix`, as the latter will always have `dimnames` `list(NULL, NULL)` exactly, in such a case.

Author(s)

Martin Maechler

See Also

`is.null`, `dimnames`, `matrix`.

Examples

```r
m1 <- m2 <- m3 <- m4 <- m <- matrix(round(100 * rnorm(6)), 2, 3)
dimnames(m1) <- list(NULL, NULL)
dimnames(m2) <- list(NULL, character())
dimnames(m3) <- rev(dimnames(m2))
dimnames(m4) <- rep(list(character()), 2)

m4 # prints absolutely identically to m

c.o <- capture.output
cm <- c.o(m)
stopifnot(exprs = {
  m == m1; m == m2; m == m3; m == m4
  identical(cm, c.o(m1)); identical(cm, c.o(m2))
  identical(cm, c.o(m3)); identical(cm, c.o(m4))
})

hasNoDimnames <- function(.) is.null.DN(dimnames(.))
stopifnot(exprs = {
  hasNoDimnames(m)
  hasNoDimnames(m1); hasNoDimnames(m2)
  hasNoDimnames(m3); hasNoDimnames(m4)
  hasNoDimnames(Matrix(m) -> M)
  hasNoDimnames(as(M, "sparseMatrix"))
})
```

Description

`isSymmetric` tests whether its argument is a symmetric square matrix, by default tolerating some numerical fuzz and requiring symmetric [dD]imnames in addition to symmetry in the mathematical sense. `isSymmetric` is a generic function in `base`, which has a `method` for traditional matrices.
of implicit class "matrix". Methods are defined here for various proper and virtual classes in Matrix, so that isSymmetric works for all objects inheriting from virtual class "Matrix".

Usage

## S4 method for signature 'symmetricMatrix'
isSymmetric(object, ...)
## S4 method for signature 'triangularMatrix'
isSymmetric(object, checkDN = TRUE, ...)
## S4 method for signature 'diagonalMatrix'
isSymmetric(object, checkDN = TRUE, ...)
## S4 method for signature 'indMatrix'
isSymmetric(object, checkDN = TRUE, ...)
## S4 method for signature 'dgeMatrix'
isSymmetric(object, tol = 100 * .Machine$double.eps, tol1 = 8 * tol, checkDN = TRUE, ...)
## S4 method for signature 'lgeMatrix'
isSymmetric(object, checkDN = TRUE, ...)
## S4 method for signature 'ngeMatrix'
isSymmetric(object, checkDN = TRUE, ...)
## S4 method for signature 'dgCMatrix'
isSymmetric(object, tol = 100 * .Machine$double.eps, checkDN = TRUE, ...)
## S4 method for signature 'lgCMatrix'
isSymmetric(object, checkDN = TRUE, ...)
## S4 method for signature 'ngCMatrix'
isSymmetric(object, checkDN = TRUE, ...)

Arguments

object a "Matrix".
tol, tol1 numerical tolerances allowing approximate symmetry of numeric (rather than logical) matrices. See also isSymmetric.matrix.
checkDN a logical indicating whether symmetry of the Dimnames slot of object should be checked.
... further arguments passed to methods (typically methods for all.equal).

Details

The Dimnames slot of object, say dn, is considered to be symmetric if and only if

- dn[[1]] and dn[[2]] are identical or one is NULL; and
- ndn <- names(dn) is NULL or ndn[1] and ndn[2] are identical or one is the empty string "".

Hence list(a=nms, a=nms) is considered to be symmetric, and so too are list(a=nms, NULL) and list(NULL, a=nms).

Note that this definition is looser than that employed by isSymmetric.matrix, which requires dn[1] and dn[2] to be identical, where dn is the dimnames attribute of a traditional matrix.
isTriangular-methods

Value

A logical, either TRUE or FALSE (never NA).

See Also

forceSymmetric; symmpart and skewpart; virtual class "symmetricMatrix" and its subclasses.

Examples

isSymmetric(Diagonal(4)) # TRUE of course
M <- Matrix(c(1,2,2,1), 2,2)
isSymmetric(M) # TRUE (*and* of formal class "dsyMatrix")
isSymmetric(as(M, "generalMatrix")) # still symmetric, even if not "formally"
isSymmetric(triu(M)) # FALSE

## Look at implementations:
showMethods("isSymmetric", includeDefs = TRUE) # includes S3 generic from base

---

**Description**

isTriangular and isDiagonal test whether their argument is a triangular or diagonal matrix, respectively. Unlike the analogous isSymmetric, these two functions are generically from Matrix rather than base. Hence Matrix defines methods for traditional matrices of implicit class "matrix" in addition to matrices inheriting from virtual class "Matrix".

By our definition, triangular and diagonal matrices are square, i.e., they have the same number of rows and columns.

**Usage**

isTriangular(object, upper = NA, ...)

isDiagonal(object)

**Arguments**

object an R object, typically a matrix.

upper a logical, either TRUE or FALSE, in which case TRUE is returned only for upper or lower triangular object; or otherwise NA (the default), in which case TRUE is returned for any triangular object.

... further arguments passed to methods (currently unused by Matrix).
Value

A logical, either TRUE or FALSE (never NA).

If object is triangular and upper is NA, then isTriangular returns TRUE with an attribute kind, either "U" or "L", indicating that object is upper or lower triangular, respectively. Users should not rely on how kind is determined for diagonal matrices, which are both upper and lower triangular.

See Also

isSymmetric; virtual classes "triangularMatrix" and "diagonalMatrix" and their subclasses.

Examples

isTriangular(Diagonal(4))
## is TRUE: a diagonal matrix is also (both upper and lower) triangular
(M <- Matrix(c(1,2,0,1), 2,2))
isTriangular(M) # TRUE (*and* of formal class "dtrMatrix")
isTriangular(as(M, "generalMatrix")) # still triangular, even if not "formally"
isTriangular(crossprod(M)) # FALSE

isDiagonal(matrix(c(2,0,0,1), 2,2)) # TRUE

## Look at implementations:
showMethods("isTriangular", includeDefs = TRUE)
showMethods("isDiagonal", includeDefs = TRUE)

KhatriRao
Khatri-Rao Matrix Product

Description

Computes Khatri-Rao products for any kind of matrices.

The Khatri-Rao product is a column-wise Kronecker product. Originally introduced by Khatri and Rao (1968), it has many different applications, see Liu and Trenkler (2008) for a survey. Notably, it is used in higher-dimensional tensor decompositions, see Bader and Kolda (2008).

Usage

KhatriRao(X, Y = X, FUN = "+", sparseY = TRUE, make.dimnames = FALSE)

Arguments

X, Y matrices of with the same number of columns.
FUN the (name of the) function to be used for the column-wise Kronecker products, see kronecker, defaulting to the usual multiplication.
sparseY logical specifying if Y should be coerced and treated as sparseMatrix. Set this to FALSE, e.g., to distinguish structural zeros from zero entries.
make.dimnames logical indicating if the result should inherit dimnames from X and Y in a simple way.
Value

a "\texttt{CsparseMatrix}\texttt{\textbackslash a\textbackslash n}" say \texttt{R}, the Khatri-Rao product of \(X (n \times k)\) and \(Y (m \times k)\), is of dimension \((n \cdot m) \times k\), where the \(j\)-th column, \(R[,j]\) is the kronecker product \texttt{kronecker}(\(X[,j]\), \(Y[,j]\)).

Note

The current implementation is efficient for large sparse matrices.

Author(s)

Original by Michael Cysouw, Univ. Marburg; minor tweaks, bug fixes etc, by Martin Maechler.

References


See Also

\texttt{kronecker}.

Examples

```r
## Example with very small matrices:
m <- matrix(1:12,3,4)
d <- diag(1:4)
KhatriRao(m,d)
KhatriRao(d,m)
dimnames(m) <- list(LETTERS[1:3], letters[1:4])
KhatriRao(m,d, make.dimnames=TRUE)
KhatriRao(d,m, make.dimnames=TRUE)
dimnames(d) <- list(NULL, paste0("D", 1:4))
KhatriRao(m,d, make.dimnames=TRUE)
KhatriRao(d,m, make.dimnames=TRUE)
dimnames(d) <- list(paste0("d", 10*1:4), paste0("D", 1:4))
(Kmd <- KhatriRao(m,d, make.dimnames=TRUE))
(Kdm <- KhatriRao(d,m, make.dimnames=TRUE))

nm <- as(m, "nsparseMatrix")
nd <- as(d, "nsparseMatrix")
KhatriRao(nm,nd, make.dimnames=TRUE)
KhatriRao(nd,nm, make.dimnames=TRUE)

stopifnot(dim(KhatriRao(m,d)) == c(nrow(m)*nrow(d), ncol(d)))
## border cases / checks:
zm <- nm; zm[] <- FALSE # all FALSE matrix
stopifnot(all(K1 <- KhatriRao(nd, zm) == 0), identical(dim(K1), c(12L, 4L)),
  all(K2 <- KhatriRao(zm, nd) == 0), identical(dim(K2), c(12L, 4L)))
```
d0 <- d; d0[] <- 0; m0 <- Matrix(d0[-1,])
stopifnot(all(K3 <- KhatriRao(d0, m) == 0), identical(dim(K3), dim(Kdm)),
  all(K4 <- KhatriRao(m, d0) == 0), identical(dim(K4), dim(Kmd)),
  all(KhatriRao(d0, d0) == 0), all(KhatriRao(m0, d0) == 0),
  all(KhatriRao(d0, m0) == 0), all(KhatriRao(m0, m0) == 0),
  identical(dimnames(KhatriRao(m, d0, make.dimnames=TRUE)), dimnames(Kmd)))

## a matrix with "structural" and non-structural zeros:
m01 <- new("dgCMatrix", i = c(0L, 2L, 0L, 1L), p = c(0L, 0L, 0L, 2L, 4L),
  Dim = 3:4, x = c(1, 0, 1, 0))
D4 <- Diagonal(4, x=1:4) # "as" d
DU <- Diagonal(4)# unit-diagonal: uplo="U"
K5 <- KhatriRao( d, m01))
K5d <- KhatriRao( d, m01, sparseY=FALSE)
K5Dd <- KhatriRao(D4, m01, sparseY=FALSE)
K5Ud <- KhatriRao(DU, m01, sparseY=FALSE)
(K6 <- KhatriRao(diag(3), t(m01)))
K6D <- KhatriRao(Diagonal(3), t(m01))
K6d <- KhatriRao(diag(3), t(m01), sparseY=FALSE)
K6Dd <- KhatriRao(Diagonal(3), t(m01), sparseY=FALSE)

## a matrix with "structural" and non-structural zeros:
m01 <- new("dgCMatrix", i = c(0L, 2L, 0L, 1L), p = c(0L, 0L, 0L, 2L, 4L),
  Dim = 3:4, x = c(1, 0, 1, 0))
D4 <- Diagonal(4, x=1:4) # "as" d
DU <- Diagonal(4)# unit-diagonal: uplo="U"
K5 <- KhatriRao( d, m01))
K5d <- KhatriRao( d, m01, sparseY=FALSE)
K5Dd <- KhatriRao(D4, m01, sparseY=FALSE)
K5Ud <- KhatriRao(DU, m01, sparseY=FALSE)
(K6 <- KhatriRao(diag(3), t(m01)))
K6D <- KhatriRao(Diagonal(3), t(m01))
K6d <- KhatriRao(diag(3), t(m01), sparseY=FALSE)
K6Dd <- KhatriRao(Diagonal(3), t(m01), sparseY=FALSE)

stopifnot(exprs = {
  all(K5 == K5d)
  identical(cbind(c(7L, 10L), c(3L, 4L)),
    which(K5 != 0, arr.ind = TRUE, useNames=FALSE))
  identical(K5d, K5Dd)
  identical(K6, K6D)
  all(K6 == K6d)
  identical(cbind(3:4, 1L),
    which(K6 != 0, arr.ind = TRUE, useNames=FALSE))
  identical(K6d, K6Dd)
})

---

**KNex**

**Koenker-Ng Example Sparse Model Matrix and Response Vector**

### Description

A model matrix mm and corresponding response vector y used in an example by Koenker and Ng. The matrix mm is a sparse matrix with 1850 rows and 712 columns but only 8758 non-zero entries. It is a "dgCMna" object. The vector y is just numeric of length 1850.

### Usage

```r
data(KNex)
```

### References

**Examples**

```r
data(KNex, package = "Matrix")
class(KNex$mm)
dim(KNex$mm)
image(KNex$mm)
str(KNex)

system.time( # a fraction of a second
  sparse.sol <- with(KNex, solve(crossprod(mm), crossprod(mm, y))))

head(round(sparse.sol,3))

## Compare with QR-based solution ("more accurate, but slightly slower"):

system.time(
  sp.sol2 <- with(KNex, qr.coef(qr(mm), y) ))

all.equal(sparse.sol, sp.sol2, tolerance = 1e-13) # TRUE
```

---

**Description**

Computes Kronecker products for objects inheriting from "Matrix".

In order to preserve sparseness, we treat 0 * NA as 0, not as NA as usually in R (and as used for the base function **kronecker**).

**Methods**

- `kronecker` signature(X = "Matrix", Y = "ANY") .......
- `kronecker` signature(X = "ANY", Y = "Matrix") .......
- `kronecker` signature(X = "diagonalMatrix", Y = "ANY") .......
- `kronecker` signature(X = "sparseMatrix", Y = "ANY") .......
- `kronecker` signature(X = "TsparseMatrix", Y = "TsparseMatrix") .......
- `kronecker` signature(X = "dgTMatrix", Y = "dgTMatrix") .......
- `kronecker` signature(X = "dtTMatrix", Y = "dtTMatrix") .......
- `kronecker` signature(X = "indMatrix", Y = "indMatrix") .......

**Examples**

```r
(t1 <- spMatrix(5,4, x= c(3,2,-7,11), i= 1:4, j=4:1)) # 5 x 4
(t2 <- kronecker(Diagonal(3, 2:4), t1)) # 15 x 12

## should also work with special-cased logical matrices
l3 <- upper.tri(matrix(,3,3))
```
ldenseMatrix-class

Virtual Class "ldenseMatrix" of Dense Logical Matrices

Description

ldenseMatrix is the virtual class of all dense logical (S4) matrices. It extends both denseMatrix and lMatrix directly.

Slots

x: logical vector containing the entries of the matrix.

Dim, Dimnames: see Matrix.

Extends

Class "lMatrix", directly. Class "denseMatrix", directly. Class "Matrix", by class "lMatrix". Class "Matrix", by class "denseMatrix".

Methods

as.vector signature(x = "ldenseMatrix", mode = "missing"): ...

which signature(x = "ndenseMatrix"), semantically equivalent to base function which(x, arr.ind); for details, see the lMatrix class documentation.

See Also

Class lgeMatrix and the other subclasses.

Examples

showClass("ldenseMatrix")

as(diag(3) > 0, "ldenseMatrix")
Description

The class "ldiMatrix" of logical diagonal matrices.

Objects from the Class

Objects can be created by calls of the form new("ldiMatrix", ...) but typically rather via Diagonal.

Slots

x: "logical" vector.

diag: "character" string, either "U" or "N", see ddiMatrix.

Dim, Dimnames: matrix dimension and dimnames, see the Matrix class description.

Extends

Class "diagonalMatrix" and class "lMatrix", directly.

Class "sparseMatrix", by class "diagonalMatrix".

See Also

Classes ddiMatrix and diagonalMatrix; function Diagonal.

Examples

(lM <- Diagonal(x = c(TRUE, FALSE, FALSE)))
str(lM)#> gory details (slots)

crossprod(lM) # numeric

(nM <- as(lM, "nMatrix"))# -> sparse (not formally \"diagonal\")
crossprod(nM) # logical sparse
**lgeMatrix-class**

Class "lgeMatrix" of General Dense Logical Matrices

Description

This is the class of general dense logical matrices.

Slots

- **x**: Object of class "logical". The logical values that constitute the matrix, stored in column-major order.
- **Dim, Dimnames**: The dimension (a length-2 "integer") and corresponding names (or NULL), see the Matrix class.
- **factors**: Object of class "list". A named list of factorizations that have been computed for the matrix.

Extends

Class "ldenseMatrix", directly. Class "lMatrix", by class "ldenseMatrix". Class "denseMatrix", by class "ldenseMatrix". Class "Matrix", by class "ldenseMatrix".

Methods

Currently, mainly `t()` and coercion methods (for `as(.)`); use, e.g., `showMethods(class="lgeMatrix")` for details.

See Also

Non-general logical dense matrix classes such as `ltrMatrix`, or `lsyMatrix`; sparse logical classes such as `lgCMatrix`.

Examples

```r
showClass("lgeMatrix")
str(new("lgeMatrix"))
set.seed(1)
(lM <- Matrix(matrix(rnorm(28), 4,7) > 0))# a simple random lgeMatrix
set.seed(11)
(lC <- Matrix(matrix(rnorm(28), 4,7) > 0))# a simple random lgCMatrix
as(lM, "CsparseMatrix")
```
Description

The `lsparseMatrix` class is a virtual class of sparse matrices with TRUE/FALSE or NA entries. Only the positions of the elements that are TRUE are stored.

These can be stored in the “triplet” form (class `TsparseMatrix`, subclasses `lgTMatrix`, `lsTMatrix`, and `ltTMatrix`) or in compressed column-oriented form (class `CsparseMatrix`, subclasses `lgCMatrix`, `lsCMatrix`, and `ltCMatrix`) or—rarely—in compressed row-oriented form (class `RsparseMatrix`, subclasses `lgRMatrix`, `lsRMatrix`, and `ltRMatrix`). The second letter in the name of these non-virtual classes indicates general, symmetric, or triangular.

Details

Note that triplet stored (`TsparseMatrix`) matrices such as `lgTMatrix` may contain duplicated pairs of indices \((i, j)\) as for the corresponding numeric class `dgTMatrix` where for such pairs, the corresponding \(x\) slot entries are added. For logical matrices, the \(x\) entries corresponding to duplicated index pairs \((i, j)\) are “added” as well if the addition is defined as logical or, i.e., “TRUE + TRUE |-> TRUE” and “TRUE + FALSE |-> TRUE”. Note the use of `uniqTsparse()` for getting an internally unique representation without duplicated \((i, j)\) entries.

Objects from the Class

Objects can be created by calls of the form `new("lgCMatrix", ...) and so on. More frequently objects are created by coercion of a numeric sparse matrix to the logical form, e.g. in an expression \(x != 0\).

The logical form is also used in the symbolic analysis phase of an algorithm involving sparse matrices. Such algorithms often involve two phases: a symbolic phase wherein the positions of the non-zeros in the result are determined and a numeric phase wherein the actual results are calculated. During the symbolic phase only the positions of the non-zero elements in any operands are of interest, hence any numeric sparse matrices can be treated as logical sparse matrices.

Slots

- `x`: Object of class "logical", i.e., either TRUE, NA, or FALSE.
- `uplo`: Object of class "character". Must be either "U", for upper triangular, and "L", for lower triangular. Present in the triangular and symmetric classes but not in the general class.
- `diag`: Object of class "character". Must be either "U", for unit triangular (diagonal is all ones), or "N" for non-unit. The implicit diagonal elements are not explicitly stored when `diag` is "U". Present in the triangular classes only.
- `p`: Object of class "integer" of pointers, one for each column (row), to the initial (zero-based) index of elements in the column. Present in compressed column-oriented and compressed row-oriented forms only.
i: Object of class "integer" of length nnzero (number of non-zero elements). These are the row numbers for each TRUE element in the matrix. All other elements are FALSE. Present in triplet and compressed column-oriented forms only.

j: Object of class "integer" of length nnzero (number of non-zero elements). These are the column numbers for each TRUE element in the matrix. All other elements are FALSE. Present in triplet and compressed row-oriented forms only.

Dim: Object of class "integer" - the dimensions of the matrix.

Methods

**coerce** signature(from = "dgCMatrix", to = "lgCMatrix")

**t** signature(x = "lgCMatrix"): returns the transpose of x

**which** signature(x = "lsparseMatrix"), semantically equivalent to base function which(x, arr.ind); for details, see the lMatrix class documentation.

See Also

the class dgCMatrix and dgTMatrix

Examples

```r
(m <- Matrix(c(0,0,2:0), 3,5, dimnames=list(LETTERS[1:3],NULL)))
(lm <- (m > 1)) # lgC
!lm # no longer sparse
stopifnot(is(lm,"lsparseMatrix"),
  identical(!lm, m <= 1))
```

```r
data(KNex, package = "Matrix")
str(mmG.1 <- (KNex $ mm) > 0.1)# "lgC..."
table(mmG.1@x)# however with many "non-structural zeros"
  ## from logical to nz_pattern -- okay when there are no NA's :
  nmG.1 <- as(mmG.1, "nMatrix") # <<< has "TRUE" also where mmG.1 had FALSE
  ## from logical to "double"
  dmG.1 <- as(mmG.1, "dMatrix") # has '0' and back:
  lmG.1 <- as(dmG.1, "lMatrix")
  stopifnot(identical(nmG.1, as((KNex $ mm) != 0,"nMatrix")),
    validObject(lmG.1),
    identical(lmG.1, mmG.1))
```

```r
class(xnx <- crossprod(nmG.1))# "nsC.."
class(xlx <- crossprod(mmG.1))# "dsC.." : numeric
is0 <- (xlx == 0)
mean(as.vector(is0))# 99.3% zeros: quite sparse, but
table(xlx@x == 0)# more than half of the entries are (non-structural!) 0
stopifnot(isSymmetric(xlx), isSymmetric(xnx),
  ## compare xnx and xlx : have the *same* non-structural 0s :
  sapply(slotNames(xnx),
    function(n) identical(slot(xnx, n), slot(xlx, n))))
```
lsyMatrix-class

Symmetric Dense Logical Matrices

Description

The "lsyMatrix" class is the class of symmetric, dense logical matrices in non-packed storage and "lspMatrix" is the class of these in packed storage. In the packed form, only the upper triangle or the lower triangle is stored.

Objects from the Class

Objects can be created by calls of the form new("lsyMatrix", ...).

Slots

- uplo: Object of class "character". Must be either "U", for upper triangular, and "L", for lower triangular.
- x: Object of class "logical". The logical values that constitute the matrix, stored in column-major order.
- Dim, Dimnames: The dimension (a length-2 "integer") and corresponding names (or NULL), see the Matrix class.
- factors: Object of class "list". A named list of factorizations that have been computed for the matrix.

Extends

Both extend classes "ldenseMatrix" and "symmetricMatrix", directly; further, class "Matrix" and others, indirectly. Use showClass("lsyMatrix"), e.g., for details.

Methods

Currently, mainly t() and coercion methods (for as(.); use, e.g., showMethods(class="lsyMatrix") for details.

