Package ‘Matrix’

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Title Sparse and Dense Matrix Classes and Methods
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Description A rich hierarchy of matrix classes, including triangular,
symmetric, and diagonal matrices, both dense and sparse and with
pattern, logical and numeric entries. Numerous methods for and
operations on these matrices, using 'LAPACK' and 'SuiteSparse' libraries.
Depends R (>= 3.2.0)
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Suggests expm, MASS
Enhances MatrixModels, graph, SparseM, sfsmisc
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LazyDataNote not possible, since we use data/*.R *and* our classes
BuildResaveData no
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  '^[A-Z]+\.[.]txt$', full.names=TRUE, system.file('doc',
  'SuiteSparse', package='Matrix'))),
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R topics documented:

Jason Riedy [ctb] (condest() and onenormest() for octave, Copyright: Regents of the University of California), R Core Team [ctb] (base R matrix implementation)

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abIndex-class  Class "abIndex" of Abstract Index Vectors

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).
**abIndex-class**

**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 if 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

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

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

Description

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

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

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

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

Usage

```r
abIseql(from = 1, to = 1)
abIseql (from = 1, to = 1, by = ((to - from)/(length.out - 1)),
  length.out = NULL, along.with = NULL)
```

```r
## 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).
all-methods

Examples

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

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

all-methods

"Matrix" Methods for Functions all() and any()

Description

The basic R functions all and any now have methods for Matrix objects and should behave as for matrix ones.

Methods

all signature(x = "Matrix", ..., na.rm = FALSE): ...
any signature(x = "Matrix", ..., na.rm = FALSE): ...
all signature(x = "ldenseMatrix", ..., na.rm = FALSE): ...
all signature(x = "lsparseMatrix", ..., na.rm = FALSE): ...

Examples

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

all.equal-methods

Matrix Package Methods for Function all.equal()

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 \code{all.equal.numeric} directly and work via \code{as.vector}().

There are more methods, notably also for "\code{sparseVector}"s, see \code{showMethods("all.equal")}.

Examples

\footnotesize
\begin{verbatim}
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 %*% Q, "CsparseMatrix"),
        L %*% U)),
    with(ex, all.equal(as(A, "CsparseMatrix"),
        t(P) %*% L %*% U %*% t(Q))))
\end{verbatim}

\end{footnotesize}

\begin{verbatim}
atomicVector-class Virtual Class "atomicVector" of Atomic Vectors
\end{verbatim}

Description

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

Objects from the Class

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

Methods

In the \pkg{Matrix} package, the "\code{atomicVector}" is used in signatures where typically "old-style" "\code{matrix}" objects can be used and can be substituted by simple vectors.

Extends

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

Author(s)

Martin Maechler
See Also

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

Examples

showClass("atomicVector")

---

**Description**

Returns a new matrix formed by extracting the lower triangle (tril) or the upper triangle (triu) or a general band relative to the diagonal (band), and setting other elements to zero. The general forms of these functions include integer arguments to specify how many diagonal bands above or below the main diagonal are not set to zero.

**Usage**

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

**Arguments**

- **x**: a matrix-like object
- **k, k1, k2**: integers specifying the diagonal bands that will not be set to zero. These are given relative to the main diagonal, which is k=0. A negative value of k indicates a diagonal below the main diagonal and a positive value indicates a diagonal above the main diagonal.
- **...**: Optional arguments used by specific methods. (None used at present.)

**Value**

An object of an appropriate matrix class. The class of the value of tril or triu inherits from triangularMatrix when appropriate. Note that the result is of class sparseMatrix only if x is.

**Methods**

- **x = "CsparseMatrix"** method for compressed, sparse, column-oriented matrices.
- **x = "TsparseMatrix"** method for sparse matrices in triplet format.
- **x = "RsparseMatrix"** method for compressed, sparse, row-oriented matrices.
- **x = "ddenseMatrix"** method for dense numeric matrices, including packed numeric matrices.

**See Also**

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

```r
## 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
band(mm, -1, 2) # general band
(m5 <- Matrix(rnorm(25), nc = 5))
tril(m5)    # lower triangle
tril(m5, -1) # strict lower triangle
triu(m5, 1)  # strict upper triangle
band(m5, -1, 2) # general band
(m65 <- Matrix(rnorm(30), nc = 5)) # not square
triu(m65)   # result in not dtrMatrix unless square
(sm5 <- crossprod(m65)) # symmetric
band(sm5, -1, 1)# symmetric band preserves symmetry property
as(band(sm5, -1, 1), "sparseMatrix") # often preferable
```

bandSparse

**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, giveCsparse = TRUE)
```

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 \(d <- length(k)\) and \(n' >= min(n, m)\). 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`).
giveCsparse  logical indicating if the result should be a \texttt{CsparseMatrix} or a \texttt{TsparseMatrix}. The default, \texttt{TRUE} is very often more efficient subsequently, but not always.

Value

a sparse matrix (of \texttt{class CsparseMatrix}) of dimension $n \times m$ with diagonal "bands" as specified.

See Also

\texttt{band}, for extraction of matrix bands; \texttt{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 \texttt{xor} 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!
)

---

### bdiag

**Construct a Block Diagonal Matrix**

**Description**

Build a block diagonal matrix given several building block matrices.
bdiag

Usage

bdiag(...)
.bdiag(lst)

Arguments

... individual matrices or a list of matrices.
lst 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() inheris 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

bdiag(matrix(1:4, 2), diag(3))
## combine "Matrix" class and traditional matrices:
bdiag(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)
bdiag(mlist)
stopifnot(identical(bdiag(mlist),
         bdiag(lapply(mlist, as.matrix)))))
The Bunch-Kaufman Decomposition of a square symmetric matrix $A$ is $A = PLDL^T P^T$ where $P$ is a permutation matrix, $L$ is unit-lower triangular and $D$ is block-diagonal with blocks of dimension $1 \times 1$ or $2 \times 2$. 

```r
ml <- c(as.matrix(c(1:24)[11 == 0, 6,4]),"nMatrix"),
    rep(list(Diagonal(2, x=TRUE)), 3))
mln <- c(ml, Diagonal(x = 1:3))
stopifnot(is(bdiag(ml), "lsparseMatrix"),
    is(bdiag(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))
```

```
##' 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{dgCMatrix}.

bdiag_m <- function(lmat) {
    # Copyright (C) 2016 Martin Maechler, ETH Zurich
    if(!length(lmat)) return(new("dgCMatrix"))
    stopifnot(is.list(lmat), is.matrix(lmat[[1]]),
        (k <- (d <- dim(lmat[[1]])[1]) == d[2], # k x k
            all(vapply(lmat, dim, integer(2)) == k)) # all of them
    N <- length(lmat)
    if(N * k > .Machine$integer.max)
        stop("resulting matrix too large; would be M x M, with M", N*k)
    M <- as.integer(N * k)
    # result: an M x M matrix
    new("dgCMatrix", Dim = c(M,M),
        # 'i:' maybe there's a faster way (w/o matrix indexing), but elegant?
        i = as.vector(matrix(0:L:(M-1L), nrow=k)[, rep(seq_len(N), each=k)],
            p = k * 0:L:M,
            x = as.double(unlist(lmat, recursive=FALSE, use.names=FALSE)))
}

l12 <- replicate(12, matrix(rpois(16, lambda = 6.4), 4,4), simplify=FALSE)
dim(T12 <- bdiag_m(l12))# 48 x 48
T12[1:20, 1:20]
```
Usage

BunchKaufman(x, ...)

Arguments

x          a symmetric square matrix.
...        potentially further arguments passed to methods.

Value

an object of class BunchKaufman, which can also be used as a (triangular) matrix directly.

Methods

Currently, only methods for dense numeric symmetric matrices are implemented.

x = "dspMatrix" uses Lapack routine dsptrf,
x = "dsyMatrix" uses Lapack routine dsytrf, computing the Bunch-Kaufman decomposition.

References

The original LAPACK source code, including documentation; http://www.netlib.org/blas/ double/dsytrf.f and http://www.netlib.org/blas/ double/dsptrf.f

See Also

The resulting class, BunchKaufman. Related decompositions are the LU, lu, and the Cholesky, chol (and for sparse matrices, Cholesky).

Examples

data(CAex)
dim(CAex)
isSymmetric(CAex)# TRUE
CAs <- as(CAex, "symmetricMatrix")
if(FALSE) # no method defined yet for *sparse* :
  bk <- BunchKaufman(CAs)
## does apply to *dense* symmetric matrices:
bkCA <- BunchKaufman(as(CAs, "denseMatrix"))
bkCA

image(bkCA)# shows how sparse it is, too
str(R.CA <- as(bkCA, "sparseMatrix"))
## an upper triangular 72x72 matrix with only 144 non-zero entries
\textit{CAex} \hspace{1cm} \textit{Albers' example Matrix with "Difficult" Eigen Factorization}

\textbf{Description}

An example of a sparse matrix for which \texttt{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.

\textbf{Usage}

\texttt{data(CAex)}

\textbf{Format}

This is a $72 \times 72$ symmetric matrix with 216 non-zero entries in five bands, stored as sparse matrix of class \texttt{dgCMatrix}.

\textbf{Details}

Historical note (2006-03-30): In earlier versions of R, \texttt{eigen(CAex)} fell into an infinite loop whereas \texttt{eigen(CAex, EISPACK=TRUE)} had been okay.

\textbf{Examples}

\texttt{data(CAex)}
\texttt{str(CAex)} \# of class "\texttt{dgCMatrix}"

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

\textit{cBind} \hspace{1cm} \textit{Versions of 'cbind' and 'rbind' recursively built on cbind2/rbind2}
The base functions `cbind` and `rbind` are defined for an arbitrary number of arguments and hence have the first formal argument `...` For that reason, in the past S4 methods could easily be defined for binding together matrices inheriting from `Matrix`.

For that reason, `cbind2` and `rbind2` have been provided for binding together two matrices, and we have defined methods for these and the 'Matrix'-matrices.

Before R version 3.2.0 (April 2015), we have needed a substitute for S4-enabled versions of `cbind` and `rbind`, and provided `cBind` and `rBind` with identical syntax and semantic in order to bind together multiple matrices ("matrix" or "Matrix" and vectors. With R version 3.2.0 and newer, `cBind` and `rBind` are deprecated and produce a deprecation warning (via `.Deprecate`), and your code should start using `cbind()` and `rbind()` instead.

### Usage

```r
Cbind(..., deparse.level = 1)
rBind(..., deparse.level = 1)
```

### Arguments

- `...` matrix-like R objects to be bound together, see `cbind` and `rbind`.
- `deparse.level` integer determining under which circumstances column and row names are built from the actual arguments’ ‘expression’, see `cbind`.

### Details

The implementation of these is recursive, calling `cbind2` or `rbind2` respectively, where these have methods defined and so should dispatch appropriately.

### 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 than non-zero ones (as the default sparse in `Matrix()`).

### Author(s)

Martin Maechler

### See Also

`cbind2`, `cbind`, Documentation in base R’s `methods` package.
Examples

```r
(a <- matrix(c(2:1,1:2), 2, 2))
D <- Diagonal(2)
if(getRversion() < "3.2.0") {
  M1 <- cbind(0, rBind(a, 7))
  print(M1) # remains traditional matrix

  M2 <- cBind(4, a, D, -1, D, 0) # a sparse matrix
  print(M2)
}
else {
  # newer versions of R do not need cBind / rBind:

  M1 <- cbind(0, suppressWarnings(rBind(a, 7)))
  print(M1) # remains traditional matrix

  M2 <- suppressWarnings(cBind(4, a, D, -1, D, 0)) # a sparse Matrix
  print(M2)

  stopifnot(identical(M1, cbind(0, rbind(a, 7))),
            identical(M2, cbind(4, a, D, -1, D, 0)))
} # R >= 3.2.0
```

CHMfactor-class  
**CHOLMOD-based Cholesky Factorizations**

Description

The virtual class "CHMfactor" is a class of CHOLMOD-based Cholesky factorizations of symmetric, sparse, compressed, column-oriented matrices. Such a factorization is simplicial (virtual class "CHMsimpl") or supernodal (virtual class "CHMsuper"). Objects that inherit from these classes are either numeric factorizations (classes "dCHMsimpl" and "dCHMsuper") or symbolic factorizations (classes "nCHMsimpl" and "nCHMsuper").

Usage

```r
isLDL(x)
```

## S4 method for signature 'CHMfactor'
update(object, parent, mult = 0, ...)
.updateCHMfactor(object, parent, mult)

## and many more methods, notably,
##  solve(a, b, system = c("A","LDLt","LD","DLt","L","Lt","D","P","Pt"), ...)
##  ----- see below
Arguments

x, object, a

A "CHMfactor" object (almost always the result of `Cholesky()`).

parent

A "dsCMatrix" or "dgCMatrix" matrix object with the same nonzero pattern as the matrix that generated object. If parent is symmetric, of class "dsCMatrix", then object should be a decomposition of a matrix with the same nonzero pattern as parent. If parent is not symmetric then object should be the decomposition of a matrix with the same nonzero pattern as tcrossprod(parent).

Since Matrix version 1.0-8, other "sparseMatrix" matrices are coerced to `dsparseMatrix` and `CsparseMatrix` if needed.

mult

A numeric scalar (default 0). mult times the identity matrix is (implicitly) added to parent or tcrossprod(parent) before updating the decomposition object.