See Also

lgeMatrix, Matrix, t

Examples

(M2 <- Matrix(c(TRUE, NA, FALSE, FALSE), 2, 2)) # logical dense (ltr)
str(M2)
# can
(sM <- M2 | t(M2)) # "lge"
as(sM, "symmetricMatrix")
str(sM <- as(sM, "packedMatrix")) # packed symmetric
Description

The "ltrMatrix" class is the class of triangular, dense, logical matrices in nonpacked storage. The "ltpMatrix" class is the same except in packed storage.

Slots

  x: Object of class "logical". The logical values that constitute the matrix, stored in column-major order.

  uplo: Object of class "character". Must be either "U", for upper triangular, and "L", for lower triangular.

  diag: Object of class "character". Must be either "U", for unit triangular (diagonal is all ones), or "N"; see triangularMatrix.

  Dim, Dimnames: The dimension (a length-2 "integer") and corresponding names (or NULL), see the Matrix class.

  factors: Object of class "list". A named list of factorizations that have been computed for the matrix.

Extends

  Both extend classes "ldenseMatrix" and "triangularMatrix", directly; further, class "Matrix", "lMatrix" and others, indirectly. Use showClass("ltrMatrix"), e.g., for details.

Methods

  Currently, mainly t() and coercion methods (for as(.)); use, e.g., showMethods(class="ltrMatrix") for details.

See Also

  Classes lgeMatrix, Matrix; function t

Examples

  showClass("ltrMatrix")

  str(new("ltpMatrix"))
  (lutr <- as(upper.tri(matrix(, 4, 4)), "ldenseMatrix"))
  str(lutp <- pack(lutr)) # packed matrix: only 10 = 4*(4+1)/2 entries
  !lutp # the logical negation (is *not* logical triangular !)
  ## but this one is:
  stopifnot(all.equal(lutp, pack(!!lutp)))
Methods for LU Factorization

**Description**

Computes the pivoted LU factorization of an $m \times n$ real matrix $A$, which has the general form

$$P_1 A P_2 = LU$$

or (equivalently)

$$A = P_1' L U P_2'$$

where $P_1$ is an $m \times m$ permutation matrix, $P_2$ is an $n \times n$ permutation matrix, $L$ is an $m \times \min(m, n)$ unit lower trapezoidal matrix, and $U$ is a $\min(m, n) \times n$ upper trapezoidal matrix.

Methods for `denseMatrix` are built on LAPACK routine `dgetrf`, which does not permute columns, so that $P_2$ is an identity matrix.

Methods for `sparseMatrix` are built on CSparse routine `cs_lu`, which requires $m = n$, so that $L$ and $U$ are triangular matrices.

**Usage**

```r
lu(x, ...) # S4 method for signature 'dgeMatrix'
lu(x, warnSing = TRUE, ...) # S4 method for signature 'dgCMatrix'
lu(x, errSing = TRUE, order = NA_integer_,
   tol = 1, ...)
lu(x, cache = TRUE, ...) # S4 method for signature 'dsyMatrix'
lu(x, cache = TRUE, ...) # S4 method for signature 'dsCMatrix'
lu(x, cache = TRUE, ...) # S4 method for signature 'matrix'
```

**Arguments**

- `x` a finite matrix or `Matrix` to be factorized, which must be square if sparse.
- `warnSing` a logical indicating if a warning should be signaled for singular `x`. Used only by methods for dense matrices.
- `errSing` a logical indicating if an error should be signaled for singular `x`. Used only by methods for sparse matrices.
- `order` an integer in 0:3 passed to CSparse routine `cs_sqr`, indicating a strategy for choosing the column permutation $P_2$. 0 means no column permutation. 1, 2, and 3 indicate a fill-reducing ordering of $A + A'$, $A' A$, and $A' A$, where $A$ is $A$ with “dense” rows removed. NA (the default) is equivalent to 2 if `tol` == 1 and 1 otherwise. Do not set to 0 unless you know that the column order of $A$ is already sensible.
tol a number. The original pivot element is used if its absolute value exceeds \( \text{tol} \times a \), where \( a \) is the maximum in absolute value of the other possible pivot elements. Set \( \text{tol} < 1 \) only if you know what you are doing.

cache a logical indicating if the result should be cached in \( x@factors[['LU']] \). Note that caching is experimental and that only methods for classes extending \texttt{compMatrix} will have this argument.

... further arguments passed to or from methods.

Details

What happens when \( x \) is determined to be near-singular differs by method. The method for class \texttt{dgeMatrix} completes the factorization, warning if \( \text{warnSing} = \text{TRUE} \) and in any case returning a valid \texttt{denseLU} object. Users of this method can detect singular \( x \) with a suitable warning handler; see \texttt{tryCatch}. In contrast, the method for class \texttt{dgCMatrix} abandons further computation, throwing an error if \( \text{errSing} = \text{TRUE} \) and otherwise returning \( \text{NA} \). Users of this method can detect singular \( x \) with an error handler or by setting \( \text{errSing} = \text{FALSE} \) and testing for a formal result with \texttt{is(., "sparseLU")}.

Value

An object representing the factorization, inheriting from virtual class \texttt{LU}. The specific class is \texttt{denseLU} unless \( x \) inherits from virtual class \texttt{sparseMatrix}, in which case it is \texttt{sparseLU}.

References

The LAPACK source code, including documentation; see https://netlib.org/lapack/double/dgetrf.f.


See Also

Classes \texttt{denseLU} and \texttt{sparseLU} and their methods.

Classes \texttt{dgeMatrix} and \texttt{dgCMatrix}.

Generic functions \texttt{expand1} and \texttt{expand2}, for constructing matrix factors from the result.

Generic functions \texttt{Cholesky}, \texttt{BunchKaufman}, \texttt{Schur}, and \texttt{qr}, for computing other factorizations.

Examples

```r
showMethods("lu", inherited = FALSE)
set.seed(0)

## ---- Dense ----------------------------------------------------------
(A1 <- Matrix(rnorm(9L), 3L, 3L))
```
(lu.A1 <- lu(A1))

(A2 <- round(10 * A1[, -3L]))
(1u.A2 <- 1u(A2))

## A ~ P1

str(e.lu.A2 <- expand2(lu.A2), max.level = 2L)
stopifnot(all.equal(A2, Reduce("%*%", e.lu.A2)))

## ---- Sparse ---------------------------------------------------------

A3 <- as(readMM(system.file("external/pores_1.mtx", package = "Matrix")), "CsparseMatrix")
(lu.A3 <- lu(A3))

## A ~ P1' L U P2' in floating point
str(e.lu.A3 <- expand2(lu.A3), max.level = 2L)
stopifnot(all.equal(A3, Reduce("%*%", e.lu.A3)))

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**mat2triplet**

Map Matrix to its Triplet Representation

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**Description**

From an **R** object coercible to "**TsparseMatrix**", typically a (sparse) matrix, produce its triplet representation which may collapse to a “Duplet” in the case of binary aka pattern, such as "**nMatrix**" objects.

**Usage**

`mat2triplet(x, uniqT = FALSE)`

**Arguments**

- **x**
  - any **R** object for which `as(x, "TsparseMatrix")` works; typically a **matrix** of one of the **Matrix** package matrices.
- **uniqT**
  - **logical** indicating if the triplet representation should be ‘unique’ in the sense of `uniqTsparse()`.

**Value**

A **list**, typically with three components,

- **i**
  - vector of row indices for all non-zero entries of **x**
- **j**
  - vector of columns indices for all non-zero entries of **x**
- **x**
  - vector of all non-zero entries of **x**; exists **only** when `as(x, "TsparseMatrix")` is **not** a "**nsparseMatrix**".

Note that the **order** of the entries is determined by the coercion to "**TsparseMatrix**" and hence typically with increasing **j** (and increasing **i** within ties of **j**).
Note

The mat2triplet() utility was created to be a more efficient and more predictable substitute for `summary(<sparseMatrix>)`. Users have wrongly expected the latter to return a data frame with columns `i` and `j` which however is wrong for a "diagonalMatrix".

See Also

The `summary()` method for "sparseMatrix", `summary,sparseMatrix-method`. `mat2triplet()` is conceptually the inverse function of `spMatrix` and (one case of) `sparseMatrix`.

Examples

```r
mat2triplet # simple definition
i <- c(1,3:8); j <- c(2,9,6:10); x <- 7 * (1:7)
(Ax <- sparseMatrix(i, j, x = x)) ## 8 x 10 "dgCMatrix"
str(trA <- mat2triplet(Ax))
stopifnot(i == sort(trA$i), sort(j) == trA$j, x == sort(trA$x))
D <- Diagonal(x=4:2)
summary(D)
str(mat2triplet(D))
```

Description

The basic matrix product, `%*%` is implemented for all our `Matrix` and also for `sparseVector` classes, fully analogously to R's base matrix and vector objects.

The functions `crossprod` and `tcrossprod` are matrix products or "cross products", ideally implemented efficiently without computing `t(.)`'s unnecessarily. They also return `symmetricMatrix` classed matrices when easily detectable, e.g., in `crossprod(m)`, the one argument case.

`tcrossprod()` takes the cross-product of the transpose of a matrix. `tcrossprod(x)` is formally equivalent to, but faster than, the call `x %*% t(x)`, and so is `tcrossprod(x, y)` instead of `x %*% t(y)`.  

Boolean matrix products are computed via either `%&%` or `boolArith = TRUE`.

Usage

```r
## S4 method for signature 'CsparseMatrix,diagonalMatrix'
x %*% y

## S4 method for signature 'dgeMatrix,missing'
```
crossprod(x, y = NULL, boolArith = NA, ...)
## S4 method for signature 'CsparseMatrix,diagonalMatrix'
crossprod(x, y = NULL, boolArith = NA, ...)
## .... and for many more signatures

tcrossprod(x, y = NULL, boolArith = NA, ...)
## S4 method for signature 'TsparseMatrix,missing'
tcrossprod(x, y = NULL, boolArith = NA, ...)
## .... and for many more signatures

Arguments

x
a matrix-like object

y
a matrix-like object, or for [t]crossprod() NULL (by default); the latter case is formally equivalent to y = x.

boolArith
logical, i.e., NA, TRUE, or FALSE. If true the result is (coerced to) a pattern matrix, i.e., "nMatrix", unless there are NA entries and the result will be a "lMatrix". If false the result is (coerced to) numeric. When NA, currently the default, the result is a pattern matrix when x and y are "nsparseMatrix" and numeric otherwise.

... potentially more arguments passed to and from methods.

Details

For some classes in the Matrix package, such as dgCMatrix, it is much faster to calculate the cross-product of the transpose directly instead of calculating the transpose first and then its cross-product. boolArith = TRUE for regular ("non cross") matrix products, ** cannot be specified. Instead, we provide the ** operator for boolean matrix products.

Value

A Matrix object, in the one argument case of an appropriate symmetric matrix class, i.e., inheriting from symmetricMatrix.

Methods

** signature(x = "dgeMatrix", y = "dgeMatrix"): Matrix multiplication; ditto for several other signature combinations, see showMethods("**", class = "dgeMatrix").

** signature(x = "dtrMatrix", y = "matrix") and other signatures (use showMethods("**", class="dtrMatrix"): matrix multiplication. Multiplication of (matching) triangular matrices now should remain triangular (in the sense of class triangularMatrix).

crossprod signature(x = "dgeMatrix", y = "dgeMatrix"): ditto for several other signatures, use showMethods("crossprod", class = "dgeMatrix"), matrix crossproduct, an efficient version of t(x) ** y.

crossprod signature(x = "CsparseMatrix", y = "missing") returns t(x) ** x as an dsCMatrix object.
crossprod signature(x = "TsparseMatrix", y = "missing") returns t(x) \times x as an dsCMatrix object.

crossprod, tcrossprod signature(x = "dtrMatrix", y = "matrix") and other signatures, see "\times\times" above.

Note

boolArith = TRUE, FALSE or NA has been newly introduced for Matrix 1.2.0 (March 2015). Its implementation has still not been tested extensively. Notably the behaviour for sparse matrices with x slots containing extra zeros had not been documented previously, see the \%\&\% help page.

Currently, boolArith = TRUE is implemented via CsparseMatrix coercions which may be quite inefficient for dense matrices. Contributions for efficiency improvements are welcome.

See Also
tcrossprod in R’s base, and crossprod and \%\times\%. Matrix package \%\&\% for boolean matrix product methods.

Examples

### A random sparse "incidence" matrix:
m <- matrix(0, 400, 500)
set.seed(12)
m[runif(314, 0, length(m))] <- 1
mm <- as(m, "C sparseMatrix")
object.size(m) / object.size(mm) # smaller by a factor of > 200

### tcrossprod() is very fast:
system.time(tCmm <- tcrossprod(mm)) # 0 (PIII, 933 MHz)
system.time(cm <- crossprod(t(m))) # 0.16
system.time(cm. <- tcrossprod(m)) # 0.02

stopifnot(cm == as(tCmm, "matrix"))

### show sparse sub matrix
tCmm[1:16, 1:30]
Matrix

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Arguments

data an optional numeric data vector or matrix.
nrow when data is not a matrix, the desired number of rows
ncol when data is not a matrix, the desired number of columns
byrow logical. If FALSE (the default) the matrix is filled by columns, otherwise the matrix is filled by rows.
dimnames a dimnames attribute for the matrix: a list of two character components. They are set if not NULL (as per default).
sparse logical or NULL, specifying if the result should be sparse or not. By default, it is made sparse when more than half of the entries are 0.
doDiag logical indicating if a diagonalMatrix object should be returned when the resulting matrix is diagonal (mathematically). As class diagonalMatrix extends sparseMatrix, this is a natural default for all values of sparse. Otherwise, if doDiag is false, a dense or sparse (depending on sparse) symmetric matrix will be returned.
forceCheck logical indicating if the checks for structure should even happen when data is already a "Matrix" object.

Details

If either of nrow or ncol is not given, an attempt is made to infer it from the length of data and the other parameter. Further, Matrix() makes efforts to keep logical matrices logical, i.e., inheriting from class lMatrix, and to determine specially structured matrices such as symmetric, triangular or diagonal ones. Note that a symmetric matrix also needs symmetric dimnames, e.g., by specifying dimnames = list(NULL,NULL), see the examples.

Most of the time, the function works via a traditional (full) matrix. However, Matrix(0, nrow, ncol) directly constructs an “empty” sparseMatrix, as does Matrix(FALSE, *).

Although it is sometime possible to mix unclassed matrices (created with matrix) with ones of class "Matrix", it is much safer to always use carefully constructed ones of class "Matrix".

Value

Returns matrix of a class that inherits from "Matrix". Only if data is not a matrix and does not already inherit from class Matrix are the arguments nrow, ncol and byrow made use of.

See Also

The classes Matrix, symmetricMatrix, triangularMatrix, and diagonalMatrix; further, matrix. Special matrices can be constructed, e.g., via sparseMatrix (sparse), bdiag (block-diagonal), bandSparse (banded sparse), or Diagonal.

Examples

Matrix(0, 3, 2) # 3 by 2 matrix of zeros -> sparse
Matrix(0, 3, 2, sparse=FALSE)# -> 'dense'
## 4 cases - 3 different results:
Matrix(0, 2, 2)  
# diagonal!
Matrix(0, 2, 2, sparse=FALSE)# (ditto)
Matrix(0, 2, 2, doDiag=FALSE)# -> sparse symm. "dsCMatrix"
Matrix(0, 2, 2, sparse=FALSE, doDiag=FALSE)# -> dense symm. "dsyMatrix"

Matrix(1:6, 3, 2)  
# a 3 by 2 matrix (+ integer warning)
Matrix(1:6 + 1, nrow=3)

## logical ones:
Matrix(diag(4) > 0) # -> "ldiMatrix" with diag = "U"
Matrix(diag(4) > 0, sparse=TRUE) # (ditto)
Matrix(diag(4) >= 0) # -> "lsyMatrix" (of all 'TRUE')

## triangular
l3 <- upper.tri(matrix(,3,3))
(M <- Matrix(l3))  
# -> "ltCMatrix"
Matrix(! l3)  
# -> "ltrMatrix"
as(l3, "CsparseMatrix")# "lgCMatrix"

Matrix(1:9, nrow=3,  
dimnames = list(c("a", "b", "c"), c("A", "B", "C")))
(I3 <- Matrix(diag(3)))# identity, i.e., unit "diagonalMatrix"
str(I3) # note 'diag = "U"' and the empty 'x' slot

(A <- cbind(a=c(2,1), b=1:2))# symmetric *apart* from dimnames
Matrix(A)  
# hence 'dgeMatrix'
(As <- Matrix(A, dimnames = list(NULL,NULL)))# -> symmetric
forceSymmetric(A) # also symmetric, w/ symm. dimnames
stopifnot(is(As, "symmetricMatrix"),  
is(Matrix(0, 3, 3), "sparseMatrix"),  
is(Matrix(FALSE, 1,1), "sparseMatrix"))

### Matrix-class

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**Virtual Class "Matrix" of Matrices**

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**Description**

The Matrix class is a class contained by all actual classes in the Matrix package. It is a “virtual” class.

**Slots**

- `Dim` an integer vector of length 2 giving the dimensions of the matrix.
- `Dimnames` a list of length 2. Each element must be NULL or a character vector of length equal to the corresponding element of `Dim`. 

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Methods

determinant signature(x = "Matrix", logarithm = "missing"): and
determinant signature(x = "Matrix", logarithm = "logical"): compute the (log) determinant of x. The method chosen depends on the actual Matrix class of x. Note that det also works for all our matrices, calling the appropriate determinant() method. The Matrix::det is an exact copy of base::det, but in the correct namespace, and hence calling the S4-aware version of determinant().

diff signature(x = "Matrix"): As diff() for traditional matrices, i.e., applying diff() to each column.

dim signature(x = "Matrix"): extract matrix dimensions dim.

dim<- signature(x = "Matrix", value = "ANY"): where value is integer of length 2. Allows to reshape Matrix objects, but only when prod(value) == prod(dim(x)).

dimnames signature(x = "Matrix"): extract dimnames.

dimnames<- signature(x = "Matrix", value = "list"): set the dimnames to a list of length 2, see dimnames<-

length signature(x = "Matrix"): simply defined as prod(dim(x)) (and hence of mode "double").

show signature(object = "Matrix"): show method for printing. For printing sparse matrices, see printSpMatrix.

image signature(object = "Matrix"): draws an image of the matrix entries, using levelplot() from package lattice.

head signature(object = "Matrix"): return only the “head”, i.e., the first few rows.

tail signature(object = "Matrix"): return only the “tail”, i.e., the last few rows of the respective matrix.

as.matrix, as.array signature(x = "Matrix"): the same as as(x, "matrix"); see also the note below.

as.vector signature(x = "Matrix", mode = "missing"): as.vector(m) should be identical to as.vector(as(m, "matrix")), implemented more efficiently for some subclasses.

as(x, "vector"), as(x, "numeric") etc, similarly.

coerce signature(from = "ANY", to = "Matrix"): This relies on a correct as.matrix() method for from.

There are many more methods that (conceptually should) work for all "Matrix" objects, e.g., colSums, rowMeans. Even base functions may work automagically (if they first call as.matrix() on their principal argument), e.g., apply, eigen, svd or kappa all do work via coercion to a “traditional” (dense) matrix.

Note

Loading the Matrix namespace “overloads” as.matrix and as.array in the base namespace by the equivalent of function(x) as(x, "matrix"). Consequently, as.matrix(m) or as.array(m) will properly work when m inherits from the "Matrix" class — also for functions in package base and other packages. E.g., apply or outer can therefore be applied to "Matrix" matrices.
Author(s)

Douglas Bates <bates@stat.wisc.edu> and Martin Maechler

See Also

the classes dgeMatrix, dgCMatrix, and function Matrix for construction (and examples).
Methods, e.g., for kronecker.

Examples

slotNames("Matrix")

cl <- getClass("Matrix")
names(cl@subclasses) # more than 40 ..

showClass("Matrix") #> output with slots and all subclasses

(M <- Matrix(c(0,1,0,0), 6, 4))
dim(M)
diag(M)
cm <- M[1:4,] + 10*Diagonal(4)
diff(M)
## can reshape it even :
dim(M) <- c(2, 12)
M
stopifnot(identical(M, Matrix(c(0,1,0,0), 2,12)),
  all.equal(det(cm),
    determinant(as(cm,"matrix"), log=FALSE)$modulus,
    check.attributes=FALSE))

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Virtual Classes Not Yet Really Implemented and Used

Description

iMatrix is the virtual class of all integer (S4) matrices. It extends the Matrix class directly.
zMatrix is the virtual class of all complex (S4) matrices. It extends the Matrix class directly.

Examples

showClass("iMatrix")
showClass("zMatrix")
MatrixClass

The Matrix (Super-) Class of a Class

Description

Return the (maybe super-)class of class cl from package Matrix, returning character(0) if there is none.

Usage

MatrixClass(cl, cld = getClassDef(cl), ...Matrix = TRUE, dropVirtual = TRUE, ...)

Arguments

cl string, class name  
cld its class definition  
...Matrix logical indicating if the result must be of pattern "[dlniz]..Matrix" where the first letter "[dlniz]" denotes the content kind.

dropVirtual logical indicating if virtual classes are included or not.
... further arguments are passed to .selectSuperClasses().

Value

a character string

Author(s)

Martin Maechler, 24 Mar 2009

See Also

Matrix, the mother of all Matrix classes.

Examples

mkA <- setClass("A", contains="dgCMatrix")  
(A <- mkA())  
stopifnot(identical(  
   MatrixClass("A"),  
   "dgCMatrix")
)
MatrixFactorization-class

Virtual Class "MatrixFactorization" of Matrix Factorizations

Description

MatrixFactorization is the virtual class of factorizations of \( m \times n \) matrices \( A \), having the general form

\[
P_1 P_2 A = A_1 \cdots A_p
\]

or (equivalently)

\[
A = P'_1 A_1 \cdots A_p P'_2
\]

where \( P_1 \) and \( P_2 \) are permutation matrices. Factorizations requiring symmetric \( A \) have the constraint \( P_2 = P'_1 \), and factorizations without row or column pivoting have the constraints \( P_1 = I_m \) and \( P_2 = I_n \), where \( I_m \) and \( I_n \) are the \( m \times m \) and \( n \times n \) identity matrices.

CholeskyFactorization, BunchKaufmanFactorization, SchurFactorization, LU, and QR are the virtual subclasses of MatrixFactorization containing all Cholesky, Bunch-Kaufman, Schur, LU, and QR factorizations, respectively.

Slots

- **Dim**: an integer vector of length 2 giving the dimensions of the factorized matrix.
- **Dimnames**: a list of length 2 preserving the dimnames of the factorized matrix. Each element must be NULL or a character vector of length equal to the corresponding element of **Dim**.

Methods

determinant signature(x = "MatrixFactorization", logarithm = "missing"): sets logarithm = TRUE and recalls the generic function.
dim signature(x = "MatrixFactorization"): returns x@Dim.
dimnames signature(x = "MatrixFactorization"): returns x@Dimnames.
dimnames<- signature(x = "MatrixFactorization", value = "NULL"): returns x with x@Dimnames set to list(NULL, NULL).
dimnames<- signature(x = "MatrixFactorization", value = "list"): returns x with x@Dimnames set to value.
length signature(x = "MatrixFactorization"): returns prod(x@Dim).
show signature(object = "MatrixFactorization"): prints the internal representation of the factorization using str.
solve signature(a = "MatrixFactorization", b = .): see solve-methods.
unname signature(obj = "MatrixFactorization"): returns obj with obj@Dimnames set to list(NULL, NULL).
See Also

The virtual class `compMatrix` of factorizable matrices.
Classes extending CholeskyFactorization, namely Cholesky, pCholesky, and CHMfactor.
Classes extending BunchKaufmanFactorization, namely BunchKaufman and pBunchKaufman.
Classes extending SchurFactorization, namely Schur.
Classes extending LU, namely denseLU and sparseLU.
Classes extending QR, namely sparseQR.
Generic functions Cholesky, BunchKaufman, Schur, lu, and qr for computing factorizations.
Generic functions expand1 and expand2 for constructing matrix factors from MatrixFactorization objects.

Examples

```r
showClass("MatrixFactorization")
```

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**ndenseMatrix-class**

Virtual Class "ndenseMatrix" of Dense Logical Matrices

**Description**

ndenseMatrix is the virtual class of all dense logical (S4) matrices. It extends both denseMatrix and lMatrix directly.

**Slots**

- **x**: logical vector containing the entries of the matrix.

- **Dim, Dimnames**: see Matrix.

**Extends**

Class "nMatrix", directly. Class "denseMatrix", directly. Class "Matrix", by class "nMatrix". Class "Matrix", by class "denseMatrix".

**Methods**

```r
%*% signature(x = "nsparseMatrix", y = "ndenseMatrix"): ...
%*% signature(x = "ndenseMatrix", y = "nsparseMatrix"): ...
crossprod signature(x = "nsparseMatrix", y = "ndenseMatrix"): ...
crossprod signature(x = "ndenseMatrix", y = "nsparseMatrix"): ...
as.vector signature(x = "ndenseMatrix", mode = "missing"): ...
diag signature(x = "ndenseMatrix"): extracts the diagonal as for all matrices, see the generic diag().
which signature(x = "ndenseMatrix"), semantically equivalent to base function which(x, arr.ind); for details, see the lMatrix class documentation.
```
See Also

Class `ngeMatrix` and the other subclasses.

Examples

```r
showClass("ndenseMatrix")
as(diag(3) > 0, "ndenseMatrix")# -> "nge"
```

nearPD

**Nearest Positive Definite Matrix**

Description

Compute the nearest positive definite matrix to an approximate one, typically a correlation or variance-covariance matrix.

Usage

```r
nearPD(x, corr = FALSE, keepDiag = FALSE, base.matrix = FALSE,
do2eigen = TRUE, doSym = FALSE,
doDykstra = TRUE, only.values = FALSE,
ensureSymmetry = !isSymmetric(x),
eig.tol = 1e-06, conv.tol = 1e-07, posd.tol = 1e-08,
maxit = 100, conv.norm.type = "I", trace = FALSE)
```

Arguments

- **x**: numeric \( n \times n \) approximately positive definite matrix, typically an approximation to a correlation or covariance matrix. If \( x \) is not symmetric (and `ensureSymmetry` is not false), `symmpart(x)` is used.
- **corr**: logical indicating if the matrix should be a correlation matrix.
- **keepDiag**: logical, generalizing `corr`: if TRUE, the resulting matrix should have the same diagonal (`diag(x)`) as the input matrix.
- **base.matrix**: logical indicating if the resulting mat component should be a base matrix or (by default) a `Matrix` of class `dpoMatrix`.
- **do2eigen**: logical indicating if a `posdefify()` eigen step should be applied to the result of the Higham algorithm.
- **doSym**: logical indicating if \( X \leftarrow (X + t(X))/2 \) should be done, after \( X \leftarrow tcrossprod(Qd, Q) \); some doubt if this is necessary.
- **doDykstra**: logical indicating if Dykstra’s correction should be used; true by default. If false, the algorithm is basically the direct fixpoint iteration \( Y_k = P_U(P_S(Y_{k-1})) \).
- **only.values**: logical; if TRUE, the result is just the vector of eigenvalues of the approximating matrix.
ensureSymmetry logical; by default, symmpart(x) is used whenever isSymmetric(x) is not true. The user can explicitly set this to TRUE or FALSE, saving the symmetry test. Beware however that setting it FALSE for an asymmetric input x, is typically nonsense!

eig.tol defines relative positiveness of eigenvalues compared to largest one, \( \lambda_1 \). Eigenvalues \( \lambda_k \) are treated as if zero when \( \lambda_k / \lambda_1 \leq \text{eig.tol} \).

conv.tol convergence tolerance for Higham algorithm.

posd.tol tolerance for enforcing positive definiteness (in the final posdefify step when do2eigen is TRUE).

maxit maximum number of iterations allowed.

conv.norm.type convergence norm type (\text{norm}(\cdot, \text{type})) used for Higham algorithm. The default is "I" (infinity), for reasons of speed (and back compatibility); using "F" is more in line with Higham’s proposal.

trace logical or integer specifying if convergence monitoring should be traced.

Details

This implements the algorithm of Higham (2002), and then (if do2eigen is true) forces positive definiteness using code from posdefify. The algorithm of Knol and ten Berge (1989) (not implemented here) is more general in that it allows constraints to (1) fix some rows (and columns) of the matrix and (2) force the smallest eigenvalue to have a certain value.

Note that setting \text{corr} = \text{TRUE} just sets diag(.) \leftarrow 1 within the algorithm.

Higham (2002) uses Dykstra’s correction, but the version by Jens Oehlschlägel did not use it (accidentally), and still gave reasonable results; this simplification, now only used if doDykstra = FALSE, was active in nearPD() up to Matrix version 0.999375-40.

Value

If \text{only.values} = \text{TRUE}, a numeric vector of eigenvalues of the approximating matrix; Otherwise, as by default, an S3 object of class "nearPD", basically a list with components

- \text{mat} a matrix of class \text{dpoMatrix}, the computed positive-definite matrix.
- \text{eigenvalues} numeric vector of eigenvalues of \text{mat}.
- \text{corr} logical, just the argument \text{corr}.
- \text{normF} the Frobenius norm (\text{norm}(x-X, "F")) of the difference between the original and the resulting matrix.
- \text{iterations} number of iterations needed.
- \text{converged} logical indicating if iterations converged.

Author(s)

Jens Oehlschlägel donated a first version. Subsequent changes by the Matrix package authors.
References


See Also

A first version of this (with non-optional corr=TRUE) has been available as nearcor(); and more simple versions with a similar purpose posdefify(), both from package sfsmisc.

Examples

```r
## Higham(2002), p.334f - simple example
A <- matrix(1, 3,3); A[1,3] <- A[3,1] <- 0
n.A <- nearPD(A, corr=TRUE, do2eigen=FALSE)
n.A[c("mat", "normF")]

n.A.m <- nearPD(A, corr=TRUE, do2eigen=FALSE, base.matrix=TRUE)$mat
stopifnot(exprs = {
  all.equal(n.A$mat[1,2], 0.760689917)
  all.equal(n.A$normF, 0.52779033, tolerance=1e-9)
  all.equal(n.A.m, unname(as.matrix(n.A$mat)), tolerance = 1e-15)# seen rel.d.= 1.46e-16
})

## A longer example, extended from Jens’ original,
## showing the effects of some of the options:
pr <- Matrix(c(1, 0.477, 0.644, 0.478, 0.651, 0.826, 0.477, 1, 0.516, 0.233, 0.682, 0.75, 0.644, 0.516, 1, 0.599, 0.581, 0.742, 0.478, 0.233, 0.599, 1, 0.741, 0.8, 0.651, 0.682, 0.581, 0.741, 1, 0.798), 9)
```
ngeMatrix-class

Class "ngeMatrix" of General Dense Nonzero-pattern Matrices

Description

This is the class of general dense nonzero-pattern matrices, see nMatrix.

Slots

x: Object of class "logical". The logical values that constitute the matrix, stored in column-major order.

Dim,Dimnames: The dimension (a length-2 "integer") and corresponding names (or NULL), see the Matrix class.
factors: Object of class "list". A named list of factorizations that have been computed for the matrix.

Extends

Class "ndenseMatrix", directly. Class "lMatrix", by class "ndenseMatrix". Class "denseMatrix", by class "ndenseMatrix". Class "Matrix", by class "ndenseMatrix". Class "Matrix", by class "ndenseMatrix".

Methods

Currently, mainly t() and coercion methods (for as(.)); use, e.g., showMethods(class="ngeMatrix") for details.

See Also

Non-general logical dense matrix classes such as ntrMatrix, or nsyMatrix; sparse logical classes such as ngCMatrix.

Examples

showClass("ngeMatrix")
### "lgeMatrix" is really more relevant

__nMatrix-class__  

Class "nMatrix" of Non-zero Pattern Matrices

Description

The nMatrix class is the virtual “mother” class of all non-zero pattern (or simply pattern) matrices in the Matrix package.

Slots

Common to all matrix object in the package:

Dim: Object of class "integer" - the dimensions of the matrix - must be an integer vector with exactly two non-negative values.

Dimnames: list of length two; each component containing NULL or a character vector length equal the corresponding Dim element.

Methods

coerce signature(from = "matrix", to = "nMatrix"): Note that these coercions (must) coerce NAs to non-zero, hence conceptually TRUE. This is particularly important when sparseMatrix objects are coerced to "nMatrix" and hence to nsparseMatrix.

Additional methods contain group methods, such as
Ops signature(e1 = "nMatrix", e2 = "...")
Arith signature(e1 = "nMatrix", e2 = "...")
Compare signature(e1 = "nMatrix", e2 = "...")
Logic signature(e1 = "nMatrix", e2 = "...")
Summary signature(x = "nMatrix", "...")

See Also
The classes lMatrix, nsparseMatrix, and the mother class, Matrix.

Examples
getClass("nMatrix")

L3 <- Matrix(upper.tri(diag(3)))
L3 # an "ltCMatrix"
as(L3, "nMatrix") # -> ntC*

## similar, not using Matrix()
as(upper.tri(diag(3)), "nMatrix")# currently "ngTMatrix"

---

The Number of Non-Zero Values of a Matrix

Description
Returns the number of non-zero values of a numeric-like R object, and in particular an object \( x \) inheriting from class Matrix.

Usage

\[
nnzero(x, \text{na.counted} = \text{NA})
\]

Arguments

- \( x \): an R object, typically inheriting from class Matrix or numeric.
- \( \text{na.counted} \): a logical describing how NAs should be counted. There are three possible settings for na.counted:
  - TRUE: NAs are counted as non-zero (since “they are not zero”).
  - NA (default): the result will be NA if there are NA’s in \( x \) (since “NA’s are not known, i.e., may be zero”).
  - FALSE: NAs are omitted from \( x \) before the non-zero entries are counted.

For sparse matrices, you may often want to use na.counted = TRUE.
Value

the number of non zero entries in x (typically integer).

Note that for a symmetric sparse matrix $S$ (i.e., inheriting from class symmetricMatrix), nnzero($S$) is typically twice the length($S \times x$).

Methods

signature(x = "ANY") the default method for non-Matrix class objects, simply counts the number 0's in x, counting NA's depending on the na.counted argument, see above.

signature(x = "denseMatrix") conceptually the same as for traditional matrix objects, care has to be taken for "symmetricMatrix" objects.

signature(x = "diagonalMatrix"), and signature(x = "indMatrix") fast simple methods for these special "sparseMatrix" classes.

signature(x = "sparseMatrix") typically, the most interesting method, also carefully taking "symmetricMatrix" objects into account.

See Also

The Matrix class also has a length method; typically, length($M$) is much larger than nnzero($M$) for a sparse matrix $M$, and the latter is a better indication of the size of $M$.

drop0, zapsmall.

Examples

```r
m <- Matrix(0+1:28, nrow = 4)
m[-3,c(2,4:5,7)] <- m[3, 1:4] <- m[1:3, 6] <- 0
(mT <- as(m, "TsparseMatrix"))
nnzero(mT)
(S <- crossprod(mT))
nnzero(S)
str(S) # slots are smaller than nnzero()
stopifnot(nnzero(S) == sum(as.matrix(S) != 0))# failed earlier
data(KNex, package = "Matrix")
M <- KNex$mm
class(M)
dim(M)
length(M); stopifnot(length(M) == prod(dim(M)))
nnzero(M) # more relevant than length
## the above are also visible from
str(M)
```
Description

Computes a matrix norm of \( x \), using Lapack for dense matrices. The norm can be the one ("0", or "1") norm, the infinity ("I") norm, the Frobenius ("F") norm, the maximum modulus ("M") among elements of a matrix, or the spectral norm or 2-norm ("2"), as determined by the value of type.

Usage

\[
\text{norm}(x, \text{type}, \ldots)
\]

Arguments

- \( x \)  
a real or complex matrix.
- \( \text{type} \)  
A character indicating the type of norm desired.
  - "O", "o" or "1" specifies the one norm, (maximum absolute column sum);
  - "I" or "i" specifies the infinity norm (maximum absolute row sum);
  - "F" or "f" specifies the Frobenius norm (the Euclidean norm of \( x \) treated as if it were a vector);
  - "M" or "m" specifies the maximum modulus of all the elements in \( x \); and
  - "2" specifies the “spectral norm” or 2-norm, which is the largest singular value (\text{svd}) of \( x \).

The default is "O". Only the first character of type[1] is used.

...  
Further arguments passed to or from other methods.

Details

For dense matrices, the methods eventually call the Lapack functions \text{dlange}, \text{dlansy}, \text{dlantr}, \text{zlange}, \text{zlansy}, and \text{zlantr}.

Value

A numeric value of class "norm", representing the quantity chosen according to type.

References


See Also

\text{onenormest}(), an approximate randomized estimate of the 1-norm condition number, efficient for large sparse matrices.

The \text{norm}() function from \text{R}'s \texttt{base} package.
Examples

```r
x <- Hilbert(9)
norm(x)# = "O" = "1"
stopifnot(identical(norm(x), norm(x, "1")))
norm(x, "1")# the same, because 'x' is symmetric

allnorms <- function(d) vapply(c("1", "1", "F", "M", "2"),
                                  norm, x = d, double(1))
allnorms(x)
allnorms(Hilbert(10))

i <- c(1, 3:8); j <- c(2, 9, 6:10); x <- 7 * (1:7)
A <- sparseMatrix(i, j, x = x) ## 8 x 10 "dgCMatrix"
(sA <- sparseMatrix(i, j, x = x, symmetric = TRUE)) ## 10 x 10 "dsCMatrix"
(tA <- sparseMatrix(i, j, x = x, triangular = TRUE)) ## 10 x 10 "dtCMatrix"
(allnorms(A) -> nA)
allnorms(sA)
allnorms(tA)
stopifnot(all.equal(nA, allnorms(as(A, "matrix"))),
          all.equal(nA, allnorms(tA))) # because tA == rbind(A, 0, 0)
A. <- A; A.[1,3] <- NA
stopifnot(is.na(allnorms(A.))) # gave error
```

nsparseMatrix-classes  Sparse "pattern" Matrices

Description

The nsparseMatrix class is a virtual class of sparse "pattern" matrices, i.e., binary matrices conceptually with TRUE/FALSE entries. Only the positions of the elements that are TRUE are stored.

These can be stored in the “triplet” form (TsparseMatrix, subclasses ngTMatrix, nsTMatrix, and ntTMatrix which really contain pairs, not triplets) or in compressed column-oriented form (class CsparseMatrix, subclasses ngCMatrix, nsCMatrix, and ntCMatrix) or—rarely—in compressed row-oriented form (class RsparseMatrix, subclasses ngRMatrix, nsRMatrix, and ntRMatrix). The second letter in the name of these non-virtual classes indicates general, symmetric, or triangular.

Objects from the Class

Objects can be created by calls of the form new("ngMatrix", ...) and so on. More frequently objects are created by coercion of a numeric sparse matrix to the pattern form for use in the symbolic analysis phase of an algorithm involving sparse matrices. Such algorithms often involve two phases: a symbolic phase wherein the positions of the non-zeros in the result are determined and a numeric phase wherein the actual results are calculated. During the symbolic phase only the positions of the non-zero elements in any operands are of interest, hence numeric sparse matrices can be treated as sparse pattern matrices.
Slots

uplo: Object of class "character". Must be either "U", for upper triangular, and "L", for lower triangular. Present in the triangular and symmetric classes but not in the general class.

diag: Object of class "character". Must be either "U", for unit triangular (diagonal is all ones), or "N" for non-unit. The implicit diagonal elements are not explicitly stored when diag is "U". Present in the triangular classes only.

p: Object of class "integer" of pointers, one for each column (row), to the initial (zero-based) index of elements in the column. Present in compressed column-oriented and compressed row-oriented forms only.

i: Object of class "integer" of length nnzero (number of non-zero elements). These are the row numbers for each TRUE element in the matrix. All other elements are FALSE. Present in triplet and compressed column-oriented forms only.

j: Object of class "integer" of length nnzero (number of non-zero elements). These are the column numbers for each TRUE element in the matrix. All other elements are FALSE. Present in triplet and compressed row-oriented forms only.

Dim: Object of class "integer" - the dimensions of the matrix.

Methods

coerce signature(from = "dgCMatrix", to = "ngCMatrix"), and many similar ones; typically you should coerce to "nsparseMatrix" (or "nMatrix"). Note that coercion to a sparse pattern matrix records all the potential non-zero entries, i.e., explicit ("non-structural") zeroes are coerced to TRUE, not FALSE, see the example.

t signature(x = "ngCMatrix"): returns the transpose of x

which signature(x = "lsparseMatrix"), semantically equivalent to base function which(x, arr.ind); for details, see the lMatrix class documentation.

See Also

the class dgCMatrix

Examples

(m <- Matrix(c(0,0,2:0), 3,5, dimnames=list(LETTERS[1:3],NULL)))
## `extract the nonzero-pattern of (m) into an nMatrix' :
mm <- as(m, "nsparseMatrix") ## -> will be a "ngCMatrix"
str(mm) # no 'x' slot
mmm <- !mm # no longer sparse
## consistency check:
stopifnot(xor(as( mm, "matrix"),
            as(nmm, "matrix")))

## low-level way of adding "non-structural zeros" :
mmm <- as(nnm, "lsparseMatrix") # "lgCMatrix"
mmm@x[2:4] <- c(FALSE, NA, NA)
mm
as(nnm, "nMatrix") # NAs *and* non-structural 0 |---〉 'TRUE'
nsyMatrix-class

Description

The "nsyMatrix" class is the class of symmetric, dense nonzero-pattern matrices in non-packed storage and "nspMatrix" is the class of these in packed storage. Only the upper triangle or the lower triangle is stored.

Objects from the Class

Objects can be created by calls of the form new("nsyMatrix", ...).

Slots

uplo: Object of class "character". Must be either "U", for upper triangular, and "L", for lower triangular.

x: Object of class "logical". The logical values that constitute the matrix, stored in column-major order.

Dim,Dimnames: The dimension (a length-2 "integer") and corresponding names (or NULL), see the Matrix class.

factors: Object of class "list". A named list of factorizations that have been computed for the matrix.

Extends

"nsyMatrix" extends class "ngeMatrix", directly, whereas "nspMatrix" extends class "ndenseMatrix", directly.

Both extend class "symmetricMatrix", directly, and class "Matrix" and others, indirectly, use showClass("nsyMatrix"), e.g., for details.

Methods

Currently, mainly t() and coercion methods (for as(.)); use, e.g., showMethods(class="nsyMatrix") for details.

See Also

ngeMatrix, Matrix, t
ntrMatrix-class

Examples

```r
(s0 <- new("nsyMatrix"))
(M2 <- Matrix(c(TRUE, NA, FALSE, FALSE), 2, 2)) # logical dense (ltr)
(sM <- M2 & t(M2)) # -> "lge"
class(sM <- as(sM, "nMatrix")) # -> "nge"
  (sM <- as(sM, "symmetricMatrix")) # -> "nsy"
str(sM <- as(sM, "packedMatrix")) # -> "nsp", i.e., packed symmetric
```

ntrMatrix-class  Triangular Dense Logical Matrices

Description

The "ntrMatrix" class is the class of triangular, dense, logical matrices in nonpacked storage. The "ntpMatrix" class is the same except in packed storage.

Slots

- `x`: Object of class "logical". The logical values that constitute the matrix, stored in column-major order.
- `uplo`: Object of class "character". Must be either "U", for upper triangular, and "L", for lower triangular.
- `diag`: Object of class "character". Must be either "U", for unit triangular (diagonal is all ones), or "N"; see triangularMatrix.
- `Dim`, `Dimnames`: The dimension (a length-2 "integer") and corresponding names (or NULL), see the Matrix class.
- `factors`: Object of class "list". A named list of factorizations that have been computed for the matrix.

Extends

"ntrMatrix" extends class "ngeMatrix", directly, whereas "ntpMatrix" extends class "ndenseMatrix", directly.

Both extend Class "triangularMatrix", directly, and class "denseMatrix", "lMatrix" and others, indirectly, use showClass("nsyMatrix"), e.g., for details.

Methods

Currently, mainly `t()` and coercion methods (for `as(.); use, e.g., `showMethods(class="ntrMatrix")` for details.

See Also

Classes `ngeMatrix`, `Matrix`; function `t`
Examples

```
showClass("ntnMatrix")
str(new("ntpMatrix"))
(nutr <- as(upper.tri(matrix(, 4, 4)), "ndenseMatrix"))
str(nutp <- pack(nutr)) # packed matrix: only 10 = 4*(4+1)/2 entries
!nutp # the logical negation (is *not* logical triangular !)
## but this one is:
stopifnot(all.equal(nutp, pack(!nutp)))
```

---

number-class

Class “number” of Possibly Complex Numbers

Description

The class "number" is a virtual class, currently used for vectors of eigen values which can be "numeric" or "complex". It is a simple class union (setClassUnion) of "numeric" and "complex".

Objects from the Class

Since it is a virtual Class, no objects may be created from it.