... potentially further arguments to the methods.

Objects from the Class

Objects can be created by calls of the form `new("dCHMsuper", ...)` but are more commonly created via `Cholesky()`, applied to `dsCMatrix` or `lsCMatrix` objects.

For an introduction, it may be helpful to look at the `expand()` method and examples below.

Slots

of "CHMfactor" and all classes inheriting from it:

perm: An integer vector giving the 0-based permutation of the rows and columns chosen to reduce fill-in and for post-ordering.

colcount: Object of class "integer" ....

type: Object of class "integer" ....

Slots of the non virtual classes “[dl]CHM(super|simpl)”: 

p: Object of class "integer" of pointers, one for each column, to the initial (zero-based) index of elements in the column. Only present in classes that contain "CHMsimp".

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. Only present in classes that contain "CHMsimp".

x: For the "d*" classes: "numeric" - the non-zero elements of the matrix.

Methods

`isLDL` (x) returns a `logical` indicating if x is an LDL' decomposition or (when FALSE) an LL' one.

`coerce` signature(from = "CHMfactor", to = "sparseMatrix") (or equivalently, to = "Matrix" or to = "triangularMatrix")

as(*, "sparseMatrix") returns the lower triangular factor L from the LL' form of the Cholesky factorization. Note that (currently) the factor from the LL' form is always returned, even if the "CHMfactor" object represents an LDL' decomposition. Furthermore, this is the factor after any fill-reducing permutation has been applied. See the expand method for obtaining both the permutation matrix, P, and the lower Cholesky factor, L.
\textbf{coerce} signature(from = "CHMfactor", to = "pMatrix") returns the permutation matrix $P$, representing the fill-reducing permutation used in the decomposition.

\textbf{expand} signature(x = "CHMfactor") returns a list with components $P$, the matrix representing the fill-reducing permutation, and $L$, the lower triangular Cholesky factor. The original positive-definite matrix $A$ corresponds to the product $A = P'LL'P$. Because of fill-in during the decomposition the product may apparently have more non-zeros than the original matrix, even after applying \texttt{drop0} to it. However, the extra "non-zeros" should be very small in magnitude.

\textbf{image} signature(x = "CHMfactor"): Plot the image of the lower triangular factor, $L$, from the decomposition. This method is equivalent to \texttt{image(as(x, "sparseMatrix"))} so the comments in the above description of the \texttt{coerce} method apply here too.

\textbf{solve} signature(a = "CHMfactor", b = "ddenseMatrix"), system = *:

The solve methods for a "CHMfactor" object take an optional third argument system whose value can be one of the character strings "A", "LDLt", "LD", "DLt", "L", "Lt", "D", "P" or "Pt". This argument describes the system to be solved. The default, "A", is to solve $Ax = b$ for $x$ where $A$ is the sparse, positive-definite matrix that was factored to produce $a$. Analogously, system = "L" returns the solution $x$, of $Lx = b$. Similarly, for all system codes but "P" and "Pt" where, e.g., $x \leftarrow \text{solve}(a, b, \text{system}="P")$ is equivalent to $x \leftarrow P^{-1}b$.

See also \texttt{solve-methods}.

\textbf{determinant} signature(x = "CHMfactor", logarithm = "logical") returns the determinant (or the logarithm of the determinant, if logarithm = \texttt{TRUE}, the default) of the factor $L$ from the $LL'$ decomposition (even if the decomposition represented by $x$ is of the $LDL'$ form (!)). This is the square root of the determinant (half the logarithm of the determinant when logarithm = \texttt{TRUE}) of the positive-definite matrix that was decomposed.

\textbf{update} signature(object = "CHMfactor"), parent. The \texttt{update} method requires an additional argument parent, which is either a "dsCMatrix" object, say $A$, (with the same structure of nonzeros as the matrix that was decomposed to produce object) or a general "dgCMatrix", say $M$, where $A := MM' (= \text{tcrossprod(parent))}$ is used for $A$. Further it provides an optional argument mult, a numeric scalar. This method updates the numeric values in object to the decomposition of $A + mI$ where $A$ is the matrix above (either the parent or $MM'$) and $m$ is the scalar mult. Because only the numeric values are updated this method should be faster than creating and decomposing $A + mI$. It is not uncommon to want, say, the determinant of $A + mI$ for many different values of $m$. This method would be the preferred approach in such cases.

\textbf{See Also}

\texttt{Cholesky}, also for examples; class \texttt{dgCMatrix}.

\textbf{Examples}

```r
# An example for the expand() method
n <- 1000; m <- 200; nnz <- 2000
set.seed(1)
M1 <- spMatrix(n, m,
               i = sample(n, nnz, replace = TRUE),
               j = sample(n, nnz, replace = TRUE),
               x = rnorm(nnz))
```

j = sample(m, nnz, replace = TRUE),
   x = round(rnorm(nnz),1))
XX <- crossprod(M)  ## = M'M = M'M'  where M <- t(M)
CX <- Cholesky(XX)
isLDL(CX)
str(CX)  ## a "dCHMsimpl" object
r <- expand(CX)
L.P <- with(r, crossprod(L,P))  ## = L'P
PLLP <- crossprod(L.P)  ## = (L'P)' L'P = P'LL'P = XX = M'M'
b <- sample(m)
stopifnot(all.equal(PLLP, XX),
   all(as.vector(solve(CX, b, system="P" )) == r$P %*% b),
   all(as.vector(solve(CX, b, system="Pt")) == t(r$P) %*% b )
}

u1 <- update(CX, XX,  mult=pi)
u2 <- update(CX, t(M), mult=pi)  # with the original M, where XX = M'M'
stopifnot(all.equal(u1,u2, tol=1e-14))

### [ See help(chol) for more examples ]
### -------------------

---

**chol**

**Choleski Decomposition - 'Matrix' S4 Generic and Methods**

**Description**

Compute the Choleski factorization of a real symmetric positive-definite square matrix.

**Usage**

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

**Arguments**

- **x**
  a (sparse or dense) square matrix, here inheriting from class `Matrix`; if `x` is not positive definite, an error is signalled.

- **pivot**
  logical indicating if pivoting is to be used. Currently, this is not made use of for dense matrices.

- **cache**
  logical indicating if the result should be cached in `x@factors`; note that this argument is experimental and only available for some sparse matrices.

- **...**
  potentially further arguments passed to methods.
Details

Note that these Cholesky factorizations are typically cached with \( x \) currently, and these caches are available in \( x@factors \), which may be useful for the sparse case when \( \text{pivot} = \text{TRUE} \), where the permutation can be retrieved; see also the examples.

However, this should not be considered part of the API and made use of. Rather consider \texttt{Cholesky()} in such situations, since \texttt{chol(x, \text{pivot=TRUE})} uses the same algorithm (but not the same return value!) as \texttt{Cholesky(x, LDL=FALSE)} and \texttt{chol(x)} corresponds to \texttt{Cholesky(x, perm=FALSE, LDL=FALSE)}.

Value

A matrix of class \texttt{Cholesky}, i.e., upper triangular: \( R \) such that \( R'R = x \) (if \( \text{pivot=FALSE} \)) or \( P'R'RP = x \) (if \( \text{pivot=TRUE} \) and \( P \) is the corresponding permutation matrix).

Methods

Use \texttt{showMethods(chol)} to see all; some are worth mentioning here:

- \texttt{chol signature(x = "dgeMatrix")}: works via "dpoMatrix", see class \texttt{dpoMatrix}.
- \texttt{chol signature(x = "dpoMatrix")}: Returns (and stores) the Cholesky decomposition of \( x \), via LAPACK routines \texttt{dlacpy} and \texttt{dpotrf}.
- \texttt{chol signature(x = "dppMatrix")}: Returns (and stores) the Cholesky decomposition via LAPACK routine \texttt{dpptrf}.
- \texttt{chol signature(x = "dsCMatrix", pivot = "logical")}: Returns (and stores) the Cholesky decomposition of \( x \). If \( \text{pivot} \) is true, the Approximate Minimal Degree (AMD) algorithm is used to create a reordering of the rows and columns of \( x \) so as to reduce fill-in.

References


See Also

The default from base, \texttt{chol}; for more flexibility (but not returning a matrix!) \texttt{Cholesky}.

Examples

\begin{verbatim}
showMethods(chol, inherited = FALSE) # show different methods

sy2 <- new("dsyMatrix", Dim = as.integer(c(2,2)), x = c(14, NA,32,77))
(c2 <- chol(sy2))#-> "Cholesky" matrix
stopifnot(all.equal(c2, chol(as(sy2, "dpoMatrix")), tolerance= 1e-13))
str(c2)

## An example where chol() can't work
(sy3 <- new("dsyMatrix", Dim = as.integer(c(2,2)), x = c(14, -1, 2, -7)))
try(chol(sy3)) # error, since it is not positive definite
\end{verbatim}
## A sparse example --- exemplifying 'pivot'

```r
(mm <- toeplitz(as(c(10, 0, 1, 0, 3), "sparseVector"))) # 5 x 5
(R <- chol(mm)) ## default: pivot = FALSE
R2 <- chol(mm, pivot=FALSE)
stopifnot( identical(R, R2), all.equal(crossprod(R), mm) )

(R. <- chol(mm, pivot=TRUE)) # nice band structure,
## but of course crossprod(R.) is *NOT* equal to mm
## --> see Cholesky() and its examples, for the pivot structure & factorization
stopifnot(all.equal(sqrt(det(mm)), det(R)),
          all.equal(prod(diag(R)), det(R)),
          all.equal(prod(diag(R)), det(R)))
```

## a second, even sparser example:

```r
(M2 <- toeplitz(as(c(1.5, rep(0,12), -1), "sparseVector")))
c2 <- chol(M2)
C2 <- chol(M2, pivot=TRUE)
## For the experts, check the caching of the factorizations:
ff <- M2@factors["SPDCholesky"]
FF <- M2@factors["SPDCholesky"]
L1 <- as(ff, "Matrix")# pivot=FALSE: no perm.
L2 <- as(FF, "Matrix"); P2 <- as(FF, "pMatrix")
stopifnot(identical(t(L1), c2),
          all.equal(t(L2), C2, tolerance=0),## why not identical()?
          all.equal(M2, tcrossprod(L1)),
          all.equal(M2, crossprod(crossprod(L2, P2)))# M = P'L L'P
```

---

### chol2inv-methods

#### Inverse from Choleski or QR Decomposition – Matrix Methods

**Description**

Invert a symmetric, positive definite square matrix from its Choleski decomposition. Equivalently, compute \((X'X)^{-1}\) from the (R part) of the QR decomposition of \(X\).

Even more generally, given an upper triangular matrix \(R\), compute \((R'R)^{-1}\).

**Methods**

- **x = "ANY"** the default method from base, see chol2inv, for traditional matrices.
- **x = "dtrMatrix"** method for the numeric triangular matrices, built on the same LAPACK DPOTRI function as the base method.
- **x = "denseMatrix"** if \(x\) is coercable to a triangularMatrix, call the "dtrMatrix" method above.
- **x = "sparseMatrix"** if \(x\) is coercable to a triangularMatrix, use solve() currently.

**See Also**

chol (for Matrix objects); further, chol2inv (from the base package), solve.
Examples

(M <- Matrix(cbind(1, 1:3, c(1,3,7))))
(cM <- chol(M)) # a "Cholesky" object, inheriting from "dtrMatrix"
chol2inv(cM) %*% M # the identity
stopifnot(all(chol2inv(cM) %*% M - Diagonal(nrow(M))) < 1e-10)

Description

Computes the Cholesky (aka “Choleski”) decomposition of a sparse, symmetric, positive-definite matrix. However, typically chol() should rather be used unless you are interested in the different kinds of sparse Cholesky decompositions.

Usage

Cholesky(A, perm = TRUE, LDL = !super, super = FALSE, Imult = 0, ...)

Arguments

A sparse symmetric matrix. No missing values or IEEE special values are allowed.
perm logical scalar indicating if a fill-reducing permutation should be computed and applied to the rows and columns of A. Default is TRUE.
LDL logical scalar indicating if the decomposition should be computed as LDL' where L is a unit lower triangular matrix. The alternative is LL' where L is lower triangular with arbitrary diagonal elements. Default is TRUE. Setting it to NA leaves the choice to a CHOLMOD-internal heuristic.
super logical scalar indicating if a supernodal decomposition should be created. The alternative is a simplicial decomposition. Default is FALSE. Setting it to NA leaves the choice to a CHOLMOD-internal heuristic.
Imult numeric scalar which defaults to zero. The matrix that is decomposed is $A + m \cdot I$ where $m$ is the value of Imult and $I$ is the identity matrix of order ncol(A).
...

Details

This is a generic function with special methods for different types of matrices. Use showMethods("Cholesky") to list all the methods for the Cholesky generic.

The method for class dsCMatrix of sparse matrices — the only one available currently — is based on functions from the CHOLMOD library.

Again: If you just want the Cholesky decomposition of a matrix in a straightforward way, you should probably rather use chol(.)

Note that if perm=TRUE (default), the decomposition is

$$A = P' \hat{L} D \hat{L}' P = P' L L' P,$$
where $L$ can be extracted by `as(*, "Matrix")`, $P$ by `as(*, "pMatrix")` and both by `expand(*)`, see the class `CHMfactor` documentation.

Note that consequently, you cannot easily get the “traditional” cholesky factor $R$, from this decomposition, as

$$
R'R = A = P'LL'P = P'\hat{R}'\hat{R}P = (\hat{R}P)'(\hat{R}P),
$$

but $\hat{R}P$ is not triangular even though $\hat{R}$ is.

**Value**

an object inheriting from either "CHMsuper", or "CHMsimpl", depending on the `super` argument; both classes extend "CHMfactor" which extends "MatrixFactorization".

In other words, the result of `cholesky()` is *not* a matrix, and if you want one, you should probably rather use `chol()`, see Details.

**References**


**See Also**

Class definitions `CHMfactor` and `dsCMatrix` and function `expand`. Note the extra `solve(*, system = .)` options in `CHMfactor`.

Note that `chol()` returns matrices (inheriting from "Matrix") whereas `cholesky()` returns a "CHMfactor" object, and hence a typical user will rather use `chol(A)`.

**Examples**

data(KNex)
mtm <- with(KNex, crossprod(mm))
str(mtm@factors) # empty list()
(CI <- Cholesky(mtm))    # uses show(<MatrixFactorization>)
str(mtm@factors) # 'SPDCholesky' (simpl)
(Cm <- Cholesky(mtm, super = TRUE))
c(CI = isLDL(CI), Cm = isLDL(Cm))
str(mtm@factors) # 'SPDCholesky' *and* 'SPDCholesky'
str(cmat <- as(CI, "sparseMatrix"))
str(cmat <- as(Cm, "sparseMatrix"))# hmm: super is *less* sparse here

b <- matrix(c(rep(0, 711), 1), nc = 1)
## solve(Cm, b) by default solves Ax = b, where A = Cm'Cm (= mtm)!
## hence, the identical() check *should* work, but fails on some GOTOblas:
x <- solve(Cm, b)
stopifnot(identical(x, solve(Cm, b, system = "A")),
          all.equal(x, solve(mtm, b)))
Cholesky-class  

Description

The "Cholesky" class is the class of Cholesky decompositions of positive-semidefinite, real dense matrices. The "BunchKaufman" class is the class of Bunch-Kaufman decompositions of symmetric, real matrices. The "pCholesky" and "pBunchKaufman" classes are their packed storage versions.
Objects from the Class

Objects can be created by calls of the form `new("Cholesky", ...)` or `new("BunchKaufman", ...)`, etc., or rather by calls of the form `chol(pm)` or `BunchKaufman(pm)` where `pm` inherits from the "dpoMatrix" or "dsyMatrix" class or as a side-effect of other functions applied to "dpoMatrix" objects (see `dpoMatrix`).

Slots

A Cholesky decomposition extends class `MatrixFactorization` but is basically a triangular matrix extending the "dtrMatrix" class.

- `uplo`: inherited from the "dtrMatrix" class.
- `diag`: inherited from the "dtrMatrix" class.
- `x`: inherited from the "dtrMatrix" class.
- `Dim`: inherited from the "dtrMatrix" class.
- `Dimnames`: inherited from the "dtrMatrix" class.

A Bunch-Kaufman decomposition also extends the "dtrMatrix" class and has a `perm` slot representing a permutation matrix. The packed versions extend the "dtpMatrix" class.

Extends

Class "MatrixFactorization" and "dtrMatrix", directly. Class "dgeMatrix", by class "dtrMatrix". Class "Matrix", by class "dtrMatrix".

Methods

Both these factorizations can directly be treated as (triangular) matrices, as they extend "dtrMatrix", see above. There are currently no further explicit methods defined with class "Cholesky" or "BunchKaufman" in the signature.

Note

1. Objects of class "Cholesky" typically stem from `chol(D)`, applied to a dense matrix $D$.
   On the other hand, the function `Cholesky(S)` applies to a sparse matrix $S$, and results in objects inheriting from class `CHMfactor`.
2. For traditional matrices $m$, `chol(m)` is a traditional matrix as well, triangular, but simply an $n \times n$ numeric matrix. Hence, for compatibility, the "Cholesky" and "BunchKaufman" classes (and their "p*" packed versions) also extend triangular Matrix classes (such as "dtrMatrix"). Consequently, `determinant(R)` for $R \leftarrow \text{chol}(A)$ returns the determinant of $R$, not of $A$. This is in contrast to class `CHMfactor` objects $C$, where `determinant(C)` gives the determinant of the original matrix $A$, for $C \leftarrow \text{Cholesky}(A)$, see also the determinant method documentation on the class `CHMfactor` page.

See Also

Classes `dtrMatrix`, `dpoMatrix`; function `chol`.

Function `Cholesky` resulting in class `CHMfactor` objects, not class "Cholesky" ones, see the section 'Note'.
colSums

Examples

(sm <- as(as(Matrix(diag(5) + 1), "dsyMatrix"), "dspMatrix"));
signif(csm <- chol(sm), 4)

(pm <- crossprod(Matrix(rnorm(18), nrow = 6, ncol = 3)))
(ch <- chol(pm))
if (toupper(ch@uplo) == "U") # which is TRUE
  crossprod(ch)
  stopifnot(all.equal(as(crossprod(ch), "matrix"),
                       as(pm, "matrix"), tolerance=1e-14))

colSums                                                  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

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

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

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

x <- colSums(MM)

(cm <- colSums(MM, sparseResult = TRUE))
stopifnot(is(cm, "sparseVector"), identical(cm, as.numeric(cm))

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(paste("r", 1:7), paste("v",1:8))

M

colSums(M)
rowMeans(M)

# Assertions :
stopifnot(all.equal(colSums(M),
                      setNames(c(1,1,6,6,6,3,2), colnames(M))),
                      all.equal(rowMeans(M), structure(c(1,1,4,8,12,3,2) / 8,
                      .Names = paste("r", 1:7))))
```
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 automagically 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**
  `n == nrow(A)`, only needed when `A` is not specified.

- **iter.max**
  maximal number of iterations for the 1-norm estimator.

- **eps**
  the relative number 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 `norm(v) = 1`. Consequently, $\text{norm}(Av) = \text{norm}(A)/\text{est}$; when `est` is large, `v` is an approximate null vector.

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

- **est**
  a number > 0, the estimated `norm(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.
CsparseMatrix-class

References


See Also

norm, rcond.

Examples

data(KNex)
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
1 / ce$est
system.time(rc <- rcond(mtm)) # takes ca 3 x longer
rc
all.equal(rc, 1/ce$est) # TRUE -- the approximation was good

one <- onenormest(mtm)
str(one) ## est = 12.3
## 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).
CsparseMatrix-class

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:

signature(e1 = "CsparseMatrix", e2 = "numeric"): ...

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

Math signature(x = "CsparseMatrix"): ...

band signature(x = "CsparseMatrix"): ...

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

- 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"): ...

coece signature(from = "CsparseMatrix", to = "Matrix"): ...

coerce signature(from = "CsparseMatrix", to = "lsparsityMatrix"): ...

coerce signature(from = "CsparseMatrix", to = "nsparseMatrix"): ...

colu signature(from = "TsparseMatrix", to = "CsparseMatrix"): ...

colu 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**

```r
getClass("CsparseMatrix")

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

---

### ddenseMatrix-class

**Virtual Class "ddenseMatrix" of Numeric Dense Matrices**

**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(*, "dgeMatrix")` 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
```r
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
```r
%*% signature(x = "ddiMatrix", y = "ddiMatrix"): ...
```

See Also
Class `diagonalMatrix` and function `Diagonal`. 
denseMatrix-class

Examples

```r
(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)))
```

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

Description

This is the virtual class of all dense (S4) matrices. It is the direct superclass of \code{ddenseMatrix}, \code{ldenseMatrix}

Extends

class "Matrix" directly.

Slots

exactly those of its superclass "Matrix".

Methods

Use \code{showMethods(class = "denseMatrix", where =  "package:Matrix")} for an overview of methods.

Extraction ("[" methods, see \code{[.methods}.

See Also

\code{colSums}, \code{kronncker}, and other such methods with own help pages.

Its superclass \code{Matrix}, and main subclasses, \code{ddenseMatrix} and \code{sparseMatrix}.

Examples

\code{showClass("denseMatrix")}
**dgCMatrix-class**  
*Compressed, sparse, column-oriented numeric matrices*

**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")
- `coerce` signature(from = "dgCMatrix", to = "matrix")
- `coerce` signature(from = "dgCMatrix", to = "dgTMatrix")
- `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 `dsCMat`, `dtCMat`, `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(1).

**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.
- **coerce** signature(from = "dgeMatrix", to = "dgeMatrix"): ...
- **coerce** signature(from = "dgeMatrix", to = "matrix"): ...
- **coerce** signature(from = "matrix", to = "dgeMatrix"): ...
- **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.
**dgTMatrix-class**

Methods

- **coerce** signature(from = "matrix", to = "dgRMatrix")
- **coerce** signature(from = "dgRMatrix", to = "matrix")
- **coerce** signature(from = "dgRMatrix", to = "dgTMatrix")

- **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.

---

**Description**

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 as(*, "dgTMatrix"), `spMatrix()`, or `sparseMatrix(*, giveCsparse=FALSE)`.

**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")
- **coerce** signature(from = "dgTMatrix", to = "dgCMatrix")
- **coerce** signature(from = "dgTMatrix", to = "dgeMatrix")
**coerce** signature(from = "dgTMatrix", to = "matrix"), and typically coercion methods for more specific signatures, we are not mentioning here.

Note that these are not guaranteed to continue to exist, but rather you should use calls like `as(x,"CsparseMatrix"),as(x, "generalMatrix"),as(x, "dMatrix"), i.e. coercion to higher level virtual classes.

**coerce** signature(from = "matrix", to = "dgTMatrix"). (direct coercion from tradition matrix).

**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, "dgTMatrix"))
str(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

# Triple 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)
```
Create Diagonal Matrix Object

Description

Create a diagonal matrix object, i.e., an object inheriting from diagonalMatrix (or a “standard” CsparseMatrix diagonal matrix in cases that is preferred).

Usage

Diagonal(n, x = NULL)

.symDiagonal(n, x = rep.int(1,n), uplo = "U", kind)
.trDiagonal(n, x = 1, uplo = "U", unitri=TRUE, kind)
.sparseDiagonal(n, x = 1, uplo = "U",
shape = if(missing(cols)) "t" else "g",
unitri, kind, cols = if(n) 0:(n - 1L) else integer(0))

Arguments

- **n**: integer specifying the dimension of the (square) matrix. If missing, length(x) is used.
- **x**: numeric or logical; if missing, a unit diagonal \( n \times n \) matrix is created.
- **uplo**: for .symDiagonal (.trDiagonal), the resulting sparse symmetricMatrix (or triangularMatrix) will have slot uplo set from this argument, either "U" or "L". Only rarely will it make sense to change this from the default.
- **shape**: string of 1 character, one of c("t", "s", "g"), to choose a triangular, symmetric or general result matrix.
- **unitri**: optional logical indicating if a triangular result should be “unit-triangular”, i.e., with diag = "U" slot, if possible. The default, missing, is the same as TRUE.
- **kind**: string of 1 character, one of c("d","l","n"), to choose the storage mode of the result, from classes dsparseMatrix, lsparseMatrix, or nsparseMatrix, respectively.
- **cols**: integer vector with values from \( 0:(n-1) \), denoting the columns to subselect conceptually, i.e., get the equivalent of Diagonal(n,x)[, cols + 1].

Value

Diagonal() returns an object of class ddiMatrix or ldiMatrix (with “superclass” diagonalMatrix).
.symDiagonal() returns an object of class dsCMat or lsCMat, i.e., a sparse symmetric matrix. Analogously, .triDiagonal gives a sparse triangularMatrix. This can be more efficient than Diagonal(n) when the result is combined with further symmetric (sparse) matrices, e.g., in kronecker, however not for matrix multiplications where Diagonal() is clearly preferred.
.sparseDiagonal(), the workhorse of .symDiagonal and .trDiagonal returns a CsparseMatrix (the resulting class depending on shape and kind) representation of Diagonal(n), or, when cols are specified, of Diagonal(n)[, cols+1].
diagonalMatrix-class

Author(s)
Martin Maechler

See Also
the generic function diag for extraction of the diagonal from a matrix works for all “Matrices”. bandSparse constructs a banded sparse matrix from its non-zero sub-/super - diagonals. band(A) returns a band matrix containing some sub-/super - diagonals of A. Matrix for general matrix construction; further, class diagonalMatrix.

Examples
Diagonal(3)
Diagonal(x = 10^(3:1))
Diagonal(x = (1:4) ^= 2) # -> "ldiMatrix"

## Use Diagonal() + kronecker() 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: code"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.
diagonalMatrix-class

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.

```r
coeerce signature(from = "matrix", to = "diagonalMatrix"): ...
coeerce signature(from = "Matrix", to = "diagonalMatrix"): ...
coeerce signature(from = "diagonalMatrix", to = "generalMatrix"): ...
coeerce signature(from = "diagonalMatrix", to = "triangularMatrix"): ...
coeerce signature(from = "diagonalMatrix", to = "nMatrix"): ...
coeerce signature(from = "diagonalMatrix", to = "matrix"): ...
coeerce 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

```r
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))

diagU2N

Transform Triangular Matrices from Unit Triangular to General Triangular and Back

Description
Transform a triangular matrix x, i.e., of class "triangularMatrix", from (internally!) unit triangular ("unitriangular") to "general" triangular (diagU2N(x)) or back (diagN2U(x)). Note that the latter, diagN2U(x), also sets the diagonal to one in cases where diag(x) was not all one.
.diagU2N(x) assumes but does not check that x is a triangularMatrix with diag slot "U", and should hence be used with care.