Examples

```
showClass("number")
stopifnot( is(1i, "number"), is(pi, "number"), is(1:3, "number") )
```

---

pack

representation of packed and unpacked dense matrices

Description

pack() coerces dense symmetric and dense triangular matrices from unpacked format (storing the full matrix) to packed format (storing only one of the upper and lower triangles). unpack() performs the reverse coercion. The two formats are formalized by the virtual classes "packedMatrix" and "unpackedMatrix".
Usage

pack(x, ...)
## S4 method for signature 'dgeMatrix'
pack(x, symmetric = NA, upperTri = NA, ...)
## S4 method for signature 'lgeMatrix'
pack(x, symmetric = NA, upperTri = NA, ...)
## S4 method for signature 'ngeMatrix'
pack(x, symmetric = NA, upperTri = NA, ...)
## S4 method for signature 'matrix'
pack(x, symmetric = NA, upperTri = NA, ...)

unpack(x, ...)

Arguments

x      A dense symmetric or dense triangular matrix.

For pack(): typically an "unpackedMatrix" or a standard "matrix", though
"packedMatrix" are allowed and returned unchanged.

For unpack(): typically a "packedMatrix", though "unpackedMatrix" are
allowed and returned unchanged.

symmetric logical (including NA) optionally indicating whether x is symmetric (or triangu-
lar).

upperTri (for triangular x only) logical (including NA) indicating whether x is upper (or
lower) triangular.

...    further arguments passed to or from other methods.

Details

pack(x) checks matrices x not inheriting from one of the virtual classes "symmetricMatrix"
"triangularMatrix" for symmetry (via isSymmetric()) then for upper and lower triangularity
(via isTriangular()) in order to identify a suitable coercion. Setting one or both of symmetric
and upperTri to TRUE or FALSE rather than NA allows skipping of irrelevant tests for large matrices
known to be symmetric or (upper or lower) triangular.

Users should not assume that pack() and unpack() are inverse operations. Specifically, y <-
unpack(pack(x)) may not reproduce an "unpackedMatrix" x in the sense of identical(). See
the examples.

Value

For pack(): a "packedMatrix" giving the condensed representation of x.

For unpack(): an "unpackedMatrix" giving the full storage representation of x.

Examples

showMethods("pack")
(s <- crossprod(matrix(sample(15), 5, 3))) # traditional symmetric matrix
(sp <- pack(s))
mt <- as.matrix(tt <- tril(s))
(pt <- pack(mt))
stopifnot(identical(pt, pack(tt)),
  dim(s) == dim(sp), all(s == sp),
  dim(mt) == dim(pt), all(mt == pt), all(mt == tt))

tp4 <- pack(cp4) # triangular [p]acked
(str(tp4))

z1 <- new("dsyMatrix", Dim = c(2L, 2L), x = as.double(1:4), uplo = "U")
z2 <- unpack(pack(z1))
stopifnot(!identical(z1, z2), # _not_ identical
  all(z1 == z2)) # but mathematically equal

packedMatrix-class

Virtual Class "packedMatrix" of Packed Dense Matrices

Description

Class "packedMatrix" is the virtual class of dense symmetric or triangular matrices in "packed" format, storing only the \( \text{choose}(n+1,2) = \frac{n(n+1)}{2} \) elements of the upper or lower triangle of an \( n \)-by-\( n \) matrix. It is used to define common methods for efficient subsetting, transposing, etc. of its proper subclasses: currently \"[dln]spMatrix" (packed symmetric), \"[dln]tpMatrix" (packed triangular), and subclasses of these, such as \"dppMatrix\", \"pCholesky\", and \"pBunchKaufman\".

Slots

uplo: "character"; either "U", for upper triangular, and "L", for lower.
Dim, Dimnames: as all \texttt{Matrix} objects.

Extends


Methods

\texttt{pack} signature(x = "packedMatrix"): ...
\texttt{unpack} signature(x = "packedMatrix"): ...
\texttt{isSymmetric} signature(object = "packedMatrix"): ...
\texttt{isTriangular} signature(object = "packedMatrix"): ...
**pMatrix-class**

`isDiagonal` signature(object = "packedMatrix"): ...

`t` signature(x = "packedMatrix"): ...

`diag` signature(x = "packedMatrix"): ...

`diag<-` signature(x = "packedMatrix"): ...

**Author(s)**

Mikael Jagan

**See Also**

`pack` and `unpack`; its virtual "complement" "unpackedMatrix"; its proper subclasses "dspMatrix", "ltpMatrix", etc.

**Examples**

```
showClass("packedMatrix")
showMethods(classes = "packedMatrix")
```

---

definition of permutation matrices

The pMatrix class is the class of permutation matrices, stored as 1-based integer permutation vectors. A permutation matrix is a square matrix whose rows and columns are all standard unit vectors. It follows that permutation matrices are a special case of index matrices (hence pMatrix is defined as a direct subclass of indMatrix).

Multiplying a matrix on the left by a permutation matrix is equivalent to permuting its rows. Analogously, multiplying a matrix on the right by a permutation matrix is equivalent to permuting its columns. Indeed, such products are implemented in Matrix as indexing operations; see 'Details' below.

**Details**

By definition, a permutation matrix is both a row index matrix and a column index matrix. However, the perm slot of a pMatrix cannot be used interchangeably as a row index vector and column index vector. If margin=1, then perm is a row index vector, and the corresponding column index vector can be computed as invPerm(perm), i.e., by inverting the permutation. Analogously, if margin=2, then perm and invPerm(perm) are column and row index vectors, respectively.

Given an n-by-n row permutation matrix P with perm slot p and a matrix M with conformable dimensions, we have

\[
PM = P \%\% M = M[p, ]
\]

\[
MP = M \%\% P = M[, i(p)]
\]

\[
P'M = \text{crossprod}(P, M) = M[i(p), ]
\]

\[
MP' = \text{tcrossprod}(M, P) = M[, p]
\]

\[
P'P = \text{crossprod}(P) = \text{Diagonal}(n)
\]

\[
PP' = \text{tcrossprod}(P) = \text{Diagonal}(n)
\]
where \( i := \text{invPerm} \).

**Objects from the Class**

Objects can be created explicitly with calls of the form `new("pMatrix", ...)`, but they are more commonly created by coercing 1-based integer index vectors, with calls of the form `as(., "pMatrix")`: see ‘Methods’ below.

**Slots**

- `margin`, `perm` inherited from superclass `indMatrix`. Here, `perm` is an integer vector of length `Dim[1]` and a permutation of `1:Dim[1]`.
- `Dim`, `Dimnames` inherited from virtual superclass `Matrix`.

**Extends**

Class "indMatrix", directly.

**Methods**

- `%*%` signature `x = "pMatrix", y = "Matrix"`) and others listed by `showMethods("%*%", classes = "pMatrix")`: matrix products implemented where appropriate as indexing operations.
- `coerce` signature (from = "numeric", to = "pMatrix") supporting typical `pMatrix` construction from a vector of positive integers, specifically a permutation of `1:n`. Row permutation is assumed.
- `t` signature `x = "pMatrix")`: the transpose, which is a `pMatrix` with identical `perm` but opposite margin. Coincides with the inverse, as permutation matrices are orthogonal.
- `solve` signature `a = "pMatrix", b = "missing")`: the inverse permutation matrix, which is a `pMatrix` with identical `perm` but opposite margin. Coincides with the transpose, as permutation matrices are orthogonal. See `showMethods("solve", classes = "pMatrix")` for more signatures.
- `determinant` signature `x = "pMatrix", logarithm = "logical")`: always returning 1 or -1, as permutation matrices are orthogonal. In fact, the result is exactly the `sign` of the permutation.

**See Also**

Superclass `indMatrix` of index matrices, for many inherited methods; `invPerm`, for computing inverse permutation vectors.

**Examples**

```r
(pm1 <- as(as.integer(c(2,3,1)), "pMatrix"))
t(pm1) # is the same as solve(pm1)
pm1 %*% t(pm1) # check that the transpose is the inverse
stopifnot(all(diag(3) == as(pm1 %*% t(pm1), "matrix")),
is.logical(as(pm1, "matrix")))
```
## random permutation matrix :
(p10 <- as(sample(10), "pMatrix"))

## Permute rows / columns of a numeric matrix :
(mm <- round(array(rnorm(3 * 3), c(3, 3)), 2))

## Permute rows / columns of a numeric matrix :
(mm %>% pm1
pm1 %>% mm

try(as(as.integer(c(3,3,1)), "pMatrix"))# Error: not a permutation

as(pm1, "TsparseMatrix")
p10[1:7, 1:4] # gives an "ngTMatrix" (most economic!)

## row-indexing of a <pMatrix> keeps it as an <indMatrix>:
p10[1:3, ]

---

### printSpMatrix

Format and Print Sparse Matrices Flexibly

#### Description

Format and print sparse matrices flexibly. These are the "workhorses" used by the `format`, `show` and `print` methods for sparse matrices. If `x` is large, `printSpMatrix2(x)` calls `printSpMatrix()` twice, namely, for the first and the last few rows, suppressing those in between, and also suppresses columns when `x` is too wide.

`printSpMatrix()` basically prints the result of `formatSpMatrix()`.

#### Usage

```r
formatSpMatrix(x, digits = NULL, maxp = 1e9,
    cld = getClassDef(class(x)), zero.print = ".",
    col.names, note.dropping.colnames = TRUE, uniDiag = TRUE,
    align = c("fancy", "right"))

printSpMatrix(x, digits = NULL, maxp = max(100L, getOption("max.print")),
    cld = getClassDef(class(x)),
    zero.print = ".", col.names, note.dropping.colnames = TRUE,
    uniDiag = TRUE, col.trailer = "",
    align = c("fancy", "right"))

printSpMatrix2(x, digits = NULL, maxp = max(100L, getOption("max.print")),
    zero.print = ".", col.names, note.dropping.colnames = TRUE,
    uniDiag = TRUE, suppRows = NULL, suppCols = NULL,
    col.trailer = if(suppCols) "......" else "",
    align = c("fancy", "right"),
    width = getOption("width"), fitWidth = TRUE)
```
Arguments

- **x**: an R object inheriting from class `sparseMatrix`.
- **digits**: significant digits to use for printing, see `print.default`, the default, `NULL`, corresponds to using `getOption("digits")`.
- **maxp**: integer, default from `options(max.print)`, influences how many entries of large matrices are printed at all. Typically should not be smaller than around 1000; values smaller than 100 are silently “rounded up” to 100.
- **cld**: the class definition of x; must be equivalent to `getClassDef(class(x))` and exists mainly for possible speedup.
- **zero.print**: character which should be printed for structural zeroes. The default "," may occasionally be replaced by " " (blank); using "0" would look almost like `print()`ing of non-sparse matrices.
- **col.names**: logical or string specifying if and how column names of x should be printed, possibly abbreviated. The default is taken from `options("sparse.colnames")` if that is set, otherwise `FALSE` unless there are less than ten columns. When `TRUE` the full column names are printed. When `col.names` is a string beginning with "abb" or "sub" and ending with an integer n (i.e., of the form "abb... <n>"), the column names are `abbreviate()`d or `substring()`ed to (target) length n, see the examples.
- **note.dropping.colnames**: logical specifying, when `col.names` is `FALSE` if the dropping of the column names should be noted, `TRUE` by default.
- **uniDiag**: logical indicating if the diagonal entries of a sparse unit triangular or unit-diagonal matrix should be formatted as "I" instead of "1" (to emphasize that the 1’s are “structural”).
- **col.trailer**: a string to be appended to the right of each column; this is typically made use of by `show(<sparseMatrix>)` only, when suppressing columns.
- **suppRows, suppCols**: logicals or `NULL`, for `printSpMatrix2()` specifying if rows or columns should be suppressed in printing. If `NULL`, sensible defaults are determined from `dim(x)` and `options(c("width", "max.print"))`. Setting both to `FALSE` may be a very bad idea.
- **align**: a string specifying how the zero.print codes should be aligned, i.e., padded as strings. The default, "fancy", takes some effort to align the typical zero.print = "," with the position of 0, i.e., the first decimal (one left of decimal point) of the numbers printed, whereas align = "right" just makes use of `print(*, right = TRUE)`.
- **width**: number, a positive integer, indicating the approximately desired (line) width of the output, see also `fitWidth`.
- **fitWidth**: logical indicating if some effort should be made to match the desired width or temporarily enlarge that if deemed necessary.

Details

**formatSpMatrix**: If x is large, only the first rows making up the approximately first `maxp` entries is used, otherwise all of x. `.formatSparseSimple()` is applied to (a dense version of) the
matrix. Then, `formatSparseM` is used, unless in trivial cases or for sparse matrices without `x` slot.

**Value**

`formatSpMatrix()`

returns a character matrix with possibly empty column names, depending on `col.names` etc, see above.

`printSpMatrix*()`

return `x` invisibly, see `invisible`.

**Author(s)**

Martin Maechler

**See Also**

the virtual class `sparseMatrix` and the classes extending it; maybe `sparseMatrix` or `spMatrix` as simple constructors of such matrices.

The underlying utilities `formatSparseM` and `.formatSparseSimple()` (on the same page).

**Examples**

```r
f1 <- gl(5, 3, labels = LETTERS[1:5])
X <- as(f1, "sparseMatrix")
X ## <==> show(X) <==> print(X)
t(X) ## shows column names, since only 5 columns

X2 <- as(gl(12, 3, labels = paste(LETTERS[1:12],"c",sep=".")), "sparseMatrix")
X2

## less nice, but possible:
print(X2, col.names = TRUE) # use [,1] [,2] .. => does not fit

## Possibilities with column names printing:
t(X2) # suppressing column names
print(t(X2), col.names=TRUE)
print(t(X2), zero.print = ",", col.names="abbr. 1")
print(t(X2), zero.print = ",", col.names="substring 2")
```

---

**qr-methods**  

*Methods for QR Factorization*
Description

Computes the pivoted QR factorization of an \( m \times n \) real matrix \( A \), which has the general form

\[
P_1 A P_2 = QR
\]

or (equivalently)

\[
A = P_1' Q R P_2'
\]

where \( P_1 \) and \( P_2 \) are permutation matrices, \( Q = \prod_{j=1}^{n} H_j \) is an \( m \times m \) orthogonal matrix equal to the product of \( n \) Householder matrices \( H_j \), and \( R \) is an \( m \times n \) upper trapezoidal matrix.

*denseMatrix* use the default method implemented in *base*, namely *qr.default*. It is built on LINPACK routine *dqrdc* and LAPACK routine *dgeqp3*, which do not pivot rows, so that \( P_1 \) is an identity matrix.

Methods for *sparseMatrix* are built on CSparse routines *cs_sqr* and *cs_qr*, which require \( m \geq n \).

Usage

```r
qr(x, ...)  
## S4 method for signature 'dgCMatrix'  
qr(x, order = 3L, ...)
```

Arguments

- **x**: a finite matrix or *Matrix* to be factorized, satisfying \( \text{nrow}(x) \geq \text{ncol}(x) \) if sparse.
- **order**: an integer in \( 0:3 \) passed to CSparse routine *cs_sqr*, indicating a strategy for choosing the column permutation \( P_2 \). 0 means no column permutation. 1, 2, and 3 indicate a fill-reducing ordering of \( A + A', \tilde{A}' \tilde{A}, \) and \( A'A \), where \( \tilde{A} \) is \( A \) with “dense” rows removed. Do not set to 0 unless you know that the column order of \( A \) is already sensible.
- **...**: further arguments passed to or from methods.

Details

If \( x \) is sparse and structurally rank deficient, having structural rank \( r < n \), then \( x \) is augmented with \( (n - r) \) rows of (partly non-structural) zeros, such that the augmented matrix has structural rank \( n \).

This augmented matrix is factorized as described above:

\[
P_1 A P_2 = P_1 \begin{bmatrix} A_0 \\ 0 \end{bmatrix} P_2 = QR
\]

where \( A_0 \) denotes the original, user-supplied \( (m - (n - r)) \times n \) matrix.

Value

An object representing the factorization, inheriting from virtual S4 class *QR* or S3 class *qr*. The specific class is *qr* unless \( x \) inherits from virtual class *sparseMatrix*, in which case it is *sparseQR*. 
qr-methods

References


See Also

Class `sparseQR` and its methods.

Class `dgCMatrix`.

Generic function `qr` from `base`, whose default method `qr.default` “defines” the S3 class `qr` of dense QR factorizations.

Generic functions `expand1` and `expand2`, for constructing matrix factors from the result.

Generic functions `Cholesky`, `BunchKaufman`, `Schur`, and `lu`, for computing other factorizations.

Examples

```r
showMethods("qr", inherited = FALSE)

## Rank deficient: columns 3 \{b2\} and 6 \{c3\} are "extra"
M <- as(cbind(a1 = 1,
            b1 = rep(c(1, 0), each = 3L),
            b2 = rep(c(0, 1), each = 3L),
            c1 = rep(c(1, 0, 0), 2L),
            c2 = rep(c(0, 1, 0), 2L),
            c3 = rep(c(0, 0, 1), 2L)),
            "CsparseMatrix")
rownames(M) <- paste0("r", seq_len(nrow(M)))
b <- 1:6
eps <- .Machine$double.eps

## .... [1] full rank ..................................................
## ===> a least squares solution of A x = b exists
## and is unique _in exact arithmetic_
(A1 <- M[, -c(3L, 6L)])
(qr.A1 <- qr(A1))

stopifnot(exprs = {
  rankMatrix(A1) == ncol(A1)
  { d1 <- diag(qr.A1@R); sum(d1 < max(d1) * eps) == 0L }
  rcond(crossprod(A1)) >= eps
  all.equal(qr.coef(qr.A1, b), drop(solve(crossprod(A1), crossprod(A1, b))))
  all.equal(qr.fitted(qr.A1, b) + qr.resid(qr.A1, b), b)
})

## .... [2] numerically rank deficient with full structural rank .......
## ===> a least squares solution of A x = b does not
## exist or is not unique _in exact arithmetic_
```
(A2 <- M)
(qr.A2 <- qr(A2))

stopifnot(exprs = {
  rankMatrix(A2) == ncol(A2) - 2L
  (d2 <- diag(qr.A2@R); sum(d2 < max(d2) * eps) == 2L )
  rcond(crossprod(A2)) < eps
}

## 'qr.coef' computes unique least squares solution of "nearby" problem
## Z x = b for some full rank Z ~ A, currently without warning {FIXME}!
tryCatch({ qr.coef(qr.A2, b); TRUE }, condition = function(x) FALSE)

all.equal(qr.fitted(qr.A2, b) + qr.resid(qr.A2, b), b)
))

## .... [3] numerically and structurally rank deficient ...............
## ===> factorization of _augmented_ matrix with
##    full structural rank proceeds as in [2]
## NB: implementation details are subject to change; see (*) below

A3 <- M
A3[, , (3L, 6L)] <- 0
A3
(qr.A3 <- qr(A3)) # with a warning ... "additional 2 row(s) of zeros"

stopifnot(exprs = {
  ## sparseQR object preserves the unaugmented dimensions (*)
  dim(qr.A3 ) == dim(A3)
  dim(qr.A3@V) == dim(A3) + c(2L, 0L)
  dim(qr.A3@R) == dim(A3) + c(2L, 0L)

  ## The augmented matrix remains numerically rank deficient
  rankMatrix(A3) == ncol(A3) - 2L
  (d3 <- diag(qr.A3@R); sum(d3 < max(d3) * eps) == 2L )
  rcond(crossprod(A3)) < eps
}

## Auxiliary functions accept and return a vector or matrix
## with dimensions corresponding to the unaugmented matrix (*),
## in all cases with a warning
qr.coef (qr.A3, b)
qr.fitted(qr.A3, b)
qr.resid (qr.A3, b)

## .... [4] yet more examples ..........................................

## By disabling column pivoting, one gets the "vanilla" factorization
## A = Q~ R, where Q~ := P1' Q is orthogonal because P1 and Q are

(qr.A1.pp <- qr(A1, order = 0L)) # partial pivoting
# rankMatrix

## Description

Compute ‘the’ matrix rank, a well-defined functional in theory(*), somewhat ambiguous in practice. We provide several methods, the default corresponding to Matlab’s definition.

(*) The rank of a \( n \times m \) matrix \( A \), \( rk(A) \), is the maximal number of linearly independent columns (or rows); hence \( rk(A) \leq \min(n,m) \).

## Usage

```r
rankMatrix(x, tol = NULL, method = c("tolNorm2", "qr", "qrLINPACK", "qr", "useGrad", "maybeGrad"), sval = svd(x, 0, 0)$d, warn.t = TRUE, warn.qr = TRUE)

qr2rankMatrix(qr, tol = NULL, isBqr = is.qr(qr), do.warn = TRUE)
```

## Arguments

- **x** numeric matrix, of dimension \( n \times m \), say.
- **tol** nonnegative number specifying a (relative, “scalefree”) tolerance for testing of “practically zero” with specific meaning depending on method; by default, \( \max(\text{dim}(x)) \times \text{.Machine}$double.eps \) is according to Matlab’s default (for its only method which is our method="tolNorm2").
- **method** a character string specifying the computational method for the rank, can be abbreviated:
  - "tolNorm2": the number of singular values \( \geq tol \times \max(sval) \);
  - "qrLINPACK": for a dense matrix, this is the rank of \( qr(x, \text{tol}, \text{LAPACK}=\text{FALSE}) \) (which is \( qr(...) \)$rank);
  - "qr": this is the maximal number of linearly independent columns in \( qr(x) \);
  - "useGrad", "maybeGrad": these are approximations via the singular values.

## Examples

```r
ea1 <- function(a, b, ...) all.equal(as(a, "matrix"), as(b, "matrix"), ...)
ea2 <- function(a, b, ...) ae1(unname(a), unname(b), ...)

stopifnot(exprs = {
  length(qr.A1@q) == ncol(A1)
  length(qr.A1.pp@q) == 0L # indicating no column pivoting
  ae2(A1[, qr.A1@q + 1L], qr.Q(qr.A1) %*% qr.R(qr.A1))
})
```
"qr.R": this is the rank of triangular matrix R, where qr() uses LAPACK or a "sparseQR" method (see qr-methods) to compute the decomposition QR. The rank of R is then defined as the number of "non-zero" diagonal entries $d_i$ of R, and "non-zero"s fulfill $|d_i| \geq \text{tol} \cdot \max(|d_i|)$.

"qr": is for back compatibility; for dense x, it corresponds to "qrLINPACK", whereas for sparse x, it uses "qr.R".

For all the "qr*" methods, singular values sval are not used, which may be crucially important for a large sparse matrix x, as in that case, when sval is not specified, the default, computing svd() currently coerces x to a dense matrix.

"useGrad": considering the “gradient” of the (decreasing) singular values, the index of the smallest gap.