Usage

diagN2U(x, cl = getClassDef(class(x)), checkDense = FALSE)

diagU2N(x, cl = getClassDef(class(x)), checkDense = FALSE)

.diagU2N(x, cl, checkDense = FALSE)

Arguments

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

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

Value
a triangular matrix of the same class but with a different diag slot. For diagU2N (semantically) with identical entries as x, whereas in 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 internal utilities.
See Also

"triangularMatrix", "dtMatrix".

Examples

(T <- Diagonal(7) + triu(Matrix(rpois(49, 1/4), 7, 7), k = 1))
(uT <- diagNZU(T)) # "unitriangular"
(t.u <- diagNZU(10*T))# changes the diagonal!
stopifnot(all(T == uT), diag(t.u) == 1,
identical(T, diagU2N(uT))
T[upper.tri(T)] <- 5
T <- diagNZU(as(T,"triangularMatrix"))
stopifnot(T@diag == "U")
dT <- as(T, "denseMatrix")
dt. <- diagNZU(dT)
dtU <- diagNZU(dT, checkDense=TRUE)
stopifnot(is(dtU, "denseMatrix"), is(dt., "sparseMatrix"),
all(dt == dt.), all(dt == dtU),
dt.@diag == "U", dtU@diag == "U")

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:

**coerce** signature(from = "dMatrix", to = "matrix"): ...

**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(rnorm(56, sd=10), 4, 14)
(M. <- zapsmall(M))
table(as.logical(M. == 0))
```

---

**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" class of correlation matrices extends "dpoMatrix" with a slot sd, which allows to restore 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") 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 "0" 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 = "dppMatrix", 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(.) $\equiv 1$ numbers (or logicals).

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(h6p <- as(h6, "dppMatrix"))

### 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 <- chol(ch6)
stopifnot(identical(chch, ch6@factors$Cholesky),
  all(abs(crossprod(chch) - ch6) < 1e-10))
```

---

**Description**

Returns a sparse matrix with no “explicit zeroes”, i.e., all zero or `FALSE` entries are dropped from the explicitly indexed matrix entries.

**Usage**

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

**Arguments**

- `x`: a Matrix, typically sparse, i.e., inheriting from `sparseMatrix`.
- `tol`: non-negative number to be used as tolerance for checking if an entry $x_{i,j}$ should be considered to be zero.
- `is.Csparse`: logical indicating prior knowledge about the “Csparseness” of `x`. This exists for possible speedup reasons only.

**Value**

A Matrix like `x` but with no explicit zeros, i.e., `!any(x@x == 0)`, always inheriting from `CsparseMatrix`.

**Note**

When a sparse matrix is the result of matrix multiplications, you may want to consider combining `drop0()` with `zapsmall()`, see the example.

**See Also**

`spMatrix`, class `sparseMatrix`; `nnzero`
dsCMatrix-class

Examples

m <- spMatrix(10,20, i= 1:8, j=2:9, x = c(0:2,3:-1))
m
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)

dsCMat}
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.

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

Cholesky signature(A = "dsCMatrix",\ldots): 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.

c coerce signature(from = "dsCMatrix", to = "dgTMatrix")

c coerce signature(from = "dsCMatrix", to = "dgeMatrix")

c coerce signature(from = "dsCMatrix", to = "matrix")

c coerce signature(from = "dsTMatrix", to = "dgeMatrix")

c coerce signature(from = "dsTMatrix", to = "dsCMatrix")

c coerce signature(from = "dsTMatrix", to = "dsyMatrix")

c coerce signature(from = "dsTMatrix", to = "matrix")

See Also

Classes dgCMatrix, dgTMatrix, dgeMatrix and those mentioned above.

Examples

mm <- Matrix(toeplitz(c(10, 0, 1, 0, 3)), sparse = TRUE)
mm # automatically dsCMatrix
str(mm)
## how would we go from a manually constructed Tsparse* :
mT <- as(mm, "dgTMatrix")

## Either
(symM <- as(mT, "symmetricMatrix"))## dsT
(symC <- as(symM, "CsparseMatrix"))## dsC
## or
sC <- Matrix(mT, sparse=TRUE, forceCheck=TRUE)
sym2 <- as(symC, "TsparseMatrix")
## --> the same as 'symM', a "dsTMatrix"

dsparseMatrix-class

### 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

`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)`.  
- `coerce` signature(`from = "dsCMatrix", to = "dsRMatrix"`)
See Also

the classes \texttt{dgCMatrix}, \texttt{dgTMatrix}, and \texttt{dgeMatrix}.

Examples

```r
(m0 <- new("dsRMatrix"))
m2 <- new("dsRMatrix", 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 # dsRMatrix
```

---

### dsyMatrix-class

**Symmetric Dense (Packed \ Non-packed) 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. Only the upper triangle or the lower triangle is stored.

**Objects from the Class**

Objects can be created by calls of the form \texttt{new("dsyMatrix", ...)} or \texttt{new("dspMatrix", ...)}, respectively.

**Slots**

- \texttt{uplo}: Object of class "character". Must be either "U", for upper triangular, and "L", for lower triangular.
- \texttt{x}: Object of class "numeric". The numeric values that constitute the matrix, stored in column-major order.
- \texttt{dim,Dim,dimnames}: The dimension (a length-2 "integer") and corresponding names (or NULL), see the \texttt{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 \texttt{showClass("dsyMatrix")}, e.g., for details.
**Methods**

- **coerce** signature(from = "denseMatrix", to = "dgeMatrix")
- **coerce** signature(from = "dspMatrix", to = "matrix")
- **coerce** signature(from = "dssMatrix", to = "matrix")
- **coerce** signature(from = "dsyMatrix", to = "dspMatrix")
- **coerce** signature(from = "dsyMatrix", to = "dsyMatrix")
- **norm** signature(x = "dsyMatrix", type = "character"), or x = "dsyMatrix" or type = "missing": Computes the matrix norm of the desired type, see, norm.
- **rcond** signature(x = "dsyMatrix", type = "character"), or x = "dsyMatrix" or type = "missing": Computes the reciprocal condition number, rcond().
- **solve** signature(a = "dsyMatrix", b = ".....") and solve signature(a = "dsyMatrix", b = "....."): x <- solve(a,b) solves A x = 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 "dsyMatrix"

## 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
```

---

**dtCMatrix-class**

**Triangular, (compressed) sparse column matrices**

**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 coercion such as `as(x, "triangularMatrix"), or as(x, "dtCMatrix").`

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

`coerce` signature(from = "dtCMatrix", to = "dgTMatrix")
`coerce` signature(from = "dtCMatrix", to = "dgeMatrix")
`coerce` signature(from = "dtTMatrix", to = "dgeMatrix")
`coerce` signature(from = "dtTMatrix", to = "dtrMatrix")
`coerce` signature(from = "dtTMatrix", to = "matrix")
`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

classHBdtcmatrixBI

showclassHBdtcmatrixBI
tQnewHBdtMatrix", 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, "dtCMatrix"))
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))

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 # should equal the identity matrix
i5 <- iu2 # should equal I5
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"

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 \(d \times d\), \(\text{length}(x)\) is of length \(d(d+1)/2\) (also when diag \(\neq "U"\)).
- **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")`.
- **coerce** signature(from = "dtpMatrix", to = "dtrMatrix")
- **coerce** signature(from = "dtpMatrix", to = "matrix")
- **determinant** signature(x = "dtpMatrix", logarithm = "logical"): the determinant(x) trivially is \(\prod(\text{diag}(x))\), 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 forwardsolve, 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**

```r
showClass("dtrMatrix")
exmple("dtrMatrix-class", echo=FALSE)
(p1 <- as(T2, "dtpMatrix"))
str(p1)
(pp <- as(T, "dtpMatrix"))
pl <- solve(p1)
stopifnot(length(p1@x) == 3, length(pp@x) == 3)
```
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.
dtrMatrix-class

See Also
Classes dgCMatrix, dgTMatrix, dgeMatrix

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

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.

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),

coerce signature(from = "dgeMatrix", to = "dtrMatrix")
coerce signature(from = "dtrMatrix", to = "matrix")
coerce signature(from = "dtrMatrix", to = "ltrMatrix")
coerce signature(from = "dtrMatrix", to = "matrix")
coerce signature(from = "matrix", to = "dtrMatrix")
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

(m <- rbind(2:3, 0:-1))
(M <- as(m, "dgeMatrix"))

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

Description

Expands decompositions stored in compact form into factors.

Usage

expand(x, ...)

Arguments

x a matrix decomposition.
... further arguments passed to or from other methods.

Details

This is a generic function with special methods for different types of decompositions, see showMethods(expand) to list them all.

Value

The expanded decomposition, typically a list of matrix factors.
**Note**

Factors for decompositions such as `lu` and `qr` can be stored in a compact form. The function `expand` allows all factors to be fully expanded.

**See Also**

The LU `lu`, and the Cholesky decompositions which have expand methods; `facmul`.

**Examples**

```r
(x <- Matrix(round(rnorm(9),2), 3, 3))
(ex <- expand(lux <- lu(x)))
```

**Description**

Compute the exponential of a matrix.

**Usage**

```r
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 Pade’ approximation with three step preconditioning.

**Value**

The matrix exponential of `x`.

**Note**

The `expm` package contains newer (partly faster and more accurate) algorithms for `expm()` and includes `logm` and `sqrts`.

**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

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


See Also

Schur; additionally, expm, logm, etc in package expm.

Examples

```r
(ml <- Matrix(c(1,0,1), nc = 2))
(e1 <- expm(ml)) ; e <- exp(1)
stopifnot(all.equal(e1@x, c(0,0,0), tolerance = 1e-15))
(ml2 <- Matrix(c(-49, -64, 24, 31), nc = 2))
(e2 <- expm(ml2))
(ml3 <- Matrix(cbind(0, rbind(6*diag(3), 0))))# sparse!
(e3 <- expm(ml3)) # 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".
- `...` 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.

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://www.cise.ufl.edu/research/sparse/matrices

Examples

```r
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")))

## Not run:
## 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 un-tar step!
str(sm <-
readHB(gzcon(url("http://www.cise.ufl.edu/research/sparse/RR/Boeing/msc00726.tar.gz"))))

str(jgl009 <-
readMM(gzcon(url("ftp://math.nist.gov/pub/MatrixMarket2/Harwell-Boeing/counterx/jgl009.mtx.gz"))))

## End(Not run)
data(KNex)
## 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)
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():
```
facmul

Multiplication by Decomposition Factors

Description

Performs multiplication by factors for certain decompositions (and allows explicit formation of those factors).

Usage

facmul(x, factor, y, transpose, left, ...)

Arguments

x a matrix decomposition. No missing values or IEEE special values are allowed.
factor an indicator for selecting a particular factor for multiplication.
y a matrix or vector to be multiplied by the factor or its transpose. No missing values or IEEE special values are allowed.
transpose a logical value. When FALSE (the default) the factor is applied. When TRUE the transpose of the factor is applied.
left a logical value. When TRUE (the default) the factor is applied from the left. When FALSE the factor is applied from the right.
... the method for "qr.Matrix" has additional arguments.

Value

the product of the selected factor (or its transpose) and y

NOTE

Factors for decompositions such as lu and qr can be stored in a compact form. The function facmul allows multiplication without explicit formation of the factors, saving both storage and operations.

References

forceSymmetric

forceSymmetric

Description

Force a square matrix \( x \) to a \code{symmetricMatrix}, \textit{without} a symmetry check as it would be applied for \code{as(x, "symmetricMatrix")}.

Usage

\function{forceSymmetric}{x, uplo}

Arguments

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

Value

a square matrix inheriting from class \code{symmetricMatrix}.

See Also

\code{symmpart} for the symmetric part of a matrix, or the coercions \code{as(x, <symmetricMatrix class>).}

Examples

\begin{verbatim}
## Hilbert matrix
i <- 1:6
h6 <- 1/outer(i - 1L, i, "+")
sd <- sqrt(diag(h6))
hh <- t(h6/sd)/sd # theoretically symmetric
isSymmetric(hh, tol=0) # FALSE; hence
try(as(hh, "symmetricMatrix")) # fails, but this works fine:
H6 <- forceSymmetric(hh)
\end{verbatim}
### 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
```r
formatSparseM(x, zero.print = ".", align = c("fancy", "right"),
m = as(x,"matrix"), asLogical=NULL, uniDiag=NULL,
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`. 
**generalMatrix-class**

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.

---

graph-sparseMatrix Conversions "graph" <-> (sparse) Matrix

Description
The Matrix package has supported conversion from and to "graph" objects from (Bioconductor) package graph since summer 2005, via the usual as(., "<class>") coercion,
as(from, Class)

Since 2013, this functionality is further exposed as the graph2T() and T2graph() functions (with
further arguments than just from), which convert graphs to and from the triplet form of sparse
matrices (of class "TsparseMatrix").