"maybeGrad": choosing method "useGrad" only when that seems reasonable; otherwise using "tolNorm2".

sval numeric vector of non-increasing singular values of x; typically unspecified and computed from x when needed, i.e., unless method = "qr".

warn.t logical indicating if rankMatrix() should warn when it needs t(x) instead of x. Currently, for method = "qr" only, gives a warning by default because the caller often could have passed t(x) directly, more efficiently.

warn.qr in the QR cases (i.e., if method starts with "qr"), rankMatrix() calls qr2rankMarix(.., do.warn = warn.qr), see below.

qr an R object resulting from qr(x,..), i.e., typically inheriting from class "qr" or "sparseQR".

isBqr logical indicating if qr is resulting from base qr(). (Otherwise, it is typically from Matrix package sparse qr.)

do.warn logical; if true, warn about non-finite (or in the sparseQR case negative) diagonal entries in the R matrix of the QR decomposition. Do not change lightly!

Details
qr2rankMatrix() is typically called from rankMatrix() for the "qr"* methods, but can be used directly - much more efficiently in case the qr-decomposition is available anyway.

Value
If x is a matrix of all 0 (or of zero dimension), the rank is zero; otherwise, typically a positive integer in $1: \min(\text{dim}(x))$ with attributes detailing the method used.

There are rare cases where the sparse QR decomposition “fails” in so far as the diagonal entries of R, the $d_i$ (see above), end with non-finite, typically NaN entries. Then, a warning is signalled (unless warn.qr / do.warn is not true) and NA (specifically, NA_integer_) is returned.

Note
For large sparse matrices x, unless you can specify sval yourself, currently method = "qr" may be the only feasible one, as the others need sval and call svd() which currently coerces x to a denseMatrix which may be very slow or impossible, depending on the matrix dimensions.
Note that in the case of sparse \( x \), \texttt{method = "qr"}, all non-strictly zero diagonal entries \( d_i \) where counted, up to including \texttt{Matrix} version 1.1-0, i.e., that method implicitly used \( \texttt{tol = 0} \), see also the \texttt{set.seed(42)} example below.

Author(s)

Martin Maechler; for the ""Grad"" methods building on suggestions by Ravi Varadhan.

See Also

qr, svd.

Examples

```r
rankMatrix(cbind(1, 0, 1:3)) # 2
(meths <- eval(formals(rankMatrix)$method))
## [1] "tolNorm2" "qr.R" "qrLINPACK" "qr" "useGrad" "maybeGrad"
## 11 11 12 12 11 11
## The meaning of 'tol' for method="qrLINPACK" and *dense* \( x \) is not entirely "scale free"
(rMQL <- function(ex, M) rankMatrix(M, method="qrLINPACK", tol = 10^-ex))
## 5 6 7 8 8 9 9 10 10 11 11
```

```r
rownames(rMQL(10, 1000 * H12))
## [1] "5" "6" "7" "8" "8" "9" "9" "10" "10" "11" "11"
```

```r
rMQR <- function(ex, M) rankMatrix(M, method="qr.R", tol = 10^-ex)
```

```r
rownames(rMQR(10, 1000 * H12))
## [1] "5" "6" "7" "8" "8" "9" "9" "10" "10" "11" "11"
```

```r
## "sparse" case:
M15 <- kronecker(diag(x=c(100,1,10)), Hilbert(5))
```

```r
rownames(rMQR(10, M15))
## [1] "5" "6" "7" "8" "8" "9" "9" "10" "10" "11" "11"
```

```r
sapply(meths, function(.m.) rankMatrix(M15, method = .m., tol = 1e-7)) # all 14
```

```r
## "large" sparse
n <- 250000; p <- 33; nnz <- 10000
L <- sparseMatrix(i = sample.int(n, nnz, replace=TRUE),
                 j = sample.int(p, nnz, replace=TRUE),
                 x = rnorm(nnz))
(st1 <- system.time(r1 <- rankMatrix(L))) # warning+ ~1.5 sec (2013)
(st2 <- system.time(r2 <- rankMatrix(L, method = "qr"))) # considerably faster!
```

```r
r1[[1]] == print(r2[[1]]) ## --> ( 33 TRUE )
```
## another sparse-"qr" one, which \texttt{\textasciigrave failed\textasciigrave} till 2013-11-23:

```
set.seed(42)
f1 <- factor(sample(50, 1000, replace=TRUE))
f2 <- factor(sample(50, 1000, replace=TRUE))
f3 <- factor(sample(50, 1000, replace=TRUE))
D <- t(do.call(rbind, lapply(list(f1,f2,f3), as, sparseMatrix)))
```

```
dim(D); nnzero(D) ## 1000 x 150 // 3000 non-zeros (= 2%)
stopifnot(rankMatrix(D, method=\texttt{\textquotesingle qr\textquotesingle}) == 148,
         rankMatrix(crossprod(D),method=\texttt{\textquotesingle qr\textquotesingle}) == 148)
```

```
## zero matrix has rank 0 :
stopifnot(sapply(meths, function(.m.)
            rankMatrix(matrix(0, 2, 2), method = .m.)) == 0)
```

### rcond-methods

#### Estimate the Reciprocal Condition Number

**Description**

Estimate the reciprocal of the condition number of a matrix.

This is a generic function with several methods, as seen by \texttt{showMethods(rcond)}.

**Usage**

```
rcond(x, norm, ...)
```

```
## S4 method for signature \texttt{\textquotesingle sparseMatrix,character\textquotesingle}
rcond(x, norm, useInv=FALSE, ...)
```

**Arguments**

- **x**: an \texttt{R} object that inherits from the \texttt{Matrix} class.
- **norm**: character string indicating the type of norm to be used in the estimate. The default is \texttt{"0"} for the 1-norm (\texttt{"0"} is equivalent to \texttt{"1\textasciigrave\textasciigrave"}). For sparse matrices, when \texttt{useInv=TRUE}, \texttt{norm} can be any of the kinds allowed for \texttt{norm}; otherwise, the other possible value is \texttt{"I"} for the infinity norm, see also \texttt{norm}.
- **useInv**: logical (or \"Matrix\" containing \texttt{solve(x)}). If not false, compute the reciprocal condition number as \(1/(\|x\| \cdot \|x^{-1}\|)\), where \(x^{-1}\) is the inverse of \(x\), \texttt{solve(x)}. This may be an efficient alternative (only) in situations where \texttt{solve(x)} is fast (or known), e.g., for (very) sparse or triangular matrices.
- **...**: further arguments passed to or from other methods.

**Value**

An estimate of the reciprocal condition number of \(x\).
BACKGROUND

The condition number of a regular (square) matrix is the product of the norm of the matrix and the norm of its inverse (or pseudo-inverse).

More generally, the condition number is defined (also for non-square matrices $A$) as

$$\kappa(A) = \frac{\max_{\|v\|=1} \|Av\|}{\min_{\|v\|=1} \|Av\|}$$

Whenever $x$ is not a square matrix, in our method definitions, this is typically computed via `rcond(qr.R(qr(X)), ...)` where $X$ is $x$ or $t(x)$.

The condition number takes on values between 1 and infinity, inclusive, and can be viewed as a factor by which errors in solving linear systems with this matrix as coefficient matrix could be magnified.

$rcond()$ computes the reciprocal condition number $1/\kappa$ with values in $[0, 1]$ and can be viewed as a scaled measure of how close a matrix is to being rank deficient (aka “singular”).

Condition numbers are usually estimated, since exact computation is costly in terms of floating-point operations. An (over) estimate of reciprocal condition number is given, since by doing so overflow is avoided. Matrices are well-conditioned if the reciprocal condition number is near 1 and ill-conditioned if it is near zero.

References


See Also

`norm`, `kappa()` from package `base` computes an approximate condition number of a “traditional” matrix, even non-square ones, with respect to the $p = 2$ (Euclidean) norm. `solve`.

`condest`, a newer approximate estimate of the (1-norm) condition number, particularly efficient for large sparse matrices.

Examples

```r
x <- Matrix(rnorm(9), 3, 3)
rcond(x)
## typically "the same" (with more computational effort):
1 / (norm(x) * norm(solve(x)))
rcond(Hilbert(9)) # should be about 9.1e-13

## For non-square matrices:
rcond(x1 <- cbind(1,1:10))# 0.05278
rcond(x2 <- cbind(x1, 2:11))# practically 0, since x2 does not have full rank

## sparse
(S1 <- Matrix(rbind(0:1,0, diag(3:-2))))
rcond(S1)
ml <- as(S1, "denseMatrix")
```
all.equal(rcond(S1), rcond(m1))

## wide and sparse
rcond(Matrix(cbind(0, diag(2:-1))))

## Large sparse example ---------
m <- Matrix(c(3,0:2), 2,2)
M <- bdiag(kronecker(Diagonal(2), m), kronecker(m,m))
36*(iM <- solve(M)) # still sparse
MM <- kronecker(Diagonal(10), kronecker(Diagonal(5),kronecker(m,M)))
dim(M3 <- kronecker(bdiag(M,M),MM)) # 12'800 ^ 2
if(interactive()) ## takes about 2 seconds if you have >= 8 GB RAM
  system.time(r <- rcond(M3))
## whereas this is *fast* even though it computes solve(M3)
  system.time(r. <- rcond(M3, useInv=TRUE))
if(interactive()) ## the values are not the same
  c(r, r.) # 0.0555 0.013888
## for all 4 norms available for sparseMatrix :
cbind(rr <- sapply(c("1","I","F","M"),
  function(N) rcond(M3, norm=N, useInv=TRUE)))

---

**rep2abI**  
*Replicate Vectors into 'abIndex' Result*

**Description**

`rep2abI(x, times)` conceptually computes `rep.int(x, times)` but with an `abIndex` class result.

**Usage**

`rep2abI(x, times)`

**Arguments**

- `x` numeric vector
- `times` integer (valued) scalar: the number of repetitions

**Value**

a vector of class `abIndex`

**See Also**

`rep.int()`, the base function; `abIseq`, `abIndex`.

**Examples**

```r
(ab <- rep2abI(2:7, 4))
stopifnot(identical(as(ab, "numeric"),
  rep(2:7, 4)))
```
Virtual Class "replValue" - Simple Class for Subassignment Values

Description
The class "replValue" is a virtual class used for values in signatures for sub-assignment of `Matrix` matrices.
In fact, it is a simple class union (`setClassUnion`) of "numeric" and "logical" (and maybe "complex" in the future).

Objects from the Class
Since it is a virtual Class, no objects may be created from it.

See Also
`Subassign-methods`, also for examples.

Examples
```
showClass("replValue")
```

Class "rleDiff" of `rle(diff(.))` Stored Vectors

Description
Class "rleDiff" is for compactly storing long vectors which mainly consist of linear stretches. For such a vector `x`, `diff(x)` consists of constant stretches and is hence well compressable via `rle()`.

Objects from the Class
Objects can be created by calls of the form `new("rleDiff", ...)`. Currently experimental, see below.

Slots
- `first`: A single number (of class "numLike", a class union of "numeric" and "logical").
- `rle`: Object of class "rle", basically a list with components "lengths" and "values", see `rle()`. As this is used to encode potentially huge index vectors, lengths may be of type `double` here.

Methods
There is a simple show method only.
rsparsematrix

Note

This is currently an experimental auxiliary class for the class abIndex, see there.

See Also

rle, abIndex.

Examples

showClass("rleDiff")

ab <- c(abIseq(2, 100), abIseq(20, -2))
ab@rleD # is "rleDiff"

rsparsematrix Random Sparse Matrix

Description

Generate a random sparse matrix efficiently. The default has rounded gaussian non-zero entries, and rand.x = NULL generates random pattern matrices, i.e. inheriting from nsparseMatrix.

Usage

rsparsematrix(nrow, ncol, density, nnz = round(density * maxE),
              symmetric = FALSE,
              rand.x = function(n) signif(rnorm(n), 2), ...)

Arguments

nrow, ncol number of rows and columns, i.e., the matrix dimension (dim).
density optional number in [0, 1], the density is the proportion of non-zero entries among all matrix entries. If specified it determines the default for nnz, otherwise nnz needs to be specified.

nnz number of non-zero entries, for a sparse matrix typically considerably smaller than nrow*ncol. Must be specified if density is not.
symmetric logical indicating if result should be a matrix of class symmetricMatrix. Note that in the symmetric case, nnz denotes the number of non zero entries of the upper (or lower) part of the matrix, including the diagonal.

rand.x NULL or the random number generator for the x slot, a function such that rand.x(n) generates a numeric vector of length n. Typical examples are rand.x = rnorm, or rand.x = runif; the default is nice for didactical purposes.

... optionally further arguments passed to sparseMatrix(), notably repr.
Details

The algorithm first samples “encoded” \((i, j)\)s without replacement, via one dimensional indices, if not symmetric \texttt{sample.int}(nrow*ncol, nnz), then—if \texttt{rand.x} is not NULL—gets \texttt{x} <- \texttt{rand.x(nnz)} and calls \texttt{spmatrix(i=i, j=j, x=x, ..)}. When \texttt{rand.x=NULL}, \texttt{spmatrix(i=i, j=j, ..)} will return a pattern matrix (i.e., inheriting from \texttt{nspmatrix}).

Value

a \texttt{sparseMatrix}, say \(M\) of dimension (nrow, ncol), i.e., with \texttt{dim(M) == c(nrow, ncol)}, if symmetric is not true, with \(nzM <\texttt{nnzero}(M)\) fulfilling \(nzM <\texttt{nnz}\) and typically, \(nzM == \texttt{nnz}\).

Author(s)

Martin Maechler

Examples

set.seed(17)# to be reproducible
\(M \leftarrow \texttt{rsparsematrix}(8, 12, \texttt{nnz} = 30)\) # small example, not very sparse
\(M\)
\(M1 \leftarrow \texttt{rsparsematrix}(1000, 20, \texttt{nnz} = 123, \texttt{rand.x = runif})\)
\texttt{summary(M1)}

## a random *symmetric* Matrix
\((S9 \leftarrow \texttt{rsparsematrix}(9, 9, \texttt{nnz} = 10, \texttt{symmetric=TRUE}))\) # \texttt{dsCMatrix}
\texttt{nnzero(S9)}# ~ 20: as 'nnz' only counts one "triangle"

## a random pattern aka boolean Matrix (no 'x' slot):
\((n7 \leftarrow \texttt{rsparsematrix}(5, 12, \texttt{nnz} = 10, \texttt{rand.x = NULL}))\)

## a [T]riplet representation \texttt{sparseMatrix}:
\(T2 \leftarrow \texttt{rsparsematrix}(40, 12, \texttt{nnz} = 99, \texttt{repr = "T"})\)
\texttt{head(T2)}
Schur-class

Slots

j: Object of class "integer" of length n nonzero (number of non-zero elements). These are the row numbers for each non-zero element in the matrix.

p: Object of class "integer" of pointers, one for each row, to the initial (zero-based) index of elements in the row.

Dim, Dimnames: inherited from the superclass, see sparseMatrix.

Extends

Class "sparseMatrix", directly. Class "Matrix", by class "sparseMatrix".

Methods

Originally, few methods were defined on purpose, as we rather use the CsparseMatrix in Matrix. Then, more methods were added but beware that these typically do not return "RsparseMatrix" results, but rather Csparse* or Tsparse* ones; e.g., R[1, j] <- v for an "RsparseMatrix" R works, but after the assignment, R is a (triplet) "TsparseMatrix".

t signature(x = "RsparseMatrix") ...
coerce signature(from = "RsparseMatrix", to = "CsparseMatrix") ...
coerce signature(from = "RsparseMatrix", to = "TsparseMatrix") ...

See Also

its superclass, sparseMatrix, and, e.g., class dgRMatrix for the links to other classes.

Examples

showClass("RsparseMatrix")

Schur-class

Schur Factorizations

Description

Schur is the class of Schur factorizations of \( n \times n \) real matrices \( A \), having the general form

\[
A = QTQ' \]

where \( Q \) is an orthogonal matrix and \( T \) is a block upper triangular matrix with 1 \( \times \) 1 or 2 \( \times \) 2 diagonal blocks specifying the real and complex conjugate eigenvalues of \( A \). The column vectors of \( Q \) are the Schur vectors of \( A \), and \( T \) is the Schur form of \( A \).

The Schur factorization generalizes the spectral decomposition of normal matrices \( A \), whose Schur form is block diagonal, to arbitrary square matrices.
Details

The matrix $A$ and its Schur form $T$ are similar and thus have the same spectrum. The eigenvalues are computed trivially as the eigenvalues of the diagonal blocks of $T$.

Slots

- Dim, Dimnames inherited from virtual class MatrixFactorization.
- Q an orthogonal matrix, inheriting from virtual class Matrix.
- T a block upper triangular matrix, inheriting from virtual class Matrix. The diagonal blocks have dimensions 1-by-1 or 2-by-2.
- EValues a numeric or complex vector containing the eigenvalues of the diagonal blocks of $T$, which are the eigenvalues of $T$ and consequently of the factorized matrix.

Extends

Class SchurFactorization, directly. Class MatrixFactorization, by class SchurFactorization, distance 2.

Instantiation

Objects can be generated directly by calls of the form new("Schur", ...), but they are more typically obtained as the value of Schur(x) for x inheriting from Matrix (often dgeMatrix).

Methods

determinant signature(from = "Schur", logarithm = "logical"): computes the determinant of the factorized matrix $A$ or its logarithm.
expand1 signature(x = "Schur"): see expand1-methods.
expand2 signature(x = "Schur"): see expand2-methods.
solve signature(a = "Schur", b = .): see solve-methods.

References

The LAPACK source code, including documentation; see https://netlib.org/lapack/double/dgees.f.

See Also

Class dgeMatrix.
Generic functions Schur, expand1 and expand2.
Examples

```
showClass("Schur")
set.seed(0)

n <- 4L
(A <- Matrix(rnorm(n * n), n, n))
## With dimnames, to see that they are propagated :
dimnames(A) <- list(paste0("r", seq_len(n)),
                 paste0("c", seq_len(n)))

(sch.A <- Schur(A))
str(e.sch.A <- expand2(sch.A), max.level = 2L)
## A ~ Q T Q' in floating point
stopifnot(exprs = {
  identical(names(e.sch.A), c("Q", "T", "Q."))
  all.equal(A, with(e.sch.A, Q %*% T %*% Q.))
})
## Factorization handled as factorized matrix
b <- rnorm(n)
stopifnot(all.equal(det(A), det(sch.A)),
          all.equal(solve(A, b), solve(sch.A, b)))
## One of the non-general cases:
Schur(Diagonal(6L))
```

---

### Description

Computes the Schur factorization of an $n \times n$ real matrix $A$, which has the general form

$$A = QTQ'$$

where $Q$ is an orthogonal matrix and $T$ is a block upper triangular matrix with $1 \times 1$ and $2 \times 2$ diagonal blocks specifying the real and complex conjugate eigenvalues of $A$. The column vectors of $Q$ are the Schur vectors of $A$, and $T$ is the Schur form of $A$.

Methods are built on LAPACK routine dgees.

### Usage

```
Schur(x, vectors = TRUE, ...)
```
Schur-methods

Arguments

x a finite square matrix or Matrix to be factorized.

vectors a logical. If TRUE (the default), then Schur vectors are computed in addition to the Schur form.

... further arguments passed to or from methods.

Value

An object representing the factorization, inheriting from virtual class SchurFactorization if vectors = TRUE. Currently, the specific class is always Schur in that case.

An exception is if x is a traditional matrix, in which case the result is a named list containing Q, T, and EValues slots of the Schur object.

If vectors = FALSE, then the result is the same named list but without Q.

References

The LAPACK source code, including documentation; see https://netlib.org/lapack/double/dgees.f.


See Also

Class Schur and its methods.

Class dgeMatrix.

Generic functions expand1 and expand2, for constructing matrix factors from the result.

Generic functions Cholesky, BunchKaufman, lu, and qr, for computing other factorizations.

Examples

showMethods("Schur", inherited = FALSE)
set.seed(0)

Schur(Hilbert(9L)) # real eigenvalues

(A <- Matrix(round(rnorm(25L, sd = 100)), 5L, 5L))
(sch.A <- Schur(A)) # complex eigenvalues

## A ~ Q T Q' in floating point
str(e.sch.A <- expand2(sch.A), max.level = 2L)
stopifnot(all.equal(A, Reduce(`%*%`, e.sch.A)))

(e1 <- eigen(sch.A@T, only.values = TRUE)$values)
(e2 <- eigen(A , only.values = TRUE)$values)
(e3 <- sch.A@EValues)

stopifnot(exprs = {
all.equal(e1, e2, tolerance = 1e-13)
all.equal(e1, e3[order(Mod(e3), decreasing = TRUE)], tolerance = 1e-13)
identical(Schur(A, vectors = FALSE),
        list(T = sch.A@T, EValues = e3))
identical(Schur(as(A, "matrix")),
        list(Q = as(sch.A@Q, "matrix"),
             T = as(sch.A@T, "matrix"), EValues = e3))
)

solve-methods

Methods in Package Matrix for Function solve

Description

Methods for generic function `solve` for solving linear systems of equations, i.e., for \( X \) in \( AX = B \), where \( A \) is a square matrix and \( X \) and \( B \) are matrices with dimensions consistent with \( A \).

Usage

```
solve(a, b, ...)
```

## S4 method for signature 'dgeMatrix,ANY'
solve(a, b, tol = .Machine$double.eps, ...)

## S4 method for signature 'dgCMatrix,missing'
solve(a, b, sparse = TRUE, ...)

## S4 method for signature 'dgCMatrix,matrix'
solve(a, b, sparse = FALSE, ...)

## S4 method for signature 'dgCMatrix,denseMatrix'
solve(a, b, sparse = FALSE, ...)

## S4 method for signature 'dgCMatrix,sparseMatrix'
solve(a, b, sparse = TRUE, ...)

## S4 method for signature 'denseLU,dgeMatrix'
solve(a, b, ...)

## S4 method for signature 'BunchKaufman,dgeMatrix'
solve(a, b, ...)

## S4 method for signature 'Cholesky,dgeMatrix'
solve(a, b, ...)

## S4 method for signature 'sparseLU,dgCMatrix'
solve(a, b, tol = .Machine$double.eps, ...)

## S4 method for signature 'sparseQR,dgCMatrix'
solve(a, b, ...)

## S4 method for signature 'CHMfactor,dgCMatrix'
solve(a, b, system = c("A", "LDLt", "LD", "DLt", "L", "Lt", "D", "P", "Pt"), ...)
Arguments

a  a finite square matrix or Matrix containing the coefficients of the linear system, or otherwise a MatrixFactorization, in which case methods behave (by default) as if the factorized matrix were specified.

b  a vector, sparseVector, matrix, or Matrix satisfying NROW(b) == nrow(a), giving the right-hand side(s) of the linear system. Vectors b are treated as length(b)-by-1 matrices. If b is missing, then methods take b to be an identity matrix.

tol  a non-negative number. For a inheriting from denseMatrix, an error is signaled if the reciprocal one-norm condition number (see rcond) of a is less than tol, indicating that a is near-singular. For a of class sparseLU, an error is signaled if the ratio min(d)/max(d) is less than tol, where d = abs(diag(a@U)). (Interpret with care, as this ratio is a cheap heuristic and not in general equal to or even proportional to the reciprocal one-norm condition number.) Setting tol = 0 disables the test.

sparse  a logical indicating if the result should be formally sparse, i.e., if the result should inherit from virtual class sparseMatrix. Only methods for sparse a and missing or matrix b have this argument. Methods for missing or sparse b use sparse = TRUE by default. Methods for dense b use sparse = FALSE by default.

system  a string specifying a linear system to be solved. Only methods for a inheriting from CHMfactor have this argument. See ‘Details’.

...  further arguments passed to or from methods.

Details

Methods for general and symmetric matrices a compute a triangular factorization (LU, Bunch-Kaufman, or Cholesky) and call the method for the corresponding factorization class. The factorization is sparse if a is. Methods for sparse, symmetric matrices a attempt a Cholesky factorization and perform an LU factorization only if that fails (typically because a is not positive definite).

Triangular, diagonal, and permutation matrices do not require factorization (they are already “factors”), hence methods for those are implemented directly. For triangular a, solutions are obtained by forward or backward substitution; for diagonal a, they are obtained by scaling the rows of b; and for permutations a, they are obtained by permuting the rows of b.

Methods for dense a are built on 14 LAPACK routines: class d..Matrix, where ..=(ge|tr|tp|sy|sp|po|pp), uses routines d..tri and d..trs for missing and non-missing b, respectively. A corollary is that these methods always give a dense result.

Methods for sparse a are built on CSparse routines cs_lsolve, cs_usolve, and cs_spsolve and CHOLMOD routines cholmod_solve and cholmod_spsolve. By default, these methods give a vector result if b is a vector, a sparse matrix result if b is missing or a sparse matrix, and a dense matrix result if b is a dense matrix. One can override this behaviour by setting the sparse argument, where available, but that should be done with care. Note that a sparse result may be sparse only in the formal sense and not at all in the mathematical sense, depending on the nonzero patterns of a and b. Furthermore, whereas dense results are fully preallocated, sparse results must be “grown” in a loop over the columns of b.

Methods for a of class sparseQR are simple wrappers around qr.coef, giving the least squares solution in overdetermined cases.
Methods for a inheriting from CHMfactor can solve systems other than the default one \( AX = B \). The correspondence between its system argument the system actually solved is outlined in the table below. See CHMfactor-class for a definition of notation.

<table>
<thead>
<tr>
<th>system</th>
<th>isLDL(a)=TRUE</th>
<th>isLDL(a)=FALSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;A&quot;</td>
<td>( AX = B )</td>
<td>( AX = B )</td>
</tr>
<tr>
<td>&quot;LDLt&quot;</td>
<td>( L_1 DL_1'X = B )</td>
<td>( LL'X = B )</td>
</tr>
<tr>
<td>&quot;LD&quot;</td>
<td>( L_1 DX = B )</td>
<td>( LX = B )</td>
</tr>
<tr>
<td>&quot;DLt&quot;</td>
<td>( DL_1'X = B )</td>
<td>( L'X = B )</td>
</tr>
<tr>
<td>&quot;L&quot;</td>
<td>( L_1 X = B )</td>
<td>( LX = B )</td>
</tr>
<tr>
<td>&quot;Lt&quot;</td>
<td>( L_1'X = B )</td>
<td>( L'X = B )</td>
</tr>
<tr>
<td>&quot;D&quot;</td>
<td>( DX = B )</td>
<td>( X = B )</td>
</tr>
<tr>
<td>&quot;Pt&quot;</td>
<td>( P_1'B )</td>
<td>( P_1'B )</td>
</tr>
</tbody>
</table>

See Also

Virtual class MatrixFactorization and its subclasses.

Generic functions Cholesky, BunchKaufman, Schur, lu, and qr for computing factorizations.

Generic function solve from base.

Function qr.coef from base for computing least squares solutions of overdetermined linear systems.

Examples

```r
## A close to symmetric example with "quite sparse" inverse:

n1 <- 7; n2 <- 3
dd <- data.frame(a = gl(n1,n2), b = gl(n2,1,n1*n2))# balanced 2-way
X <- sparse.model.matrix(~ -1+ a + b, dd)# no intercept --> even sparser
XXt <- tcrossprod(X)
diag(XXt) <- rep(c(0,0,1,0), length.out = nrow(XXt))
n <- nrow(ZZ <- kronecker(XXt, Diagonal(x=c(4,1))))
image(a <- 2*Diagonal(n) + ZZ %*% Diagonal(x=c(10, rep(1, n-1))))
isSymmetric(a) # FALSE
image(drop0(skewpart(a)))
image(ia0 <- solve(a, tol = 0)) # checker board, dense [but really, a is singular!]
try(solve(a, sparse=TRUE))##-> error [ TODO: assertError ]

```
sparse.model.matrix

Construct Sparse Design / Model Matrices

Description

Construct a sparse model or “design” matrix, from a formula and data frame (sparse.model.matrix) or a single factor (fac2sparse).

The fac2[Sp]arse() functions are utilities, also used internally in the principal user level function sparse.model.matrix().

Usage

sparse.model.matrix(object, data = environment(object),
contrasts.arg = NULL, xlev = NULL, transpose = FALSE,
drop.unused.levels = FALSE, row.names = TRUE,
sep = "", verbose = FALSE, ...)

fac2sparse(from, to = c("d", "l", "n"),
drop.unused.levels = TRUE, repr = c("C", "R", "T"), giveCsparse)
fac2Sparse(from, to = c("d", "l", "n"),
drop.unused.levels = TRUE, repr = c("C", "R", "T"), giveCsparse,
factorPatt12, contrasts.arg = NULL)

Arguments

object an object of an appropriate class. For the default method, a model formula or terms object.
data a data frame created with model.frame. If another sort of object, model.frame is called first.

contrasts.arg for sparse.model.matrix(): A list, whose entries are contrasts suitable for input to the contrasts replacement function and whose names are the names of columns of data containing factors.

for fac2Sparse(): character string or NULL or (coercable to) "sparseMatrix", specifying the contrasts to be applied to the factor levels.
xlev to be used as argument of model.frame if data has no "terms" attribute.

transpose logical indicating if the transpose should be returned; if the transposed is used anyway, setting transpose = TRUE is more efficient.
drop.unused.levels should factors have unused levels dropped? The default for sparse.model.matrix has been changed to FALSE, 2010-07, for compatibility with R’s standard (dense) model.matrix().
row.names logical indicating if row names should be used.
sep character string passed to \texttt{paste()} when constructing column names from the variable name and its levels.
verbose logical or integer indicating if (and how much) progress output should be printed.
... further arguments passed to or from other methods.
from (for \texttt{fac2sparse()}) a \texttt{factor}.
to a character indicating the “kind” of sparse matrix to be returned. The default, "d" is for \texttt{double}.
giveCsparse \texttt{deprecated}, replaced with \texttt{repr}; logical indicating if the result must be a \texttt{CsparseMatrix}.
repr character string, one of "C", "T", or "R", specifying the sparse representation to be used for the result, i.e., one from the super classes \texttt{CsparseMatrix}, \texttt{TsparseMatrix}, or \texttt{RsparseMatrix}.
factorPatt12 logical vector, say fp, of length two; when fp[1] is true, return “contrasted” t(X); when fp[2] is true, the original (“dummy”) t(X), i.e, the result of \texttt{fac2sparse()}.  

Value  
a sparse matrix, extending \texttt{CsparseMatrix} (for \texttt{fac2sparse()} if \texttt{repr = "C"} as per default; a \texttt{TsparseMatrix} or \texttt{RsparseMatrix}, otherwise).

For \texttt{fac2Sparse()}, a \texttt{list} of length two, both components with the corresponding transposed model matrix, where the corresponding \texttt{factorPatt12} is true.

\texttt{fac2sparse()}, the basic workhorse of \texttt{sparse.model.matrix()}, returns the transpose (t) of the model matrix.

Note  
model.Matrix(sparse = TRUE) from package \texttt{MatrixModels} may be nowadays be preferable to \texttt{sparse.model.matrix}, as model.Matrix returns an object of class modelMatrix with additional slots assign and contrasts relating to the model variables.

Author(s)  
Doug Bates and Martin Maechler, with initial suggestions from Tim Hesterberg.

See Also  
\texttt{model.matrix} in package \texttt{stats}, part of base \texttt{R}.
model.Matrix in package \texttt{MatrixModels}; see ‘Note’.
\texttt{as(f, "sparseMatrix")} (see \texttt{coerce(from = "factor", \ldots)} in the class doc \texttt{sparseMatrix}) produces the transposed sparse model matrix for a single factor \texttt{f} (and no contrasts).
Examples

dd <- data.frame(a = gl(3,4), b = gl(4,1,12))  # balanced 2-way
options("contrasts") # the default: "contr.treatment"
sparse.model.matrix(~ a + b, dd)
sparse.model.matrix(~ -1+ a + b, dd)  # no intercept --> even sparser
sparse.model.matrix(~ a + b, dd, contrasts = list(a="contr.sum"))
sparse.model.matrix(~ a + b, dd, contrasts = list(b="contr.SAS"))

## Sparse method is equivalent to the traditional one:
stopifnot(all(sparse.model.matrix(~ a + b, dd) ==
              Matrix(model.matrix(~ a + b, dd), sparse=TRUE)),
          all(sparse.model.matrix(~0 + a + b, dd) ==
              Matrix(model.matrix(~0 + a + b, dd), sparse=TRUE)))

(ff <- gl(3,4,, c("X","Y", "Z")))
fac2sparse(ff)  # 3 x 12 sparse Matrix of class "dgCMatrix"

## can also be computed via sparse.model.matrix():
f30 <- gl(3,0)
f12 <- gl(3,0, 12)
stopifnot(
    all.equal(t( fac2sparse(ff) ),
               sparse.model.matrix(~ 0+ff),
               tolerance = 0, check.attributes=FALSE),
    is(M <- fac2sparse(f30, drop= TRUE),"CsparseMatrix"), dim(M) == c(0, 0),
    is(M <- fac2sparse(f30, drop=FALSE),"CsparseMatrix"), dim(M) == c(3, 0),
    is(M <- fac2sparse(f12, drop= TRUE),"CsparseMatrix"), dim(M) == c(0,12),
    is(M <- fac2sparse(f12, drop=FALSE),"CsparseMatrix"), dim(M) == c(3,12) )

sparseLU-class  Sparse LU Factorizations

Description

sparseLU is the class of sparse, row- and column-pivoted LU factorizations of \( n \times n \) real matrices \( A \), having the general form

\[
P_1 A P_2 = LU
\]

or (equivalently)

\[
A = P_1' L U P_2'
\]

where \( P_1 \) and \( P_2 \) are permutation matrices, \( L \) is a unit lower triangular matrix, and \( U \) is an upper triangular matrix.
slots

Dim, Dimnames inherited from virtual class MatrixFactorization.

L an object of class dtCMatrix, the unit lower triangular L factor.

U an object of class dtCMatrix, the upper triangular U factor.

p, q 0-based integer vectors of length Dim[1], specifying the permutations applied to the rows and columns of the factorized matrix. q of length 0 is valid and equivalent to the identity permutation, implying no column pivoting. Using R syntax, the matrix \( P_1 A P_2 \) is precisely \( A[p+1, q+1] \) (\( A[p+1, \) when \( q \) has length 0).

extends

Class LU, directly. Class MatrixFactorization, by class LU, distance 2.

instantiation

Objects can be generated directly by calls of the form new("sparseLU", ...), but they are more typically obtained as the value of lu(x) for x inheriting from sparseMatrix (often dgCMatrix).

methods

determinant signature(from = "sparseLU", logarithm = "logical"): computes the determinant of the factorized matrix \( A \) or its logarithm.

expand signature(x = "sparseLU"): see expand-methods.

expand1 signature(x = "sparseLU"): see expand1-methods.

expand2 signature(x = "sparseLU"): see expand2-methods.

solve signature(a = "sparseLU", b = .): see solve-methods.

references


see also

Class denseLU for dense LU factorizations.

Class dgCMatrix.

Generic functions lu, expand1 and expand2.
Examples

showClass("sparseLU")
set.seed(2)

A <- as(readMM(system.file("external", "pores_1.mtx", package = "Matrix")), "CsparseMatrix")
(n <- A@Dim[1L])

## With dimnames, to see that they are propagated :
dimnames(A) <- dn <- list(paste0("r", seq_len(n)),
paste0("c", seq_len(n)))

(lu.A <- lu(A))
str(e.lu.A <- expand2(lu.A), max.level = 2L)

ae1 <- function(a, b, ...) all.equal(as(a, "matrix"), as(b, "matrix"), ...)
ae2 <- function(a, b, ...) ae1(unname(a), unname(b), ...)

## A ~ P1' L U P2' in floating point
stopifnot(exprs = {
  identical(names(e.lu.A), c("P1.", "L", "U", "P2.")),
  identical(e.lu.A[["P1."]],
    new("pMatrix", Dim = c(n, n), Dimnames = c(dn[1L], list(NULL)),
      margin = 1L, perm = invertPerm(lu.A@p, 0L, 1L)));
  identical(e.lu.A[["P2."]],
    new("pMatrix", Dim = c(n, n), Dimnames = c(list(NULL), dn[2L]),
      margin = 2L, perm = invertPerm(lu.A@q, 0L, 1L)));
  identical(e.lu.A[["L"]], lu.A@L),
  identical(e.lu.A[["U"]], lu.A@U),
  ae1(A, with(e.lu.A, P1. %*% L %*% U %*% P2.))
  ae2(A[lu.A@p + 1L, lu.A@q + 1L], with(e.lu.A, L %*% U))})

## Factorization handled as factorized matrix
b <- rnorm(n)
stopifnot(identical(det(A), det(lu.A)),
  identical(solve(A, b), solve(lu.A, b)))

Description

User-friendly construction of sparse matrices (inheriting from virtual class CsparseMatrix, RsparseMatrix, or TsparseMatrix) from the positions and values of their nonzero entries.

This interface is recommended over direct construction via calls such as new("..[CRT]Matrix", ...).
Usage

sparseMatrix(i, j, p, x, dims, dimnames,
    symmetric = FALSE, triangular = FALSE, index1 = TRUE,
    repr = c("C", "R", "T"), giveCsparse,
    check = TRUE, use.last.ij = FALSE)

Arguments

i, j   integer vectors of equal length specifying the positions (row and column indices) of the nonzero (or non-TRUE) entries of the matrix. Note that, when x is non-missing, the \( x_k \) corresponding to repeated pairs \((i_k, j_k)\) are added, for consistency with the definition of class \texttt{TsparseMatrix}, unless use.last.ij is TRUE, in which case only the last such \( x_k \) is used.

p   integer vector of pointers, one for each column (or row), to the initial (zero-based) index of elements in the column (or row). Exactly one of i, j, and p must be missing.

x   optional, typically nonzero values for the matrix entries. If specified, then the length must equal that of i (or j) or equal 1, in which case x is recycled as necessary. If missing, then the result is a nonzero pattern matrix, i.e., inheriting from class \texttt{n sparseMatrix}.

dims   optional length-2 integer vector of matrix dimensions. If missing, then !index1+c(max(i),max(j)) is used.

dimnames   optional list of \texttt{dimnames}; if missing, then \texttt{NULL} ones are used.

symmetric   logical indicating if the resulting matrix should be symmetric. In that case, \((i, j, p)\) should specify only one triangle (upper or lower).

triangular   logical indicating if the resulting matrix should be triangular. In that case, \((i, j, p)\) should specify only one triangle (upper or lower).

index1   logical. If TRUE (the default), then i and j are interpreted as 1-based indices, following the \texttt{R} convention. That is, counting of rows and columns starts at 1. If FALSE, then they are interpreted as 0-based indices.

repr   character string, one of "C", "R", and "T", specifying the representation of the sparse matrix result, i.e., specifying one of the virtual classes \texttt{CsparseMatrix}, \texttt{RsparseMatrix}, and \texttt{T sparseMatrix}.

giveCsparse   (deprecated, replaced by \texttt{repr}) logical indicating if the result should inherit from \texttt{CsparseMatrix} or \texttt{T sparseMatrix}. Note that operations involving \texttt{CsparseMatrix} are very often (but not always) more efficient.

check   logical indicating whether to check that the result is formally valid before returning. Do not set to FALSE unless you know what you are doing!

use.last.ij   logical indicating if, in the case of repeated (duplicated) pairs \((i_k, j_k)\), only the last pair should be used. FALSE (the default) is consistent with the definition of class \texttt{TsparseMatrix}.

Details

Exactly one of the arguments i, j and p must be missing.
In typical usage, \( p \) is missing, \( i \) and \( j \) are vectors of positive integers and \( x \) is a numeric vector. These three vectors, which must have the same length, form the triplet representation of the sparse matrix.

If \( i \) or \( j \) is missing then \( p \) must be a non-decreasing integer vector whose first element is zero. It provides the compressed, or “pointer” representation of the row or column indices, whichever is missing. The expanded form of \( p \), \( \text{rep(seq_along(dp),dp)} \) where \( dp \leftarrow \text{diff}(p) \), is used as the (1-based) row or column indices.

You cannot set both singular and triangular to true; rather use \texttt{Diagonal()} (or its alternatives, see there).

The values of \( i \), \( j \), \( p \) and \texttt{index1} are used to create 1-based index vectors \( i \) and \( j \) from which a \texttt{TsparseMatrix} is constructed, with numerical values given by \( x \), if non-missing. Note that in that case, when some pairs \((i_k,j_k)\) are repeated (aka “duplicated”), the corresponding \( x_k \) are added, in consistency with the definition of the \texttt{TsparseMatrix} class, unless \texttt{use.last.ij} is set to true.

By default, when \texttt{repr = "C"}, the \texttt{CsparseMatrix} derived from this triplet form is returned, where \texttt{repr = "R"} now allows to directly get an \texttt{RsparseMatrix} and \texttt{repr = "T"} leaves the result as \texttt{TsparseMatrix}.

The reason for returning a \texttt{CsparseMatrix} object instead of the triplet format by default is that the compressed column form is easier to work with when performing matrix operations. In particular, if there are no zeros in \( x \) then a \texttt{CsparseMatrix} is a unique representation of the sparse matrix.

### Value

A sparse matrix, by default in compressed sparse column format and (formally) without symmetric or triangular structure, i.e., by default inheriting from both \texttt{CsparseMatrix} and \texttt{generalMatrix}.

### Note

You do need to use \texttt{index1 = FALSE} (or add + 1 to \( i \) and \( j \)) if you want use the 0-based \( i \) (and \( j \)) slots from existing sparse matrices.

### See Also

\texttt{Matrix(*, sparse=TRUE)} for the constructor of such matrices from a \textit{dense} matrix. That is easier in small sample, but much less efficient (or impossible) for large matrices, where something like \texttt{sparseMatrix()} is needed. Further \texttt{bdiag} and \texttt{Diagonal} for (block-)diagonal and \texttt{bandSparse} for banded sparse matrix constructors.

Random sparse matrices via \texttt{rsparsematrix()}.

The standard \texttt{xtabs(*, sparse=TRUE)}, for sparse tables and \texttt{sparse.model.matrix()} for building sparse model matrices.

Consider \texttt{CsparseMatrix} and similar class definition help files.

### Examples

```r
## simple example
i <- c(1,3:8); j <- c(2,9,6:10); x <- 7 * 1:7
(A <- sparseMatrix(i, j, x = x))  # 8 x 10 "dgCMatrix"
```
summary(A)
str(A) # note that *internally* 0-based row indices are used

(sA <- sparseMatrix(i, j, x = x, symmetric = TRUE)) ## 10 x 10 "dsCMatrix"
(tA <- sparseMatrix(i, j, x = x, triangular= TRUE)) ## 10 x 10 "dtCMatrix"

stopifnot( all(sA == tA + t(tA)) ,
           identical(sA, as(tA + t(tA), "symmetricMatrix")))

## dims can be larger than the maximum row or column indices

AA <- sparseMatrix(c(1,3:8), c(2,9,6:10), x = 7 * (1:7), dims = c(10,20))

summary(AA)

## i, j and x can be in an arbitrary order, as long as they are consistent

set.seed(1); (perm <- sample(1:7))

(A1 <- sparseMatrix(i[perm], j[perm], x = x[perm]))

stopifnot(identical(A, A1))

## The slots are 0-index based, so

try( sparseMatrix(i=A$i, p=A$p, x= seq_along(A$x)) )

## fails and you should say so: 1-indexing is FALSE:

sparseMatrix(i=A$i, p=A$p, x= seq_along(A$x), index1 = FALSE)

## the (i,j) pairs can be repeated, in which case the x's are summed

(args <- data.frame(i = c(i, 1), j = c(j, 2), x = c(x, 2)))

(Aa <- do.call(sparseMatrix, args))

## explicitly ask for elimination of such duplicates, so

## that the last one is used:

(A. <- do.call(sparseMatrix, c(args, list(use.last.ij = TRUE))))

stopifnot(Aa[1,2] == 9, # 2+7 == 9
           A.[1,2] == 2) # 2 was *after* 7

## for a pattern matrix, of course there is no "summing":

(nA <- do.call(sparseMatrix, args[c("i","j")]))

dn <- list(LETTERS[1:3], letters[1:5])

## pointer vectors can be used, and the (i,x) slots are sorted if necessary:

m <- sparseMatrix(i = c(3,1, 3:2, 2:1), p= c(0:2, 4,4,6), x = 1:6, dimnames = dn)

str(m)

stopifnot(identical(dimnames(m), dn))

sparseMatrix(x = 2.72, i=1:3, j=2:4) # recycling x
sparseMatrix(x = TRUE, i=1:3, j=2:4) # recycling x, |--> "lgCMatrix"

## no 'x' --> pattern* matrix:

(n <- sparseMatrix(i=1:6, j=rev(2:7)))# -> ngCMatrix

## an empty sparse matrix:

(e <- sparseMatrix(dims = c(4,6), i={}, j={}))

## a symmetric one:

(sy <- sparseMatrix(i= c(2,4,3:5), j= c(4,7:5,5), x = 1:5,
                       dims = c(7,7), symmetric=TRUE))
stopifnot(isSymmetric(sy),
    identical(sy, ## switch i <-> j (and transpose )
    t( sparseMatrix(j= c(2,4,3:5), i= c(4,7:5,5), x = 1:5,
        dims = c(7,7), symmetric=TRUE))))

## rsparsematrix() calls sparseMatrix() :
M1 <- rsparsematrix(1000, 20, nnz = 200)
summary(M1)

## pointers example in converting from other sparse matrix representations.
if(requireNamespace("SparseM") &&
    packageVersion("SparseM") >= "0.87" &&
    nzchar(dfil <- system.file("extdata", "rua_32_ax.rua", package = "SparseM"))) {
    X <- SparseM::model.matrix(SparseM::read.matrix.hb(dfil))
    XX <- sparseMatrix(j = X@ja, p = X@ia - 1L, x = X@ra, dims = X@dimension)
    validObject(XX)

    ## Alternatively, and even more user friendly :
    X. <- as(X, "Matrix") # or also
    X2 <- as(X, "sparseMatrix")
    stopifnot(identical(XX, X.), identical(X., X2))
}

---

sparseMatrix-class  
Virtual Class "sparseMatrix" — Mother of Sparse Matrices

Description

Virtual Mother Class of All Sparse Matrices

Slots

Dim: Object of class "integer" - the dimensions of the matrix - must be an integer vector with exactly two non-negative values.