Usage
graph2T(from, use.weights = )
T2graph(from, need.uniq = is_not_uniqT(from), edgemode = NULL)

Arguments
from for graph2T(), an R object of class "graph";
for T2graph(), a sparse matrix inheriting from "TsparseMatrix".
use.weights logical indicating if weights should be used, i.e., equivalently the result will be
numeric, i.e. of class dgTMatrix; otherwise the result will be ngTMatrix or
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.
need.uniq a logical indicating if from may need to be internally “uniqified”; do not set this
and hence rather use the default, unless you know what you are doing!
edgemode one of NULL, "directed", or "undirected". The default NULL looks if the
matrix is symmetric and assumes "undirected" in that case.
For \texttt{graph2T()}, a sparse matrix inheriting from "\texttt{TsparseMatrix}".
For \texttt{T2graph()} an \texttt{R} object of class "\texttt{graph}".

\textbf{See Also}

Note that the CRAN package \texttt{igraph} also provides conversions from and to sparse matrices (of package \texttt{Matrix}) via its \texttt{graph.adjacency()} and \texttt{get.adjacency()}.

\textbf{Examples}

\begin{verbatim}
if(isTRUE(try(require(graph)))) {  # super careful .. for "checking reasons"
  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(edgeWeights(g1)) # all '2'

  show(a2 <- sparseMatrix(i=c(1:4,1), 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), giveC=FALSE) # no 'x'
  show(a.) # "ngTMatrix"
  show(g. <- as(a., "graph"))
}
\end{verbatim}

---

\textbf{Hilbert} \hspace{1cm} \textit{Generate a Hilbert matrix}

\textbf{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.

\textbf{Usage}

\texttt{Hilbert(n)}

\textbf{Arguments}

\begin{itemize}
  \item \texttt{n} \hspace{1cm} a non-negative integer.
\end{itemize}

\textbf{Value}

the \( n \) by \( n \) symmetric Hilbert matrix as a "\texttt{dpoMatrix}" object.
See Also
the class `dpoMatrix`

Examples

```r
Hilbert(6)
```
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.

color: 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

showMethods(image)
## If you want to see all the methods' implementations:
showMethods(image, incl=TRUE, inherit=FALSE)

data(CAex)
image(CAex, main = "image(CAex)"
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)
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(1,300), 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), all.equal(I2, I3))
## using an opaque border color
image(USCounties, c(1,100), c(1,100), useAbs=FALSE, lwd=3, border.col = adjustcolor("skyblue", 1/2))

if(doExtras <- interactive() || nzchar(Sys.getenv("R_MATRIX_CHECK_EXTRA")) ||
   identical("true", unname(Sys.getenv("R_PKG_CHECKING_doExtras")))){
## 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
}

---

### 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

showClass("index")

indMatrix-class  Index Matrices

Description

The "indMatrix" class is the class of index matrices, stored as 1-based integer index vectors. An index matrix is a matrix with exactly one non-zero entry per row. Index matrices are useful for mapping observations to unique covariate values, for example.

Matrix (vector) multiplication with index matrices is equivalent to replicating and permuting rows, or "sampling rows with replacement", and is implemented that way in the Matrix package, see the 'Details' below.

Details

Matrix (vector) multiplication with index matrices from the left is equivalent to replicating and permuting rows of the matrix on the right hand side. (Similarly, matrix multiplication with the transpose of an index matrix from the right corresponds to selecting columns.) The crossproduct of an index matrix $M$ with itself is a diagonal matrix with the number of entries in each column of $M$ on the diagonal, i.e., $M'M = \text{Diagonal}(x=\text{table}(M@\text{perm}))$.

Permutation matrices (of class pMatrix) are special cases of index matrices: They are square, of dimension, say, $n \times n$, and their index vectors contain exactly all of 1:n.

While “row-indexing” (of more than one row or using drop=FALSE) stays within the "indMatrix" class, all other subsetting/indexing operations (“column-indexing”, including, diag) on "indMatrix" objects treats them as nonzero-pattern matrices ("ngTMatrix" specifically), such that non-matrix subsetting results in logical vectors. Sub-assignment (M[i,j] <- v) is not sensible and hence an error for these matrices.

Objects from the Class

Objects can be created by calls of the form new("indMatrix", ...) or by coercion from an integer index vector, see below.
Slots

perm: An integer, 1-based index vector, i.e. an integer vector of length \( \text{Dim}[1] \) whose elements are taken from \( 1: \text{Dim}[2] \).

Dim: integer vector of length two. In some applications, the matrix will be skinny, i.e., with at least as many rows as columns.

Dimnames: a list of length two where each component is either NULL or a character vector of length equal to the corresponding Dim element.

Extends

Class "sparseMatrix" and "generalMatrix", directly.

Methods

```r
%*% signature(x = "matrix", y = "indMatrix") and other signatures (use showMethods("%*%", class="indMatrix") ... 
```

coerce signature(from = "integer", to = "indMatrix"): This enables typical "indMatrix" construction, given an index vector from elements in \( 1: \text{Dim}[2] \), see the first example.

coerce signature(from = "numeric", to = "indMatrix"): a user convenience, to allow as(perm, "indMatrix") for numeric perm with integer values.

coerce signature(from = "list", to = "indMatrix"): The list must have two (integer-valued) entries: the first giving the index vector with elements in \( 1: \text{Dim}[2] \), the second giving Dim[2]. This allows "indMatrix" construction for cases in which the values represented by the rightmost column(s) are not associated with any observations, i.e., in which the index does not contain values Dim[2], Dim[2]-1, Dim[2]-2, ...

coerce signature(from = "indMatrix", to = "matrix"): coercion to a traditional FALSE/TRUE matrix of mode logical.

coerce signature(from = "indMatrix", to = "ngTMatrix"): coercion to sparse logical matrix of class ngTMatrix.

t signature(x = "indMatrix"): return the transpose of the index matrix (which is no longer an indMatrix, but of class ngTMatrix.

colSums, colMeans, rowSums, rowMeans signature(x = "indMatrix"): return the column or row sums or means.

rbind2 signature(x = "indMatrix", y = "indMatrix"): a fast method for rowwise catenation of two index matrices (with the same number of columns).

kronecker signature(X = "indMatrix", Y = "indMatrix"): return the kronecker product of two index matrices, which corresponds to the index matrix of the interaction of the two.

Author(s)

Fabian Scheipl, Uni Muenchen, building on existing "pMatrix", after a nice hike's conversation with Martin Maechler; diverse tweaks by the latter. The crossprod(x,y) and kronecker(x,y) methods when both arguments are "indMatrix" have been made considerably faster thanks to a suggestion by Boris Vaillant.
See Also

The permutation matrices \texttt{pMatrix} are special index matrices. The “pattern” matrices, \texttt{nMatrix} and its subclasses.

Examples

```r
pl <- as(c(2,3,1), "pMatrix")
(sm1 <- as(rep(c(2,3,1), e=3), "indMatrix"))
stopifnot(all(sm1 == pl[rep(1:3, each=3),]))

## row-indexing of a \texttt{pMatrix} turns it into an \texttt{indMatrix}:
class(pl[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(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, "ngTMatrix")
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 <- suppressWarnings(rBind(I1, I2)))
stopifnot(is(I12, "indMatrix"),
  if(getRversion() >= "3.2.0") identical(I12, rbind(I1, I2)) else TRUE,
  colSums(I12) == c(2L,2:4,2:4))
```

---

**invPerm**  
*Inverse Permutation Vector*

**Description**

From a permutation vector \( p \), compute its *inverse* permutation vector.
Usage

invPerm(p, zero.p = FALSE, zero.res = FALSE)

Arguments

- **p**: an integer vector of length, say, n.
- **zero.p**: logical indicating if p contains values 0:(n-1) or rather (by default, zero.p = FALSE) 1:n.
- **zero.res**: logical indicating if the result should contain values 0:(n-1) or rather (by default, zero.res = FALSE) 1:n.

Value

an integer vector of the same length (n) as p. By default, (zero.p = FALSE, zero.res = FALSE), invPerm(p) is the same as order(p) or sort.list(p) and for that case, the function is equivalent to invPerm. <- function(p) { p[p] <- seq_along(p) ; p }.

Author(s)

Martin Maechler

See Also

the class of permutation matrices, pMatrix.

Examples

```r
p <- sample(10) # a random permutation vector
ip <- invPerm(p)
p[ip] # == 1:10
## they are indeed inverse of each other:
stopifnot(
  identical(p[ip], 1:10),
  identical(ip[p], 1:10),
  identical(invPerm(ip), p)
)
```

---

is.na-methods

**is.na**, **is.infinite** Methods for 'Matrix' Objects

Description

Methods for function **is.na()**, **is.finite()**, and **is.infinite()** for all Matrices (objects extending the Matrix class):

- **x = "denseMatrix"** returns a "nMatrix" object of same dimension as x, with TRUE's whenever x is NA, finite, or infinite, respectively.
- **x = "sparseMatrix"** ditto.
Usage

```r
## S4 method for signature 'sparseMatrix'
is.na(x)
## S4 method for signature 'dsparseMatrix'
is.finite(x)
## S4 method for signature 'ddenseMatrix'
is.infinite(x)
## ...
## and for other classes

## S4 method for signature 'xMatrix'
anyNA(x)
## S4 method for signature 'nsparseMatrix'
anyNA(x)
## S4 method for signature 'sparseVector'
anyNA(x)
## S4 method for signature 'nsparseVector'
anyNA(x)
```

Arguments

- `x` sparse or dense matrix or sparse vector (here; any R object in general).

See Also

`NA`, `is.na`; `is.finite`, `is.infinite`; `nMatrix`, `denseMatrix`, `sparseMatrix`.

The `sparseVector` class.

Examples

```r
M <- Matrix(1:6, nrow=4, ncol=3,
    dimnames = list(c("a", "b", "c", "d"), c("A", "B", "C")))
stopifnot(all(!is.na(M)))
M[2:3,2] <- NA
is.na(M)
if(exists("anyNA", mode="function"))
anyNA(M)

A <- spMatrix(10, 20, i = c(1,3:8),
    j = c(2,9,6:10),
    x = 7 * (1:7))
stopifnot(all(!is.na(A)))

inA <- is.na(A)
stopifnot(sum(inA) == 1+1+5)
```
is.null.DN

Are the Dimnames dn NULL-like?

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
m <- matrix(round(100 * rnorm(6)), 2, 3); m1 <- m2 <- m3 <- m4 <- m
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

stopifnot(m == m1, m1 == m2, m2 == m3, m3 == m4,
          identical(capture.output(m) -> cm,
                     capture.output(m1))),
isSymmetric-methods

Methods for Function isSymmetric in Package 'Matrix'

Description

isSymmetric(M) returns a logical indicating if M is a symmetric matrix. This (now) is a base function with a default method for the traditional matrices of class "matrix". Methods here are defined for virtual Matrix classes such that it works for all objects inheriting from class Matrix.

See Also

forceSymmetric, symmpart, and the formal class (and subclasses) "symmetricMatrix".

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, "dgeMatrix")) # still symmetric, even if not "formally"
isSymmetric(triu(M)) # FALSE

## Look at implementations:
showMethods("isSymmetric", includeDefs=TRUE)# "ANY": base's S3 generic; 6 more

isTriangular isTriangular() and isDiagonal() Methods

Description

isTriangular(M) returns a logical indicating if M is a triangular matrix. Analogously, isDiagonal(M) is true iff M is a diagonal matrix.

Contrary to isSymmetric(), these two functions are generically from package Matrix, and hence also define methods for traditional (class "matrix") matrices.

By our definition, triangular, diagonal and symmetric matrices are all square, i.e. have the same number of rows and columns.

Usage

isDiagonal(object)

isTriangular(object, upper = NA, ...)
Arguments

- **object**: any R object, typically a matrix (traditional or Matrix package).
- **upper**: logical, one of NA (default), FALSE, or TRUE where the last two cases require a lower or upper triangular object to result in TRUE.
- **...**: potentially further arguments for other methods.

Value

A ("scalar") logical, TRUE or FALSE, never NA. For isTriangular(), if the result is TRUE, it may contain an attribute (see attributes "kind", either "L" or "U" indicating if it is a lower or upper triangular matrix.

See Also

- `isSymmetric`: formal class (and subclasses) "triangularMatrix" and "diagonalMatrix".