Dimnames: a list of length two - inherited from class Matrix, see Matrix.

Extends

Class "Matrix", directly.

Methods

show (object = "sparseMatrix"): The show method for sparse matrices prints "structural" zeroes as "." using printSpMatrix() which allows further customization.

print signature(x = "sparseMatrix"), ....
  The print method for sparse matrices by default is the same as show() but can be called with extra optional arguments, see printSpMatrix().

---
format signature(x = "sparseMatrix"), ....

The format method for sparse matrices, see formatSpMatrix() for details such as the extra optional arguments.

summary (object = "sparseMatrix", uniqT=FALSE): Returns an object of S3 class "sparseSummary" which is basically a data.frame with columns (i,j,x) (or just (i,j) for nsparseMatrix class objects) with the stored (typically non-zero) entries. The print method resembles Matlab's way of printing sparse matrices, and also the MatrixMarket format, see writeMM.

cbind2 (x = *, y = *): several methods for binding matrices together, column-wise, see the basic cbind and rbind functions.

Note that the result will typically be sparse, even when one argument is dense and larger than the sparse one.

rbind2 (x = *, y = *): binding matrices together row-wise, see cbind2 above.

determinant (x = "sparseMatrix", logarithm=TRUE): determinant() methods for sparse matrices typically work via Cholesky or lu decompositions.

diag (x = "sparseMatrix"): extracts the diagonal of a sparse matrix.

dim< signature(x = "sparseMatrix", value = "ANY"): allows to reshape a sparse matrix to a sparse matrix with the same entries but different dimensions. value must be of length two and fulfill prod(value) == prod(dim(x)).

coerce signature(from = "factor", to = "sparseMatrix"): Coercion of a factor to "sparseMatrix" produces the matrix of indicator rows stored as an object of class "dgCMatrix". To obtain columns representing the interaction of the factor and a numeric covariate, replace the "x" slot of the result by the numeric covariate then take the transpose. Missing values (NA) from the factor are translated to columns of all 0s.

See also colSums, norm, ... for methods with separate help pages.

Note

In method selection for multiplication operations (i.e. %*% and the two-argument form of crossprod) the sparseMatrix class takes precedence in the sense that if one operand is a sparse matrix and the other is any type of dense matrix then the dense matrix is coerced to a dgeMatrix and the appropriate sparse matrix method is used.

See Also

sparseMatrix, and its references, such as xtabs(*, sparse=TRUE), or sparse.model.matrix(), for constructing sparse matrices.

T2graph for conversion of "graph" objects (package graph) to and from sparse matrices.

Examples

showClass("sparseMatrix") ## and look at the help() of its subclasses
M <- Matrix(0, 10000, 100)
M[1,1] <- M[2,3] <- 3.14
M ## show(.) method suppresses printing of the majority of rows

data(CAex, package = "Matrix")
sparseQR-class

Sparse QR Factorizations

Description

sparseQR is the class of sparse, row- and column-pivoted QR factorizations of \( m \times n \) \( (m \geq n) \) real matrices, having the general form

\[
P_1AP_2 = QR = \begin{bmatrix} Q_1 & Q_2 \end{bmatrix} \begin{bmatrix} R_1 \\ 0 \end{bmatrix} = Q_1R_1
\]

or (equivalently)

\[
A = P'_2'QRP'_2 = P'_1' \begin{bmatrix} Q_1 & Q_2 \end{bmatrix} \begin{bmatrix} R_1 \\ 0 \end{bmatrix} P'_2 = P'_1 Q_1 R_1 P'_2
\]

where \( P_1 \) and \( P_2 \) are permutation matrices, \( Q = \prod_{j=1}^{n} H_j \) is an \( m \times m \) orthogonal matrix (\( Q_1 \) contains the first \( n \) column vectors) equal to the product of \( n \) Householder matrices \( H_j \), and \( R \) is an \( m \times n \) upper trapezoidal matrix (\( R_1 \) contains the first \( n \) row vectors and is upper triangular) with non-negative diagonal elements.

Usage

\[
\text{qrR(qr, complete = FALSE, backPermute = TRUE, row.names = TRUE)}
\]

Arguments

- **qr**: an object of class `sparseQR`, almost always the result of a call to generic function `qr` with sparse `x`.
- **complete**: a logical indicating if \( R \) should be returned instead of \( R_1 \).
- **backPermute**: a logical indicating if \( R \) or \( R_1 \) should be multiplied on the right by \( P'_2 \).
- **row.names**: a logical indicating if `dimnames(qr)[1]` should be propagated unpermuted to the result. If `complete = FALSE`, then only the first \( n \) names are kept.
Details

The method for qr.Q does not return $Q$ but rather the (also orthogonal) product $P_1'Q$. This behaviour is algebraically consistent with the base implementation (see qr), which can be seen by noting that qr.default in base does not pivot rows, constraining $P_1$ to be an identity matrix. It follows that qr.Q(qr.default(x)) also returns $P_1'Q$.

Similarly, the methods for qr.qy and qr.qty multiply on the left by $P_1'Q$ and $Q'P_1$ rather than $Q$ and $Q'$.

It is wrong to expect the values of qr.Q (or qr.R, qr.qy, qr.qty) computed from “equivalent” sparse and dense factorizations (say, qr(x) and qr(as(x, "matrix")) for x of class dgCMatrix) to compare equal. The underlying factorization algorithms are quite different, notably as they employ different pivoting strategies, and in general the factorization is not unique even for fixed $P_1$ and $P_2$.

On the other hand, the values of qr.X, qr.coef, qr.fitted, and qr.resid are well-defined, and in those cases the sparse and dense computations should compare equal (within some tolerance).

The method for qr.R is a simple wrapper around qrR, but not back-permuting by default and never giving row names. It did not support backPermute = TRUE until Matrix 1.6-0, hence code needing the back-permuted result should call qrR if Matrix >= 1.6-0 is not known.

Slots

Dim, Dimnames inherited from virtual class MatrixFactorization.

beta a numeric vector of length Dim[2], used to construct Householder matrices; see V below.

V an object of class dgCMatrix with Dim[2] columns. The number of rows nrow(V) is at least Dim[1] and at most Dim[1]+Dim[2]. V is lower trapezoidal, and its column vectors generate the Householder matrices $H_j$ that compose the orthogonal $Q$ factor. Specifically, $H_j$ is constructed as diag(Dim[1]) - beta[j] * tcrossprod(V[, j]).

R an object of class dgCMatrix with nrow(V) rows and Dim[2] columns. R is the upper trapezoidal $R$ factor with non-negative diagonal elements.

p, q 0-based integer vectors of length nrow(V) and Dim[2], respectively, specifying the permutations applied to the rows and columns of the factorized matrix. q of length 0 is valid and equivalent to the identity permutation, implying no column pivoting. Using R syntax, the matrix $P_1AP_2$ is precisely $A[p+1, q+1]$ ($A[p+1, ]$ when q has length 0).

Extends

Class QR, directly. Class MatrixFactorization, by class QR, distance 2.

Instantiation

Objects can be generated directly by calls of the form new("sparseQR", ...), but they are more typically obtained as the value of qr(x) for x inheriting from sparseMatrix (often dgCMatrix).

Methods

determinant signature(from = "sparseQR", logarithm = "logical"): computes the determinant of the factorized matrix $A$ or its logarithm.

expand1 signature(x = "sparseQR"): see expand1-methods.
expand2 signature(x = "sparseQR"): see expand2-methods.

qr.Q signature(qr = "sparseQR"): returns as a dgeMatrix either $P_1^TQ$ or $P_1^TQ_1$, depending on optional argument complete. The default is FALSE, indicating $P_1^TQ_1$.

qr.R signature(qr = "sparseQR"): qrR returns $R$, $R_1$, $RP_2^T$, or $R_1P_2^T$, depending on optional arguments complete and backPermute. The default in both cases is FALSE, indicating $R_1$, for compatibility with base. The class of the result in that case is dtCMatrix. In the other three cases, it is dgCMatrix.

qr.X signature(qr = "sparseQR"): returns $A$ as a dgeMatrix, by default. If $m > n$ and optional argument ncol is greater than $n$, then the result is augmented with $P_1^TQJ$, where $J$ is composed of columns $(n + 1)$ through ncol of the $m \times m$ identity matrix.

qr.coef signature(qr = "sparseQR", y = .): returns as a dgeMatrix or vector the result of multiplying $y$ on the left by $P_2R_1^{-1}Q_1'P_1$.

qr.fitted signature(qr = "sparseQR", y = .): returns as a dgeMatrix or vector the result of multiplying $y$ on the left by $P_1^TQ_1Q_1'P_1$.

qr.resid signature(qr = "sparseQR", y = .): returns as a dgeMatrix or vector the result of multiplying $y$ on the left by $P_1^TQ_2Q_2'P_1$.

qr.qty signature(qr = "sparseQR", y = .): returns as a dgeMatrix or vector the result of multiplying $y$ on the left by $Q'P_1$.

qr.qy signature(qr = "sparseQR", y = .): returns as a dgeMatrix or vector the result of multiplying $y$ on the left by $P_1^TQ$.

solve signature(a = "sparseQR", b = .): see solve-methods.

References


See Also

Class dgCMat.

Generic function qr from base, whose default method qr.default “defines” the S3 class qr of dense QR factorizations.

qr-methods for methods defined in Matrix.

Generic functions expand1 and expand2.


Examples

showClass("sparseQR")
set.seed(2)
m <- 300L
n <- 60L
A <- rsparsematrix(m, n, 0.05)

## With dimnames, to see that they are propagated:
dimnames(A) <- dn <- list(paste0("r", seq_len(m)),
paste0("c", seq_len(n)))

(qr.A <- qr(A))
str(e.qr.A <- expand2(qr.A, complete = FALSE), max.level = 2L)
str(E.qr.A <- expand2(qr.A, complete = TRUE), max.level = 2L)
t(sapply(e.qr.A, dim))
t(sapply(E.qr.A, dim))

### Horribly inefficient, but instructive:
slowQ <- function(V, beta) {
d <- dim(V)
Q <- diag(d[1L])
if(d[2L] > 0L) {
  for(j in d[2L]:1L) {
    cat(j, "\n", sep = "")
    Q <- Q - (beta[j] * tcrossprod(V[, j])) %*% Q
  }
}
Q
}

ae1 <- function(a, b, ...) all.equal(as(a, "matrix"), as(b, "matrix"), ...)
ae2 <- function(a, b, ...) ae1(unname(a), unname(b), ...)

## A ~ P1' QR P2' ~ P1' Q1 R1 P2' in floating point
stopifnot(exprs = {
  identical(names(e.qr.A), c("P1.", "Q1", "R1", "P2."))
  identical(names(E.qr.A), c("P1.", "Q", "R", "P2."))
  identical(e.qr.A[["P1."]],
    new("pMatrix", Dim = c(m, m), Dimnames = c(dn[1L], list(NULL)),
      margin = 1L, perm = invertPerm(qr.A@p, 0L, 1L)))
  identical(e.qr.A[["P2."]],
    new("pMatrix", Dim = c(n, n), Dimnames = c(list(NULL), dn[2L]),
      margin = 2L, perm = invertPerm(qr.A@q, 0L, 1L)))
  identical(e.qr.A[["R1"]], triu(E.qr.A["R"][seq_len(n),]))
  identical(e.qr.A[["Q1"]], E.qr.A["Q"][, seq_len(n)]
  identical(E.qr.A[["R"]], qr.A@R)
  
  # More identities
  ae1(E.qr.A[["Q"]], slowQ(qr.A@V, qr.A@beta))
  ae1(crossprod(E.qr.A[["Q"]], diag(m))
  ae1(A, with(e.qr.A, P1. %*% Q1 %*% R1 %*% P2.))
  ae1(A, with(E.qr.A, P1. %*% Q %*% R %*% P2.))
  ae2(A.perm <- A[qr.A@p + 1L, qr.A@q + 1L], with(e.qr.A, Q1 %*% R1))
  ae2(A.perm
    , with(E.qr.A, Q %*% R ))
})
b <- rnorm(m)
stopifnot(exprs = {
  ae1(qrX <- qr.X (qr.A ), A)
  ae2(qrQ <- qr.Q (qr.A ), with(e.qr.A, P1. %*% Q1))
  ae2(qr.R (qr.A ), with(e.qr.A, R1))
  ae2(qrc <- qr.coef (qr.A, b), with(e.qr.A, solve(R1 %*% P2., t(qrQ)) %*% b))
  ae2(qrf <- qr.fitted(qr.A, b), with(e.qr.A, tcrossprod(qrQ) %*% b))
  ae2(qrr <- qr.resid (qr.A, b), b - qrf)
  ae2(qrq <- qr.qy (qr.A, b), with(E.qr.A, P1. %*% Q %*% b))
  ae2(qr.qty(qr.A, qrq), b)
})
## Sparse and dense computations should agree here
qr.Am <- qr(as(A, "matrix")) # <= qr.default(A)
stopifnot(exprs = {
  ae2(qrX, qr.X (qr.Am ))
  ae2(qrc, qr.coef (qr.Am, b))
  ae2(qrf, qr.fitted(qr.Am, b))
  ae2(qrr, qr.resid (qr.Am, b))
})

---

sparseVector

Sparse Vector Construction from Nonzero Entries

Description

User friendly construction of sparse vectors, i.e., objects inheriting from class sparseVector, from indices and values of its non-zero entries.

Usage

sparseVector(x, i, length)

Arguments

x vector of the non zero entries; may be missing in which case a "nsparseVector" will be returned.

i integer vector (of the same length as x) specifying the indices of the non-zero (or non-TRUE) entries of the sparse vector.

length length of the sparse vector.

Details

zero entries in x are dropped automatically, analogously as drop0() acts on sparse matrices.

Value

a sparse vector, i.e., inheriting from class sparseVector.
Author(s)

Martin Maechler

See Also

sparseMatrix() constructor for sparse matrices; the class sparseVector.

Examples

str(sv <- sparseVector(x = 1:10, i = sample(999, 10), length=1000))

sx <- c(0,0,3, 3.2, 0,0,0,-3:1,0,0,2,0,0,5,0,0)
nss <- as(sx, "sparseVector")
stopifnot(identical(nss,
    sparseVector(x = c(2, -1, -2, 3, 1, -3, 5, 3.2),
    i = c(15L, 10:9, 3L,12L,8L,18L, 4L), length = 20L)))

(ns <- sparseVector(i= c(7, 3, 2), length = 10))
stopifnot(identical(ns,
    new("nsparseVector", length = 10, i = c(2, 3, 7))))

## sparseVector-class Sparse Vector Classes

Description

Sparse Vector Classes: The virtual mother class "sparseVector" has the five actual daughter classes "dsparseVector", "lsparseVector", "nsparseVector", and "zsparseVector", where we've mainly implemented methods for the d*, l* and n* ones.

Slots

length: class "numeric" - the length of the sparse vector. Note that "numeric" can be considerably larger than the maximal "integer", .Machine$integer.max, on purpose.

i: class "numeric" - the (1-based) indices of the non-zero entries. Must not be NA and strictly sorted increasingly.
    Note that "integer" is "part of" "numeric", and can (and often will) be used for non-huge sparseVectors.

x: (for all but "nsparseVector"): the non-zero entries. This is of class "numeric" for class "dsparseVector", "logical" for class "lsparseVector", etc.
    Note that "nsparseVector"s have no x slot. Further, mainly for ease of method definitions, we've defined the class union (see setClassUnion) of all sparse vector classes which have an x slot, as class "xsparseVector".
Methods

**length**  signature(x = "sparseVector"): simply extracts the length slot.

**show**  signature(object = "sparseVector"): The show method for sparse vectors prints "structural" zeroes as "." using the non-exported prSpVector function which allows further customization such as replacing "." by " " (blank).

Note that options(max.print) will influence how many entries of large sparse vectors are printed at all.

**as.vector**  signature(x = "sparseVector", mode = "character") coerces sparse vectors to "regular", i.e., atomic vectors. This is the same as as(x, "vector").

**as ...**: see coerce below

**coerce**  signature(from = "sparseVector", to = "sparseMatrix"). and

**coerce**  signature(from = "sparseMatrix", to = "sparseVector"), etc: coercions to and from sparse matrices (sparseMatrix) are provided and work analogously as in standard R, i.e., a vector is coerced to a 1-column matrix.

**dim<-**  signature(x = "sparseVector", value = "integer") coerces a sparse vector to a sparse Matrix, i.e., an object inheriting from sparseMatrix, of the appropriate dimension.

**head**  signature(x = "sparseVector"): as with R’s (package util) head, head(x, n) (for \( n \geq 1 \)) is equivalent to \( x[1:n] \), but here can be much more efficient, see the example.

**tail**  signature(x = "sparseVector"): analogous to head, see above.

**toeplitz**  signature(x = "sparseVector"): as toeplitz(x), produce the \( n \times n \) Toeplitz matrix from \( x \), where \( n = \text{length}(x) \).

**rep**  signature(x = "sparseVector") repeat \( x \), with the same argument list \( (x, \text{times}, \text{length.out}, \text{each}, \ldots) \) as the default method for rep().

**which**  signature(x = "nsparseVector") and

**which**  signature(x = "lsparseVector") return the indices of the non-zero entries (which is trivial for sparse vectors).

**Ops**  signature(e1 = "sparseVector", e2 = ").": define arithmetic, compare and logic operations, (see Ops).

**Summary**  signature(x = "sparseVector"): define all the Summary methods.

**[**  signature(x = "atomicVector", i = \ldots"): not only can you subset (aka “index into”) sparseVectors \( x[i] \) using sparseVectors \( i \), but we also support efficient subsetting of traditional vectors \( x \) by logical sparse vectors (i.e., \( i \) of class "nsparseVector" or "lsparseVector").

**is.na**, **is.finite**, **is.infinite**  \( x = \"sparseVector\")", and

**is.na**, **is.finite**, **is.infinite**  \( x = \"nsparseVector\")": return logical or "nsparseVector" of the same length as \( x \), indicating if/where \( x \) is NA (or NaN), finite or infinite, entirely analogously to the corresponding base R functions.

c. sparseVector() is an S3 method for all "sparseVector"s, but automatic dispatch only happens for the first argument, so it is useful also as regular R function, see the examples.

See Also

**sparseVector**() for friendly construction of sparse vectors (apart from as(*, "sparseVector")).
Examples

```
getClass("sparseVector")
getClass("dsparseVector")
getClass("xsparseVector") # those with an 'x' slot
sx <- c(0,0,3, 3.2, 0,0,0,-3:1,0,0,2,0,0,5,0,0)
(ss <- as(sx, "sparseVector"))

ix <- as.integer(round(sx))
(is <- as(ix, "sparseVector")) ## an "isparseVector" (!)
(ns <- sparseVector(i= c(7, 3, 2), length = 10)) # "nsparseVector"
## rep() works too:
(ri <- rep(is, length.out= 25))

## Using `dim<-` as in base R:
 r <- ss
dim(r) <- c(4,5) # becomes a sparse Matrix:
 r
## or coercion (as as.matrix() in base R):
 as(ss, "Matrix")
 stopifnot(all(ss == print(as(ss, "CsparseMatrix"))))

## currently has "non-structural" FALSE -- printing as ":"
 (lis <- is & FALSE)
 (nn <- is[is == 0]) # all "structural" FALSE

## NA-case
 sN <- sx; sN[4] <- NA
 (svN <- as(sN, "sparseVector"))

 v <- as(c(0,0,3, 3.2, rep(0,9),-3,0,-1, rep(0,20),5,0),
 "sparseVector")
 v <- rep(rep(v, 50), 5000)
 set.seed(1); v[sample(v@i, 1e6)] <- 0
str(v)
```

```
system.time(for(i in 1:4) hv <- head(v, 1e6))
## user  system elapsed
## 0.033 0.000 0.032

system.time(for(i in 1:4) h2 <- v[1:1e6])
## user  system elapsed
## 1.317 0.000 1.319

stopifnot(identical(hv, h2),
  identical(is | FALSE, is != 0),
  validObject(svN), validObject(lis), as.logical(is.na(svN[4])),
  identical(is^2 > 0, is & TRUE),
  all(!lis), !any(lis), length(nn@i) == 0, !any(nn), all(!nn),
```
sum(lis) == 0, !prod(lis), range(lis) == c(0,0))

## create and use the t(.) method:
t(x20 <- sparseVector(c(9,3:1), i=c(1:2,4,7), length=20))
(T20 <- toeplitz(x20))
stopifnot(is(T20, "symmetricMatrix"), is(T20, "sparseMatrix"),
  identical(unname(as.matrix(T20)),
  toeplitz(as.vector(x20))))

## c() method for "sparseVector" - also available as regular function
(c1 <- c(x20, 0,0,0, -10*x20))
(c2 <- c(ns, is, FALSE))
(c3 <- c(ns, !ns, TRUE, NA, FALSE))
(c4 <- c(ns, rev(ns)))
## here, c() would produce a list {not dispatching to c.sparseVector()}
(c5 <- c.sparseVector(0,0, x20))

## checking (consistency)
.v <- as.vector
.s <- function(v) as(v, "sparseVector")
stopifnot(
  all.equal(c1, .s(c(.v(x20), 0,0,0, -10*.v(x20))), tol=0),
  all.equal(c2, .s(c(.v(ns), .v(is), FALSE)), tol=0),
  all.equal(c3, .s(c(.v(ns), !.v(ns), TRUE, NA, FALSE)), tol=0),
  all.equal(c4, .s(c(.v(ns), rev(.v(ns)))), tol=0),
  all.equal(c5, .s(c(0,0, .v(x20))), tol=0)
)

spMatrix

Sparse Matrix Constructor From Triplet

Description

User friendly construction of a sparse matrix (inheriting from class TsparseMatrix) from the triplet representation.

This is much less flexible than sparseMatrix() and hence somewhat deprecated.

Usage

spMatrix(nrow, ncol, i = integer(), j = integer(), x = double())

Arguments

nrow, ncol  integers specifying the desired number of rows and columns.
i, j        integer vectors of the same length specifying the locations of the non-zero (or non-TRUE) entries of the matrix.
x          atomic vector of the same length as i and j, specifying the values of the non-zero entries.
spMatrix

Value

A sparse matrix in triplet form, as an \texttt{R} object inheriting from both \texttt{TsparseMatrix} and \texttt{generalMatrix}.

The matrix \( M \) will have \( M[i[k], j[k]] = x[k] \), for \( k = 1, 2, \ldots, n \), where \( n = \text{length}(i) \) and \( M[i', j'] = 0 \) for all other pairs \((i', j')\).

See Also

\texttt{Matrix}(*, sparse=TRUE) for the more usual constructor of such matrices. Then, \texttt{sparseMatrix} is more general and flexible than \texttt{spMatrix()} and by default returns a \texttt{CsparseMatrix} which is often slightly more desirable. Further, \texttt{bdiag} and \texttt{Diagonal} for (block-)diagonal matrix constructors.

Consider \texttt{TsparseMatrix} and similar class definition help files.

Examples

```r
## simple example
A <- spMatrix(10,20, i = c(1,3:8),
              j = c(2,9,6:10),
              x = 7 * (1:7))
A # a "dgTMatrix"
summary(A)
str(A) # note that *internally* 0-based indices \((i,j)\) are used

L <- spMatrix(9, 30, i = rep(1:9, 3), 1:27,
              (1:27) %% 4 != 1)
L # an "lgTMatrix"

## A simplified predecessor of Matrix' rsparsematrix() function :

rSpMatrix <- function(nrow, ncol, nnz,
                      rand.x = function(n) round(rnorm(nnz), 2))
{
  # Purpose: random sparse matrix
  # ---------------------------------------------------------------
  # Arguments: (nrow,ncol): dimension
  # nnz : number of non-zero entries
  # rand.x: random number generator for 'x' slot
  # ---------------------------------------------------------------
  # Author: Martin Maechler, Date: 14.-16. May 2007
  stopifnot((nnz <- as.integer(nnz)) >= 0,
             nrow >= 0, ncol >= 0, nnz <= nrow * ncol)
  spMatrix(nrow, ncol,
           i = sample(nrow, nnz, replace = TRUE),
           j = sample(ncol, nnz, replace = TRUE),
           x = rand.x(nnz))
}

M1 <- rSpMatrix(100000, 20, nnz = 200)
summary(M1)
```

Description

Methods for "[<-", i.e., extraction or subsetting mostly of matrices, in package Matrix.

Note: Contrary to standard matrix assignment in base R, in x[..] <- val it is typically an error (see stop) when the type or class of val would require the class of x to be changed, e.g., when x is logical, say "lsparseMatrix", and val is numeric. In other cases, e.g., when x is a "nsparseMatrix" and val is not TRUE or FALSE, a warning is signalled, and val is "interpreted" as logical, and (logical) NA is interpreted as TRUE.

Methods

There are many many more than these:

x = "Matrix", i = "missing", j = "missing", value = "ANY" is currently a simple fallback method implementation which ensures "readable" error messages.

x = "Matrix", i = "ANY", j = "ANY", value = "ANY" currently gives an error

x = "denseMatrix", i = "index", j = "missing", value = "numeric" ...

x = "denseMatrix", i = "index", j = "index", value = "numeric" ...

x = "denseMatrix", i = "missing", j = "index", value = "numeric" ...

See Also

[-methods for subsetting "Matrix" objects; the index class; Extract about the standard subset assignment (and extraction).

Examples

```R
set.seed(101)
(a <- m <- Matrix(round(rnorm(7*4),2), nrow = 7))

a[] <- 2.2 # <<- replaces **every** entry
a
## as do these:
a[,] <- 3 ; a[TRUE,] <- 4

m[2, 3] <- 3.14 # simple number
m[3, 3:4]<- 3:4 # simple numeric of length 2

## sub matrix assignment:
m[-(4:7), 3:4] <- cbind(1,2:4) #-> upper right corner of 'm'
m[3:5, 2:3] <- 0
m[6:7, 1:2] <- Diagonal(2)
```
## rows or columns only:
m[1,] <- 10
m[,2] <- 1:7
m[-(1:6), ] <- 3:0 # not the first 6 rows, i.e. only the 7th
as(m, "sparseMatrix")

### Description
Methods for "[", i.e., extraction or subsetting mostly of matrices, in package `Matrix`.

### Methods
There are more than these:

- `x = "Matrix", i = "missing", j = "missing", drop= "ANY"` ...
- `x = "Matrix", i = "numeric", j = "missing", drop= "missing"` ...
- `x = "Matrix", i = "missing", j = "numeric", drop= "missing"` ...
- `x = "dsparseMatrix", i = "missing", j = "numeric", drop= "logical"` ...
- `x = "dsparseMatrix", i = "numeric", j = "missing", drop= "logical"` ...
- `x = "dsparseMatrix", i = "numeric", j = "numeric", drop= "logical"` ...

### See Also

- `<-<-methods` for subassignment to "Matrix" objects. `Extract` about the standard extraction.

### Examples

```r
str(m <- Matrix(round(rnorm(7*4),2), nrow = 7))
stopifnot(identical(m, m[]))
m[2, 3] # simple number
m[2, 3:4] # simple numeric of length 2
m[2, 3:4, drop=FALSE] # sub matrix of class 'dgeMatrix'
## rows or columns only:
m[1,] # first row, as simple numeric vector
m[,1:2] # sub matrix of first two columns
showMethods("[", inherited = FALSE)
```
symmetricMatrix-class  Virtual Class of Symmetric Matrices in Package Matrix

Description

The virtual class of symmetric matrices, "symmetricMatrix", from the package Matrix contains numeric and logical, dense and sparse matrices, e.g., see the examples with the “actual” subclasses.

The main use is in methods (and C functions) that can deal with all symmetric matrices, and in as(*, "symmetricMatrix").

Slots

uplo: Object of class "character". Must be either "U", for upper triangular, and "L", for lower triangular.

Dim, Dimnames: The dimension (a length-2 "integer") and corresponding names (or NULL), inherited from the Matrix, see there. See below, about storing only one of the two Dimnames components.

factors: a list of matrix factorizations, also from the Matrix class.

Extends

Class "Matrix", directly.

Methods

dimnames signature(object = "symmetricMatrix"): returns symmetric dimnames, even when the Dimnames slot only has row or column names. This allows to save storage for large (typically sparse) symmetric matrices.

isSymmetric signature(object = "symmetricMatrix"): returns TRUE trivially.

There’s a C function symmetricMatrix_validate() called by the internal validity checking functions, and also from getValidity(getClass("symmetricMatrix")).

Validity and dimnames

The validity checks do not require a symmetric Dimnames slot, so it can be list(NULL, <character>), e.g., for efficiency. However, dimnames() and other functions and methods should behave as if the dimnames were symmetric, i.e., with both list components identical.

See Also

isSymmetric which has efficient methods (isSymmetric-methods) for the Matrix classes. Classes triangularMatrix, and, e.g., dsyMatrix for numeric dense matrices, or lsCMatrix for a logical sparse matrix class.
Examples

```r
## An example about the symmetric Dimnames:
sy <- sparseMatrix(i = c(2,4,3:5), j = c(4,7:5,5), x = 1:5,
                     symmetric = TRUE, dimnames = list(NULL, letters[1:7]))
sy # shows symmetrical dimnames
sy@Dimnames # internally only one part is stored
dimnames(sy) # both parts - as sy *is* symmetrical

showClass("symmetricMatrix")

## The names of direct subclasses:
scl <- getClass("symmetricMatrix")@subclasses
directly <- sapply(lapply(scl, slot, "by"), length) == 0
names(scl)[directly]

## Methods -- applicable to all subclasses above:
showMethods(classes = "symmetricMatrix")
```

---

### symmpart-methods

**Symmetric Part and Skew(symmetric) Part of a Matrix**

**Description**

`symmpart(x)` computes the symmetric part \( (x + t(x))/2 \) and `skewpart(x)` the skew symmetric part \( (x - t(x))/2 \) of a square matrix \( x \), more efficiently for specific Matrix classes.

Note that \( x == symmpart(x) + skewpart(x) \) for all square matrices – apart from extraneous `NA` values in the RHS.

**Usage**

```r
symmpart(x)
skewpart(x)
```

**Arguments**

- `x` a *square* matrix; either “traditional” of class "matrix", or typically, inheriting from the `Matrix` class.

**Details**

These are generic functions with several methods for different matrix classes, use e.g., `showMethods(symmpart)` to see them.

If the row and column names differ, the result will use the column names unless they are (partly) NULL where the row names are non-NULL (see also the examples).
triangularMatrix-class

Value

symmpart() returns a symmetric matrix, inheriting from symmetricMatrix iff x inherited from Matrix.
skewpart() returns a skew-symmetric matrix, typically of the same class as x (or the closest “general” one, see generalMatrix).

See Also

isSymmetric.

Examples

m <- Matrix(1:4, 2,2)
symmpart(m)
skewpart(m)

stopifnot(all(m == symmpart(m) + skewpart(m)))

dn <- dimnames(m) <- list(row = c("r1", "r2"), col = c("var.1", "var.2"))
stopifnot(all(m == symmpart(m) + skewpart(m)))
colnames(m) <- NULL
stopifnot(all(m == symmpart(m) + skewpart(m)))
dimnames(m) <- unname(dn)
stopifnot(all(m == symmpart(m) + skewpart(m)))

### investigate the current methods:
showMethods(skewpart, include = TRUE)

triangularMatrix-class

Virtual Class of Triangular Matrices in Package Matrix

Description

The virtual class of triangular matrices,"triangularMatrix", the package Matrix contains square (nrow == ncol) numeric and logical, dense and sparse matrices, e.g., see the examples. A main use of the virtual class is in methods (and C functions) that can deal with all triangular matrices.

Slots

uplo: String (of class "character"). Must be either "U", for upper triangular, and "L", for lower triangular.
diag: String (of class "character"). Must be either "U", for unit triangular (diagonal is all ones), or "N" for non-unit. The diagonal elements are not accessed internally when diag is "U". For denseMatrix classes, they need to be allocated though, such that the length of the x slot does not depend on diag.

Dim, Dimnames: The dimension (a length-2 "integer") and corresponding names (or NULL), inherited from the Matrix, see there.
TsparseMatrix-class

Extends

Class "Matrix", directly.

Methods

There's a C function triangularMatrix_validity() called by the internal validity checking functions.

Currently, Schur, isSymmetric and as() (i.e. coerce) have methods with triangularMatrix in their signature.

See Also

isTriangular() for testing any matrix for triangularity; classes symmetricMatrix, and, e.g., dtrMatrix for numeric dense matrices, or ltCMatrix for a logical sparse matrix subclass of "triangularMatrix".

Examples

showClass("triangularMatrix")

## The names of direct subclasses:
scl <- getClass("triangularMatrix")@subclasses
directly <- sapply(lapply(scl, slot, "by"), length) == 0
names(scl)[directly]

(m <- matrix(c(5,1,0,3), 2))
as(m, "triangularMatrix")

---

TsparseMatrix-class Class "TsparseMatrix" of Sparse Matrices in Triplet Form

Description

The "TsparseMatrix" class is the virtual class of all sparse matrices coded in triplet form. Since it is a virtual class, no objects may be created from it. See showClass("TsparseMatrix") for its subclasses.

Slots

Dim, Dimnames: from the "Matrix" class,

i: Object of class "integer" - the row indices of non-zero entries in 0-base, i.e., must be in 0:(nrow(.)-1).

j: Object of class "integer" - the column indices of non-zero entries. Must be the same length as slot i and 0-based as well, i.e., in 0:(ncol(.)-1). For numeric Tsparse matrices, (i,j) pairs can occur more than once, see dgTMatrix.
uniqTsparse

**Description**

Detect or “unify” (or “standardize”) non-unique TsparseMatrix matrices, producing unique \((i, j, x)\) triplets which are sorted, first in \(j\), then in \(i\) (in the sense of order\((j, i)\)).

Note that `new(., spMatrix or sparseMatrix(x, repr="T") constructors for “TsparseMatrix” classes implicitly add \(x_k\)’s that belong to identical \((i_k, j_k)\) pairs.

anyDuplicatedT() reports the index of the first duplicated pair, or 0 if there is none.

uniqTsparse(x) replaces duplicated index pairs \((i, j)\) and their corresponding x slot entries by the triple \((i, j, sx)\) where \(sx = \text{sum}(x \text{[<all pairs matching \((i, j)\)]})\), and for logical x, addition is replaced by logical or.
uniqTsparse

Usage

uniqTsparse(x, class.x = c(class(x)))
anyDuplicatedT(x, di = dim(x))

Arguments

x a sparse matrix stored in triplet form, i.e., inheriting from class TsparseMatrix.
class.x optional character string specifying class(x).
di the matrix dimension of x, dim(x).

Value

uniqTsparse(x) returns a TsparseMatrix “like x”, of the same class and with the same elements,
just internally possibly changed to “unique” (i,j,x) triplets in sorted order.
anyDuplicatedT(x) returns an integer as anyDuplicated, the index of the first duplicated entry
(from the (i,j) pairs) if there is one, and 0 otherwise.

See Also

TsparseMatrix, for uniqueness, notably dgTMatrix.

Examples

e.example("dgTMatrix-class", echo=FALSE)
## -> 'T2' with (i,j,x) slots of length 5 each
T2u <- uniqTsparse(T2)
stopifnot(## They "are" the same (and print the same):
  all.equal(T2, T2u, tol=0),
  ## but not internally:
  anyDuplicatedT(T2) == 2,
  anyDuplicatedT(T2u) == 0,
  length(T2 @x) == 5,
  length(T2u@x) == 3)

## is 'x' a "uniq Tsparse" Matrix ? [requires x to be TsparseMatrix!]
non_uniqT <- function(x, di = dim(x))
  is.unsorted(x@j) || anyDuplicatedT(x, di)
non_uniqT(T2) # TRUE
non_uniqT(T2u) # FALSE

T3 <- T2u
T3[1, c(1,3)] <- 10; T3[2, c(1,5)] <- 20
T3u <- uniqTsparse(T3)
str(T3u) # sorted in 'j', and within j, sorted in i
stopifnot(!non_uniqT(T3u))

## Logical l.TMatrix and n.TMatrix :
(L2 <- T2 > 0)
validObject(L2u <- uniqTsparse(L2))
(N2 <- as(L2, "nMatrix"))
validObject(N2u <- uniqTsparse(N2))
stopifnot(N2u@i == L2u@i, L2u@i == T2u@i,
N2u@j == L2u@j, L2u@j == T2u@j, N2@i == L2@i, L2@i == T2@i,
N2@j == L2@j, L2@j == T2@j)
# now with a nasty NA  [partly failed in Matrix 1.1-5]:
L.0N <- L.1N <- L2
L.0N@x[1:2] <- c(FALSE, NA)
L.1N@x[1:2] <- c(TRUE, NA)
validObject(L.0N)
validObject(L.1N)
(m.0N <- as.matrix(L.0N))
(m.1N <- as.matrix(L.1N))
stopifnot(identical(10L, which(is.na(m.0N))), !anyNA(m.1N))
symnum(m.0N)
symnum(m.1N)

unpackedMatrix-class  Virtual Class "unpackedMatrix" of Unpacked Dense Matrices

Description

Class "unpackedMatrix" is the virtual class of dense matrices in "unpacked" format, storing all m*n elements of an m-by-n matrix. It is used to define common methods for efficient subsetting, transposing, etc. of its proper subclasses: currently "[dln]geMatrix" (unpacked general), "[dln]syMatrix" (unpacked symmetric), "[dln]trMatrix" (unpacked triangular), and subclasses of these, such as "dpoMatrix", "Cholesky", and "BunchKaufman".

Slots

Dim, Dimnames: as all Matrix objects.

Extends


Methods

pack  signature(x = "unpackedMatrix"): ...
unpack signature(x = "unpackedMatrix"): ...
isSymmetric signature(object = "unpackedMatrix"): ...
isTriangular signature(object = "unpackedMatrix"): ...
isDiagonal signature(object = "unpackedMatrix"): ...
t signature(x = "unpackedMatrix"): ...
diag signature(x = "unpackedMatrix"): ...
diag<- signature(x = "unpackedMatrix"): ...
Author(s)

Mikael Jagan

See Also

pack and unpack; its virtual "complement" "packedMatrix"; its proper subclasses "dsyMatrix", "ltrMatrix", etc.

Examples

showClass("unpackedMatrix")
showMethods(classes = "unpackedMatrix")

updown-methods

Updating and Downdating Sparse Cholesky Factorizations

Description

Computes a rank-k update or downdate of a sparse Cholesky factorization

\[ P_1 A P'_1 = L_1 D L_1' = L L' \]

which for some k-column matrix \( C \) is the factorization

\[ P_1 (A + sCC')P'_1 = \tilde{L} \tilde{D} \tilde{L}' \]

Here, \( s = 1 \) for an update and \( s = -1 \) for a downdate.

Usage

updown(update, C, L)

Arguments

update               a logical (TRUE or FALSE) or character ("+" or ") indicating if \( L \) should be updated (or otherwise downdated).
C                    a finite matrix or Matrix such that \( tcrossprod(C) \) has the dimensions of \( L \).
L                    an object of class dCHMsimpl or dCHMsuper specifying a sparse Cholesky factorization.

Value

A sparse Cholesky factorization with dimensions matching \( L \), typically of class dCHMsimpl.

Author(s)

Initial implementation by Nicholas Nagle, University of Tennessee.
References


See Also

Classes `dCHMsimpl` and `dCHMsuper` and their methods, notably for generic function `update`, which is not equivalent to `updown(update = TRUE)`. Generic function `Cholesky`.

Examples

```r
m <- sparseMatrix(i = c(3, 1, 3:2, 2:1), p = c(0:2, 4, 4, 6), x = 1:6, dimnames = list(LETTERS[1:3], letters[1:5]))
uc0 <- Cholesky(A <- crossprod(m) + Diagonal(5))
uc1 <- updown(“+”, Diagonal(5, 1), uc0)
uc2 <- updown(“-”, Diagonal(5, 1), uc1)
stopifnot(all.equal(uc0, uc2))
```

USCounties

**Contiguity Matrix of U.S. Counties**

Description

This matrix gives the contiguities of 3111 U.S. counties, using the queen criterion of at least one shared vertex or edge.

Usage

`data(USCounties)`

Format

A $3111 \times 3111$ sparse, symmetric matrix of class `dsCMat`, with 9101 nonzero entries.

Source

GAL lattice file `usc_q.GAL` (retrieved in 2008 from `http://sal.uiuc.edu/weights/zips/usc.zip` with permission from Luc Anselin for use and distribution) was read into R using function `read.gal` from package `spdep`.

Neighbour lists were augmented with row-standardized (and then symmetrized) spatial weights, using functions `nb2listw` and `similar.listw` from packages `spdep` and `spatialreg`. The resulting `listw` object was coerced to class `dsTMatrix` using `as_dsTMatrix_listw` from `spatialreg`, and subsequently to class `dsCMat`. 
References


Examples

data(USCounties, package = "Matrix")
(n <- ncol(USCounties))
I <- .symDiagonal(n)
set.seed(1)
r <- 50L
rho <- 1 / runif(r, 0, 0.5)

system.time(MJ0 <- sapply(rho, function(mult)
  determinant(USCounties + mult * I, logarithm = TRUE)$modulus))

## Can be done faster by updating the Cholesky factor:

C1 <- Cholesky(USCounties, Imult = 2)

system.time(MJ1 <- sapply(rho, function(mult)
  determinant(update(C1, USCounties, mult), sqrt = FALSE)$modulus))
stopifnot(all.equal(MJ0, MJ1))

C2 <- Cholesky(USCounties, super = TRUE, Imult = 2)

system.time(MJ2 <- sapply(rho, function(mult)
  determinant(update(C2, USCounties, mult), sqrt = FALSE)$modulus))
stopifnot(all.equal(MJ0, MJ2))

wrld_1deg

Contiguity Matrix of World One-Degree Grid Cells

Description

This matrix gives the contiguities of 15260 one-degree grid cells of world land areas, using a criterion based on the great-circle distance between centers.

Usage

data(wrld_1deg)

Format

A $15260 \times 15260$ sparse, symmetric matrix of class `dsCMatrix`, with 55973 nonzero entries.
Shoreline data were read into R from the GSHHS database using function Rgshhs from package maptools. Antarctica was excluded. An approximately one-degree grid was generated using function Sobj_SpatialGrid, also from maptools. Grid cells with centers on land were identified using the over method for classes SpatialPolygons and SpatialGrid, defined in package sp. Neighbours of these were identified by passing the resulting SpatialPixels object to function dnearneigh from package spdep, using as a cut-off a great-circle distance of $\sqrt{2}$ kilometers between centers.

Neighbour lists were augmented with row-standardized (and then symmetrized) spatial weights, using functions nb2listw and similar.listw from packages spdep and spatialreg. The resulting listw object was coerced to class dsTMatrix using as_dsTMatrix_listw from spatialreg, and subsequently to class dsCMatrix.

References


Examples

data(wrld_1deg, package = "Matrix")
(n <- ncol(wrld_1deg))
I <- .symDiagonal(n)

doExtras <- interactive() || nzchar(Sys.getenv("R_MATRIX_CHECK_EXTRA"))
set.seed(1)
r <- if(doExtras) 20L else 3L
rho <- 1 / runif(r, 0, 0.5)

system.time(MJ0 <- sapply(rho, function(mult)
  determinant(wrld_1deg + mult * I, logarithm = TRUE)$modulus))
  ## Can be done faster by updating the Cholesky factor:
  C1 <- Cholesky(wrld_1deg, Imult = 2)
  system.time(MJ1 <- sapply(rho, function(mult)
    determinant(update(C1, wrld_1deg, mult), sqrt = FALSE)$modulus))
  stopifnot(all.equal(MJ0, MJ1))

C2 <- Cholesky(wrld_1deg, super = TRUE, Imult = 2)
  system.time(MJ2 <- sapply(rho, function(mult)
    determinant(update(C2, wrld_1deg, mult), sqrt = FALSE)$modulus))
  stopifnot(all.equal(MJ0, MJ2))
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