Examples

```r
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, "dgeMatrix")) # still triangular, even if not "formally"
isTriangular(crossprod(M)) # FALSE

isDiagonal(matrix(c(2,0,0,1), 2, 2)) # 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

```r
KhatriRao(X, Y = X, FUN = "+", 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.
- **make.dimnames**: logical indicating if the result should inherit dimnames from X and Y in a simple way.
Value

A "C sparseMatrix", say R, the Khatri-Rao product of X (n × k) and Y (m × k), is of dimension (n · m) × k, where the j-th column, R[,j] is the kronecker product 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

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,"nMatrix")
nm <- as(d,"nMatrix")
KhatriRao(nm,nm, make.dimnames=TRUE)
KhatriRao(nm,nm, make.dimnames=TRUE)

stopifnot(dim(KhatriRao(m,d)) == c(nrow(m)*nrow(d), ncol(d)))
## border cases / checks:
```

```r
```
zm <- nm; zm[] <- 0 # all 0 matrix
stopifnot(all(K1 <- KrChFrNd(zm, zm) == 0), identical(dim(K1), c(12L, 4L)),
  all(K2 <- KrChFrNd(zm, nd) == 0), identical(dim(K2), c(12L, 4L))

d0 <- d; d0[] <- 0; m0 <- Matrix(d0[-1,])
stopifnot(all(K3 <- KrChFrNd(d0, m) == 0), identical(dim(K3), dim(Kdm)),
  all(K4 <- KrChFrNd(m, d0) == 0), identical(dim(K4), dim(Kmd)),
  all(KrChFrNd(d0, d0) == 0), all(KrChFrNd(m0, d0) == 0),
  all(KrChFrNd(d0, m0) == 0), all(KrChFrNd(m0, m0) == 0),
  identical(dimnames(KrChFrNd(m, d0, make.dimnames=TRUE)), dimnames(Kmd))

---

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 "dgCMatrix" object. The vector y is just numeric of length 1850.

Usage

data(KNex)

References


Examples

data(KNex)
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 \( \emptyset \star \text{NA} \) as \( \emptyset \), not as \text{NA} as usually in \text{R} (and as used for the \text{base} function \text{kronecker}).

**Methods**

```r
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(1,3,3))
M <- Matrix(l3)
(N <- as(M, "nsparseMatrix")) # "ntCMatrix" (upper triangular)
N2 <- as(N, "generalMatrix") # (lost "t"riangularity)
MM <- kronecker(M,M)
NN <- kronecker(N,N) # "dtTMatrix" i.e. did keep
NN2 <- kronecker(N2,N2)
stopifnot(identical(NN,MM),
          is(NN2, "sparseMatrix"); all(NN2 == NN),
          is(NN, "triangularMatrix"))
```
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

coerce signature(from = "matrix", to = "ldenseMatrix"): ...

coerce signature(from = "ldenseMatrix", to = "matrix"): ...

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")
Class "ldiMatrix" of Diagonal Logical Matrices

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

```r
(1M <- Diagonal(x = c(TRUE, FALSE, FALSE)))
str(1M)#> gory details (slots)
crossprod(1M) # numeric
(nM <- as(1M, "nMatrix"))# -> sparse (not formally `\'diagonal\'`)
crossprod(nM) # logical sparse
```
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". 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

showClass("lgeMatrix")
str(new("lgeMatrix"))
set.seed(1)
(IM <- Matrix(matrix(rnorm(28), 4,7) > 0))# a simple random lgeMatrix
set.seed(11)
(IC <- Matrix(matrix(rnorm(28), 4,7) > 0))# a simple random lgCMatrix
as(IM, "lgCMatrix")
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.
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

(m <- Matrix(c(0,0,2:0), 3,5, dimnames= LETTERS[1:3],NULL)))
(lm <- (m > 1)) # lgC

# no longer sparse
stopifnot(is(lm,"lsparseMatrix"),
identical(!lm, m <= 1))

data(KNex)
str(mmG.1 <- (KNex $ mm) > 0.1)# "lgC"

table(mmG.1)# however with many "non-structural zeros"'

## from logical to nz_pattern -- okay when there are no NA's:
mmG.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") # has no extra FALSE, i.e. drop0() included

stopifnot(identical(mmG.1, as((KNex $ mm) != 0,"nMatrix")),
validObject(lmG.1), all(lmG.1==x),
  # same "logical" but lmG.1 has no 'FALSE' in x slot:
  all(lmG.1 == mmG.1))

class(xnx <- crossprod(mmG.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

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="dsyMatrix") 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, "lsyMatrix")
str(sM <- as(sM, "lspMatrix")) # packed symmetric
ltrMatrix-class

Triangular Dense Logical Matrices

Description

The "ltrMatrix" class is the class of triangular, dense, logical matrices in nonpacked storage. The "ltrMatrix" 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("ltrMatrix"))

(lutr <- as(upper.tri(matrix(4, 4), "ltrMatrix"))
str(lutp <- as(lutr, "ltrMatrix"))# packed matrix: only 10 = (4+1)*4/2 entries
!lutp ## the logical negation (is *not* logical triangular !)
## but this one is:
stopifnot(all.equal(lutp, as(!!lutp, "ltrMatrix")))
(Generalized) Triangular Decomposition of a Matrix

Description

Computes (generalized) triangular decompositions of square (sparse or dense) and non-square dense matrices.

Usage

lu(x, ...)  
## S4 method for signature 'matrix'
lu(x, warnSing = TRUE, ...)

## S4 method for signature 'dgeMatrix'
lu(x, warnSing = TRUE, ...)

## S4 method for signature 'dgCMatrix'
lu(x, errSing = TRUE, order = TRUE, tol = 1,  
    keep.dimnames = TRUE, ...)

Arguments

- **x**: a dense or sparse matrix, in the latter case of square dimension. No missing values or IEEE special values are allowed.
- **warnSing**: (when x is a "denseMatrix") logical specifying if a warning should be signalled when x is singular.
- **errSing**: (when x is a "sparseMatrix") logical specifying if an error (see stop) should be signalled when x is singular. When x is singular, lu(x, errSing=FALSE) returns NA instead of an LU decomposition. No warning is signalled and the user should be careful in that case.
- **order**: logical or integer, used to choose which fill-reducing permutation technique will be used internally. Do not change unless you know what you are doing.
- **tol**: positive number indicating the pivoting tolerance used in cs_lu. Do only change with much care.
- **keep.dimnames**: logical indicating that dimnames should be propagated to the result, i.e., “kept”. This was hardcoded to FALSE in upto Matrix version 1.2-0. Setting to FALSE may gain some performance.
- **...**: further arguments passed to or from other methods.

Details

lu() is a generic function with special methods for different types of matrices. Use showMethods("lu") to list all the methods for the lu generic.

The method for class dgeMatrix (and all dense matrices) is based on LAPACK’s "dgetrf" subroutine. It returns a decomposition also for singular and non-square matrices.
The method for class \texttt{dgCMatrix} (and all sparse matrices) is based on functions from the \texttt{CSparse} library. It signals an error (or returns \texttt{NA}, when \texttt{errSing = FALSE}, see above) when the decomposition algorithm fails, as when \(x\) is (too close to) singular.

\section*{Value}

An object of class "LU", i.e., "\texttt{denseLU}" (see its separate help page), or "\texttt{sparseLU}". see \texttt{sparseLU}; this is a representation of a triangular decomposition of \(x\).

\section*{Note}

Because the underlying algorithm differ entirely, in the \texttt{dense} case (class \texttt{denseLU}), the decomposition is

\[ A = PLU, \]

where as in the \texttt{sparse} case (class \texttt{sparseLU}), it is

\[ A = P'L'U'Q. \]

\section*{References}


\section*{See Also}

Class definitions \texttt{denseLU} and \texttt{sparseLU} and function \texttt{expand}; \texttt{qr}, \texttt{chol}.

\section*{Examples}

```r
#--- Dense -----------------------------
x <- Matrix(rnorm(9), 3, 3)
lu(x)
dim(x2 <- round(10 * x[, -3]))# non-square
expand(lu2 <- lu(x2))

#--- Sparse (see more in "sparseLU-class")------ % ./sparseLU-class.Rd

pm <- as(readMM(system.file("external/pores_1.mtx",
package = "Matrix")),
"CsparseMatrix")
str(pmLU <- lu(pm)) # p is a 0-based permutation of the rows
# q is a 0-based permutation of the columns

# permute rows and columns of original matrix
ppm <- pm[pmLU@p + 1L, pmLU@q + 1L]
plU <- drop0(pmLU@L %*% pmLU@U) # L %*% U -- dropping extra zeros

# equal up to "rounding"
ppm[1:14, 1:5]
plU[1:14, 1:5]
```
LU-class

LU (dense) Matrix Decompositions

Description

The "LU" class is the virtual class of LU decompositions of real matrices. "denseLU" the class of LU decompositions of dense real matrices.

Details

The decomposition is of the form

\[ A = PLU \]

where typically all matrices are of size \( n \times n \), and the matrix \( P \) is a permutation matrix, \( L \) is lower triangular and \( U \) is upper triangular (both of class \( \text{dtrMatrix} \)).

Note that the dense decomposition is also implemented for a \( m \times n \) matrix \( A \), when \( m \neq n \).

If \( m < n \) ("wide case"), \( U \) is \( m \times n \), and hence not triangular.

If \( m > n \) ("long case"), \( L \) is \( m \times n \), and hence not triangular.

Objects from the Class

Objects can be created by calls of the form `new("denseLU", ...)`. More commonly the objects are created explicitly from calls of the form `lu(mm)` where `mm` is an object that inherits from the "dgeMatrix" class or as a side-effect of other functions applied to "dgeMatrix" objects.

Extends

"LU" directly extends the virtual class "MatrixFactorization".

"denseLU" directly extends "LU".

Slots

- `x`: object of class "numeric". The "L" (unit lower triangular) and "U" (upper triangular) factors of the original matrix. These are stored in a packed format described in the Lapack manual, and can retrieved by the `expand()` method, see below.
- `perm`: Object of class "integer" - a vector of length \( \min(\text{Dim}) \) that describes the permutation applied to the rows of the original matrix. The contents of this vector are described in the Lapack manual.
- `Dim`: the dimension of the original matrix; inherited from class `MatrixFactorization`.

Methods

- `expand` signature(`x = "denseLU"`): Produce the "L" and "U" (and "P") factors as a named list of matrices, see also the example below.
- `solve` signature(`a = "denseLU", b = "missing"`): Compute the inverse of \( A, A^{-1} \), `solve(A)` using the LU decomposition, see also `solve-methods`. 
See Also
class `sparseLU` for LU decompositions of `sparse` matrices; further, class `dgeMatrix` and functions `lu, expand`.

Examples

```r
set.seed(1)
mm <- Matrix(round(rnorm(9), 2), nrow = 3)
mm
str(lum <- lu(mm))
elu <- expand(lum)
elu # three components: "L", "U", and "P", the permutation
eelu$L %*% elu$U
(m2 <- with(elu, P %*% L %*% U)) # the same as 'mm'
stopifnot(all.equal(as(mm, "matrix"),
                    as(m2, "matrix")))
```

---

**Matrix**

**Construct a Classed Matrix**

**Description**

Construct a Matrix of a class that inherits from `Matrix`.

**Usage**

```r
Matrix(data=NA, nrow=1, ncol=1, byrow=FALSE, dimnames=NULL,
       sparse = NULL, doDiag = TRUE, forceCheck = FALSE)
```

**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. Note that when the resulting matrix is diagonal ("mathematically"), `sparse=FALSE` results in a `diagonalMatrix`, unless `doDiag=FALSE` as well, see the first examples.
- **doDiag**: only when `sparse = FALSE`, logical indicating if a `diagonalMatrix` object should be considered (default). Otherwise, in such a case, a dense (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 Matrix, 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'
Matrix(0, 2, 2, sparse=FALSE)# diagonal !
Matrix(0, 2, 2, sparse=FALSE, doDiag=FALSE)# -> dense
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)# -> sparse...
Matrix(diag(4) >= 0)# -> "lsyMatrix" (of all 'TRUE')

## triangular
ll <- upper.tri(matrix(c, 3, 3))
(M <- Matrix(ll))  # -> "ltMMatrix"
Matrix(1, ll)# -> "ltrMatrix"
as(ll, "CsparseMatrix")

Matrix(1:9, nrow=3, dimnames = list(c("a", "b", "c"), c("A", "B", "C")))
(ll <- Matrix(diag(3)))# identity, i.e., unit "diagonalMatrix"
str(ll)# note 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
stopifnot(is(As, "symmetricMatrix"),
Matrix-class

Virtual Class "Matrix" Class of Matrices

Description

The Matrix class is a class contained by all actual classes in the Matrix package. It is a "virtual" class.

Slots

Common to all matrix objects 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

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 "tradi-
tional" (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))
matrix-products

Matrix (Cross) Products (of Transpose)

Description

The basic matrix product, \( \times \times \) 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 \( x \times \times \ t(x) \), and so is tcrossprod(x, y) instead of \( x \times \times \ t(y) \).

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

## S4 method for signature 'CsparseMatrix,ddenseMatrix'
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) %*% x as an `dsCMatrix` object.
- `crossprod,tcrossprod` signature(x = "dtrMatrix", y = "matrix") and other signatures, see "%*%" above.

Note

```
boolArith = TRUE, FALSE or NA has been newly introduced for Matrix 1.2.0 (March 2015). Its implementation may be incomplete and partly missing. Please report such omissions if detected!
```

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, crossprod and %*%.

Examples

```r
## A random sparse "incidence" matrix :
m <- matrix(0, 400, 500)
set.seed(12)
m[runif(314, 0, length(m))] <- 1
mm <- as(m, "dgCMatrix")
object.size(m) / object.size(mm) # smaller by a factor of > 200
```
## 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

```r
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.
Description
The class "MatrixFactorization" is the virtual (super) class of (potentially) all matrix factorizations of matrices from package Matrix.

The class "CholeskyFactorization" is the virtual class of all Cholesky decompositions from Matrix (and trivial sub class of "MatrixFactorization").

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

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

Methods
dim (x) simply returns x@Dim, see above.
expand signature(x = "MatrixFactorization"): this has not been implemented yet for all matrix factorizations. It should return a list whose components are matrices which when multiplied return the original Matrix object.
show signature(object = "MatrixFactorization"): simple printing, see show.
solve signature(a = "MatrixFactorization", b = .): solve Ax = b for x; see solve-methods.

See Also
classes inheriting from "MatrixFactorization", such as LU, Cholesky, CHMfactor, and sparseQR.

Examples
showClass("MatrixFactorization")
getClass("CholeskyFactorization")
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

%*% signature(x = "nsparseMatrix", y = "ndenseMatrix"): ...
%*% signature(x = "ndenseMatrix", y = "nsparseMatrix"): ...
coerce signature(from = "matrix", to = "ndenseMatrix"): ...
coerce signature(from = "ndenseMatrix", to = "matrix"): ...
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

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

nearPD(x, corr = FALSE, keepdiag = 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.
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 $Y_k = P_V(P_S(Y_{k-1}))$.
only.values logical; if TRUE, the result is just the vector of eigen values 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, $\lambda_1$. Eigen values $\lambda_k$ are treated as if zero when $\lambda_k/\lambda_1 \leq eig.tol$.
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 (\texttt{norm(*, type)}) used for Higham algorithm. The default is "1" (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 \texttt{posdefify}. The algorithm of Knol DL and ten Berge (1989) (not implemented here) is more general in (1) that it allows constraints to fix some rows (and columns) of the matrix and (2) to force the smallest eigenvalue to have a certain value.

Note that setting \texttt{corr = TRUE} just sets \texttt{diag(.)} \textless{}= 1 within the algorithm.

Higham (2002) uses Dykstra’s correction, but the version by Jens Oehlschlægel did not use it (accidentally), and has still lead to good results; this simplification, now only via \texttt{doDykstra = FALSE}, was active in \texttt{nearPD()} upto Matrix version 0.999375-40.

Value

If \texttt{only.values = TRUE}, a numeric vector of eigen values of the approximating matrix; Otherwise, as by default, an S3 object of \texttt{class "nearPD"}, basically a list with components

\begin{itemize}
  \item \texttt{mat} a matrix of class \texttt{dpoMatrix}, the computed positive-definite matrix.
  \item \texttt{eigenvalues} numeric vector of eigen values of \texttt{mat}.
  \item \texttt{corr} logical, just the argument \texttt{corr}.
  \item \texttt{normF} the Frobenius norm (\texttt{norm(x-X, "F")}) of the difference between the original and the resulting matrix.
  \item \texttt{iterations} number of iterations needed.
  \item \texttt{converged} logical indicating if iterations converged.
\end{itemize}

Author(s)

Jens Oehlschlægel donated a first version. Subsequent changes by the Matrix package authors.

References


See Also

A first version of this (with non-optional \texttt{corr=TRUE}) has been available as \texttt{nearcor()}; and more simple versions with a similar purpose \texttt{posdefify()}, both from package \texttt{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")]
  stopifnot(all.equal(n.A$mat[,1], 0.760689917),
            all.equal(n.A$normF, 0.52779033, tolerance=1e-9))

set.seed(27)
m <- matrix(round(rnorm(25),2), 5, 5)
m <- m + t(m)
diag(m) <- pmax(0, diag(m)) + 1
(m <- round(cov2cor(m), 2))

str(near.m <- nearPD(m, trace = TRUE))
  round(near.m$mat, 2)
  norm(m - near.m$mat) # 1.102 / 1.08

if(require("sfsmisc")){
  m2 <- posdefify(m) # a simpler approach
  norm(m - m2) # 1.185, i.e., slightly "less near"
}

round(nearPD(m, only.values=TRUE), 9)

## 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,
               0.826, 0.75, 0.742, 0.8, 0.798, 1,
               nrow = 6, ncol = 6))

nc. <- nearPD(pr, conv.tol = 1e-7) # default
nc.1$iterations # 2
nc.1 <- nearPD(pr, conv.tol = 1e-7, corr = TRUE)
nc.1$iterations # 11 / 12 (!)
ncr <- nearPD(pr, conv.tol = 1e-15)
str(ncr)# still 2 iterations
ncr.1 <- nearPD(pr, conv.tol = 1e-15, corr = TRUE)
ncr.1 $ iterations # 27 / 30 !

ncF <- nearPD(pr, conv.tol = 1e-15, conv.norm = "F")
stopifnot(all.equal(ncr, ncF)) # norm type does not matter at all in this example

## But indeed, the 'corr = TRUE' constraint did ensure a better solution;
## cov2cor() does not just fix it up equivalently:

norm(pr - cov2cor(ncr$mat)) # = 0.09994
norm(pr - ncr.1$mat) # = 0.08746 / 0.08805
```
### 3) a real data example from a 'systemfit' model (3 eq.):  
(load(system.file("external", "symW.rda", package="Matrix"))) # "symW"  
dim(symW) # 24 x 24  
class(symW) # "dsCMatrix": sparse symmetric  
if(dev.interactive()) image(symW)  
EV <= eigen(symW, only=TRUE)$values  
summary(EV) # looking more closely (EV sorted decreasingly):  
tail(EV)# all 6 are negative  
EV2 <= eigen(sWpos <- nearPD(symW)$mat, only=TRUE)$values  
stopifnot(EV2 > 0)  
if(require("sfsmisc")) {  
   plot(pmax(le-3,EV), EV2, type="o", log="xy", xaxt="n",yaxt="n")  
   eaxis(); eaxis(2)  
} else plot(pmax(le-3,EV), EV2, type="o", log="xy")  
abline(0,1, col="red3",lty=2)
**nMatrix-class**

**Examples**

```r
showClass("ngeMatrix")
## "lgeMatrix" is really more relevant
```

---

**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**

There is a bunch of coercion methods (for `as(..)`), e.g.,

- **coerce** signature(from = "matrix", to = "nMatrix"): Note that these coercions (must) coerce `NA` to non-zero, hence conceptually TRUE. This is particularly important when `sparseMatrix` objects are coerced to "nMatrix" and hence to `nsparseMatrix`.
- **coerce** signature(from = "dmatrix", to = "nMatrix").
- **coerce** signature(from = "lmatrix", to = "nMatrix"): For dense matrices with `NA`, these coercions are valid since `Matrix` version 1.2.0 (still with a `warning` or a `message` if `Matrix.warn`, or `Matrix.verbose` options are set.)
- **coerce** signature(from = "nMatrix", to = "matrix"): ...
- **coerce** signature(from = "nMatrix", to = "dmatrix"): ...
- **coerce** signature(from = "nMatrix", to = "lmatrix"): ...

---

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", "..."): ...
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 \texttt{Matrix}.

Usage

\[
nnzero(x, \text{na.counted} = \text{NA})
\]

Arguments

- \( x \) an R object, typically inheriting from class \texttt{Matrix} or \texttt{numeric}.
- \( \text{na.counted} \) a \texttt{logical} describing how \texttt{NAs} should be counted. There are three possible settings for \( \text{na.counted} \):
  - \texttt{TRUE} \texttt{NAs are counted as non-zero} (since “they are not zero”).
  - \texttt{NA} (default)\texttt{the result will be NA} if there are \texttt{NA’s} in \( x \) (since “\texttt{NA’s} are not known, i.e., \texttt{may be zero}”).
  - \texttt{FALSE} \texttt{NAs are omitted} from \( x \) before the non-zero entries are counted.

For sparse matrices, you may often want to use \texttt{na.counted = TRUE}.

Value

the number of non zero entries in \( x \) (typically \texttt{integer}).

Note that for a \texttt{symmetric} sparse matrix \( S \) (i.e., inheriting from class \texttt{symmetricMatrix}), \texttt{nnzero(S)} is typically \texttt{twice} the \texttt{length(S@x)}.
Methods

signature(x = "ANY") the default method for non-
Matrix class objects, simply counts the num-
ber 0s 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

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, "dgTMatrix"))

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)
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 ("O", 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

norm(x, type, ...)
Arguments

- **x**: A real or complex matrix.
- **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 (`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 `dlange`, `dlansy`, `dlantr`, `zlange`, `zlansy`, and `zlantr`.

Value

A numeric value of class "norm", representing the quantity chosen according to `type`.

References


See Also

- `onenormest()`, an approximate randomized estimate of the 1-norm condition number, efficient for large sparse matrices.
- The `norm()` function from R’s `base` package.

Examples

```r
x <- Hilbert(9)
norm(x)# = "0" = "1"
stopifnot(identical(norm(x), norm(x, "1")))
norm(x, "I")# the same, because 'x' is symmetric

allnorms <- function(d) vapply(c("1","I","F","M","2"),
                                  norm, x = d, double(1))
allnorms(x)

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"
```
nsparseMatrix-classes

(allnorms(A) -> nA)
allnorms(asA)
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

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("ngCMatrix", ...) 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 column-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 "nspMatrix" (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 = "lspMatrix"), 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':
mn <- as(m, "nspMatrix") ## -> will be a "ngCMatrix"
str(mn) # no 'x' slot

mm <- !mn # no longer sparse

(nmn <- as(nmn, "sparseMatrix"))# "lgCMatrix"
## consistency check:
stopifnot(xor(as( mm, "matrix"),
               as(nmn, "matrix")))

## low-level way of adding "non-structural zeros":
nmm

as(nmn, "nMatrix") # NAs *and* non-structural 0 |--> 'TRUE'

data(KNex)
nmm <- as(KNex $ mm, "ngCMatrix")

str(xlx <- crossprod(nmn))# "nsCMatrix"
stopifnot(isSymmetric(xlx))

image(xlx, main=paste("crossprod(nmn) : Sparse", class(xlx)))

---

nsyMatrix-class Symmetric Dense Nonzero-Pattern Matrices

Description

The "nsyMatrix" class is the class of symmetric, dense nonzero-pattern matrices in non-packed storage and "nspMatrix" is the class of 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", ...).
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

- **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="dsyMatrix")` for details.

### See Also

`ngeMatrix, Matrix, t`

### 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, "nspMatrix")) # -> "nsp"    # -> "nsp": packed symmetric
```

---

**ntrMatrix-class**

### 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="nsyMatrix") for details.

See Also

Classes ngeMatrix, Matrix; function t

Examples

showClass("ntrMatrix")

str(new("ntpMatrix"))
(nutr <- as(upper.tri(matrix(4,4), "ntrMatrix"))
str(nutp <- as(nutr, "ntpMatrix"))# packed matrix: only 10 = (4+1)*4/2 entries
!nutp ## the logical negation (is *not* logical triangular !)
## but this one is:
stopifnot(all.equal(nutp, as(!nutp, "ntpMatrix")))

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

```r
showClass("number")
stopifnot(is(1i, "number"), is(pi, "number"), is(1:3, "number") )
```

---

### Description

The "pMatrix" class is the class of permutation matrices, stored as 1-based integer permutation vectors.

Matrix (vector) multiplication with permutation matrices is equivalent to row or column permutation, and is implemented that way in the `Matrix` package, see the ‘Details’ below.

### Details

Matrix multiplication with permutation matrices is equivalent to row or column permutation. Here are the four different cases for an arbitrary matrix \( M \) and a permutation matrix \( P \) (where we assume matching dimensions):

\[
\begin{align*}
MP &= M \times P = M[, i(p)] \\
PM &= P \times M = M[, p, ] \\
P'M &= \text{crossprod}(P, M) (\approx t(P) \times M) = M[i(p), ] \\
MP' &= t\text{crossprod}(M, P) (\approx M \times t(P)) = M[, p ]
\end{align*}
\]

where \( p \) is the “permutation vector” corresponding to the permutation matrix \( P \) (see first note), and \( i(p) \) is short for \texttt{invPerm}(p).

Also one could argue that these are really only two cases if you take into account that inversion (\texttt{solve}) and transposition (\texttt{t}) are the same for permutation matrices \( P \).

### Objects from the Class

Objects can be created by calls of the form \texttt{new("pMatrix", ...)} or by coercion from an integer permutation vector, see below.

### Slots

- \texttt{perm}: An integer, 1-based permutation vector, i.e. an integer vector of length \texttt{Dim[1]} whose elements form a permutation of \( 1: \text{Dim}[1] \).

- \texttt{Dim}: Object of class "\texttt{integer}". The dimensions of the matrix which must be a two-element vector of equal, non-negative integers.
Dimnames: list of length two; each component containing NULL or a character vector length equal the corresponding Dim element.

Extends

Class "indMatrix", directly.

Methods

```%/%` signature(x = "matrix", y = "pMatrix") and other signatures (use showMethods("%/%", class="pMatrix")):
...```  

```coerce` signature(from = "integer", to = "pMatrix"): This is enables typical "pMatrix" construction, given a permutation vector of 1:n, see the first example.
```  
```coerce` signature(from = "numeric", to = "pMatrix"): a user convenience, to allow as(perm, "pMatrix") for numeric perm with integer values.
```  
```coerce` signature(from = "pMatrix", to = "matrix"): coercion to a traditional FALSE/TRUE matrix of mode logical. (in earlier version of Matrix, it resulted in a 0/1-integer matrix; logical makes slightly more sense, corresponding better to the "natural" sparseMatrix counterpart, "ngTMatrix").
```  
```coerce` signature(from = "pMatrix", to = "ngTMatrix"): coercion to sparse logical matrix of class ngTMatrix.
```  
```determinant` signature(x = "pMatrix", logarithm="logical"): Since permutation matrices are orthogonal, the determinant must be +1 or -1. In fact, it is exactly the sign of the permutation.
```  
```solve` signature(a = "pMatrix", b = "missing"): return the inverse permutation matrix; note that solve(P) is identical to t(P) for permutation matrices. See solve-methods for other methods.
```  
```t` signature(x = "pMatrix"): return the transpose of the permutation matrix (which is also the inverse of the permutation matrix).

Note

For every permutation matrix `P`, there is a corresponding permutation vector `p` (of indices, 1:n), and these are related by

```P <- as(p, "pMatrix")
p <- P@perm```

see also the ‘Examples’.

“Row-indexing” a permutation matrix typically returns an "indMatrix". See "indMatrix" for all other subsetting/indexing and subassignment (`A[...] <- v`) operations.

See Also

`invPerm(p)` computes the inverse permutation of an integer (index) vector `p`. 
Examples

```r
(pml <- as(as.integer(c(2,3,1)), "pMatrix"))
t(pml) # is the same as
solve(pml)
pml %*% t(pml) # check that the transpose is the inverse
stopifnot(all(diag(3) == as(pml %*% t(pml), "matrix")),
              is.logical(as(pml, "matrix")))

set.seed(11)
## 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))
mm %*% pml
pml %*% mm
try(as(as.integer(c(3,3,1)), "pMatrix"))# Error: not a permutation
as(pml, "ngTMatrix")
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, `printSpMatrix(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 = 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 =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.
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 "1" instead of "\" (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 \( x \). \( \text{.formatSparseSimple()} \) is applied to (a dense version of) the matrix. Then, \( \text{formatSparseM} \) is used, unless in trivial cases or for sparse matrices without \( x \) slot.

Value

```r
formatspMmatrix()
returns a character matrix with possibly empty column names, depending on
col.names etc, see above.
```

```r
printSpMatrix()
return \( x \) invisibly, see \texttt{invisible}.
```

Author(s)

Martin Maechler

See Also

the virtual class \texttt{sparseMatrix} and the classes extending it; maybe \texttt{sparseMatrix} or \texttt{spMatrix} as simple constructors of such matrices.

The underlying utilities \texttt{formatSparseM} and \texttt{.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], "e", 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")
```
Description

The Matrix package provides methods for the QR decomposition of special classes of matrices. There is a generic function which uses qr as default, but methods defined in this package can take extra arguments. In particular there is an option for determining a fill-reducing permutation of the columns of a sparse, rectangular matrix.

Usage

qr(x, ...) 
qrR(qr, complete=FALSE, backPermute=TRUE, row.names = TRUE)

Arguments

x 
a numeric or complex matrix whose QR decomposition is to be computed. Logical matrices are coerced to numeric.

qr 
a QR decomposition of the type computed by qr.

complete 
logical indicating whether the R matrix is to be completed by binding zero-value rows beneath the square upper triangle.

backPermute 
logical indicating if the rows of the R matrix should be back permuted such that qrR()'s result can be used directly to reconstruct the original matrix X.

row.names 
logical indicating if rownames should propagated to the result.

... 
further arguments passed to or from other methods

Methods

x = "dgCMatrix" QR decomposition of a general sparse double-precision matrix with nrow(x) >= ncol(x). Returns an object of class "sparseQR".

x = "sparseMatrix" works via "dgCMatrix".

See Also

qr; then, the class documentations, mainly sparseQR, and also dgCMMatrix.

Examples

##---------- example of pivoting -- from base' qraux.Rd ----------
X <- cbind(int = 1,
    b1=rep(1:0, each=3), b2=rep(0:1, each=3),
    c1=rep(c(1,0,0), 2), c2=rep(c(0,1,0), 2), c3=rep(c(0,0,1),2))
rownames(X) <- paste0("r", seq_len(nrow(X)))
dnX <- dimnames(X)
bX <- X # [b]ase version of X
X <- as(bX, "sparseMatrix")
X # is singular, columns "b2" and "c3" are "extra"
stopifnot(identical(dimnames(X), dnX)) # some versions changed X's dimnames!
c(rankMatrix(X)) # = 4 (not 6)
m <- function(.) as(. , "matrix")

###----- regular case -----------------------------------------------
Xr <- X[ , -c(3,6)] # the "regular" (non-singular) version of X
stopifnot(rankMatrix(Xr) == ncol(Xr))
Y <- cbind(y <- setNames(1:6, paste0("y", 1:6)))

### regular case:
qXr <- qr( Xr)
qxrLA <- qr(m(Xr), LAPACK=TRUE) # => qr.fitted() , qr.resid() not supported
qcfXY <- qr.coef (qxrL, y) # vector
qcfXY <- qr.coef (qxrL, Y) # 4x1 dgeMatrix
cf <- c(int=6, b1=-3, c1=-2, c2=-1)
doExtras <- interactive() || nzchar(Sys.getenv("R_MATRIX_CHECK_EXTRA")) ||
         identical("true", unname(Sys.getenv("R_PKG_CHECKING_doExtras")))
tolE <- if(doExtras) 1e-15 else 1e-13
stopifnot(
  all.equal(qr.coef(qxrL, y), cf, tol=tolE),
  getRversion() <> "3.4.1" ||
  all.equal(qr.coef(qxrLA,y), cf, tol=tolE),
  all.equal(qr.coef(qxrL, Y), m(cf), tol=tolE),
  all.equal( qcfXY, cf, tol=tolE),
  all.equal(m(qcfXY), m(cf), tol=tolE),
  all.equal(y, qr.fitted(qxrL, y), tol=2*tolE),
  all.equal(y, qr.fitted(qxrL, Y), tol=2*tolE),
  all.equal(m(qr.fitted(qxrL, Y)), qr.fitted(qxrL, Y), tol=tolE),
  all.equal( qr.resid (qxrL, y), qr.resid (qxrL, y), tol=tolE),
  all.equal(m(qr.resid (qxrL, Y)), qr.resid (qxrL, Y), tol=tolE)
)

###----- rank-deficient ("singular") case ---------------------------------

(qX <- qr( X)) # both @p and @q are non-trivial permutations
qX <- qr(m(X)) ; str(qX) # $pivot is non-trivial, too

drop0(R. <- qr.R(qX), tol=tolE) # columns *permuted*: c3 b1 ..
Q. <- qr.Q(qX)
qI <- sort.list(qX@q) # the inverse 'q' permutation
(X. <- drop0(Q. , %% R [, qI], tol=tolE))## just = X, incl. correct colnames
stopifnot(all(X - X.) < 8*.Machine$double.eps,
  ## qrR(.) returns R already "back permuted" (as with qI):
  identical(R.[, qI], qrR(qX)) )

## In this sense, classical qr.coef() is fine:
cfX <- qr.coef(qX, y) # quite different from
mna <- !is.na(cfX)
stopifnot(all.equal(unname(qr.fitted(qX,y)),
  as.numeric(X[,mna] %%% cfX[mna])))
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

\[
\text{rankMatrix}(x, \text{tol} = \text{NULL}, \text{method} = c("\text{tolNorm2}", "\text{qr}\_R", "\text{qrLINPACK}", "\text{qr}", \\
\text{useGrad"}, "\text{maybeGrad}") \text{,} \\
\text{sval} = \text{svd}(x, 0, 0)\text{d, warn.t = TRUE)}
\]

Arguments

\( x \)
numeric matrix, of dimension \( n \times m \), say.

\( \text{tol} \)
nonnegative number specifying a (relative, "scalefree") tolerance for testing of "practically zero" with specific meaning depending on method; by default, \( \max(\text{dim}(x)) \times \text{Machine}\_\text{double}\_\text{eps} \) is according to Matlab’s default (for its only method which is our method="tolNorm2").

\( \text{method} \)
a character string specifying the computational method for the rank, can be abbreviated:

- "\text{tolNorm2}": the number of singular values \( \geq \text{tol} \times \max(\text{sval}) \);
- "\text{qrLINPACK}": for a dense matrix, this is the rank of \( \text{qr}(x, \text{tol}, \text{LAPACK}=\text{FALSE}) \) (which is \( \text{qr}(...)\text{rank} \));
  This ("\text{qr}"; dense) version used to be the recommended way to compute a matrix rank for a while in the past.
  For sparse \( x \), this is equivalent to "\text{qr}\_R".
- "\text{qr}\_R": this is the rank of triangular matrix \( R \), where \( \text{qr}() \) uses LAPACK or a "sparseQR" method (see \texttt{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 \( |d_i| \geq \text{tol} \times \max(|d_i|) \).
- "\text{qr}" : is for back compatibility: for dense \( x \), it corresponds to "\text{qrLINPACK}",
  whereas for sparse \( x \), it uses "\text{qr}\_R".

For all the "\text{qr}" methods, singular values \( \text{sval} \) are not used, which may be crucially important for a large sparse matrix \( x \), as in that case, when \( \text{sval} \) is not specified, the default, computing \( \text{svd}() \) 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.

Value
If x is a matrix of all 0, the rank is zero; otherwise, a positive integer in 1:min(dim(x)) with
attributes detailing the method used.

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, method = "qr", all non-strictly zero diagonal entries d, where
counted, up to including Matrix version 1.1-0, i.e., that method implicitly used tol = 0, see also
the seed(42) example below.

Author(s)
Martin Maechler; for the "Grad" methods, building on suggestions by Ravi Varadhan.

See Also
qr, svd.

Examples
rankMatrix(cbind(1, 0, 1:3)) # 2

(meths <- eval(formals(rankMatrix)$method))

## a "border" case:
H12 <- Hilbert(12)
rankMatrix(H12, tol = 1e-20) # 12; but 11 with default method & tol.
sapply(meths, function(.m) rankMatrix(H12, method = .m))

## tolNorm2       qr   qr.R qrLINPACK useGrad maybeGrad
## 11 12 11 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)
rMQR <- function(ex, M) rankMatrix(M, method="qr.R",     tol = 10^-ex)
sapply(5:15, rMQL, M = H12) # result is platform dependent
## 7 7 8 10 11 11 11 12 12 12 (x86_64)
sapply(5:15, rMQL, M = 1000 * H12) # not identical unfortunately
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 `showMethods(rcond)`.

Usage

```r
rcond(x, norm, ...)
```

## S4 method for signature 'sparseMatrix,character'

```r
rcond(x, norm, useInv=FALSE, ...)
```
Arguments

- **x**: an R object that inherits from the `matrix` class.
- **norm**: character string indicating the type of norm to be used in the estimate. The default is "0" for the 1-norm ("0" is equivalent to "1"). For sparse matrices, when `useInv=TRUE`, `norm` can be any of the kinds allowed for `norm`; otherwise, the other possible value is "1" for the infinity norm, see also `norm`.
- **useInv**: logical (or "Matrix" containing `solve(x)`). If not false, compute the reciprocal condition number as $1/(\|x\| \cdot \|x^{-1}\|)$, where $x^{-1}$ is the inverse of $x$, `solve(x)`.

This may be an efficient alternative (only) in situations where `solve(x)` is fast (or known), e.g., for (very) sparse or triangular matrices.

Note that the result may differ depending on `useInv`, as per default, when it is false, an approximation is computed.

- ... 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(1:10))  # 0.05278
rcond(x2 <- cbind(x1, 2:11))# practically 0, since x2 does not have full rank

## sparse
(S1 <- Matrix(cbind(0:1, 0, diag(3:-2))))
rcond(S1)
m1 <- 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*m <- 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.)  # 0.05555 0.013888
## for all 4 norms available for sparseMatrix:
cbind(rr <- sapply(c("1","1","F","M"),
  function(N) rcond(M3, norm=N, useInv=TRUE)))
```

---

**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

(ab <- rep2abI(2:7, 4))
stopifnot(identical(as(ab, "numeric"),
rep(2:7, 4)))

---

replValue-class  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 \( x \), \( \text{diff}(x) \) consists of constant stretches and is hence well compressable via \( \text{rle}() \).

Objects from the Class

Objects can be created by calls of the form \( \text{new("rleDiff", \ldots)} \).

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 \( \text{rle}() \). As this is used to encode potentially huge index vectors, lengths may be of type double here.

Methods

There is a simple \( \text{show} \) method only.

Note

This is currently an experimental auxiliary class for the class \( \text{abIndex} \), see there.

See Also

\( \text{rle, abIndex} \).

Examples

\[
\text{showClass("rleDiff")}
\]
\[
\text{ab <- c(abIseq}(2, 100), \text{abIseq}(20, -2))}
\]
\[
\text{ab@rleD  # is "rleDiff"}
\]
### 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

```r
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 `giveCsparse`.

### Details

The algorithm first samples “encoded” `(i,j)`s without replacement, via one dimensional indices, if not symmetric `sample.int(nrow*ncol, nnz)`, then—if `rand.x` is not `NULL`—gets `x <- rand.x(nnz)` and calls `sparseMatrix(i=i, j=j, x=x, ..)`). When `rand.x=NULL`, `sparseMatrix(i=i, j=j, ..)` will return a pattern matrix (i.e., inheriting from `nsparseMatrix`).

### Value

A `sparseMatrix`, say `M` of dimension `(nrow, ncol)`, i.e., with `dim(M) == c(nrow, ncol)`, if symmetric is not true, with `nzM <- nnzero(M)` fulfilling `nzM <= nnz` and typically, `nzM == nnz`.

### Author(s)

Martin Maechler
Examples

set.seed(17)# to be reproducible
M <- rsparsematrix(8, 12, nnz = 30) # small example, not very sparse
M
M1 <- rsparsematrix(1000, 20, nnz = 123, rand.x = runif)
summary(M1)

## a random *symmetric* Matrix
(S9 <- rsparsematrix(9, 9, nnz = 10, symmetric=TRUE)) # dsCMatrix
nnzero(S9)# - 20: as 'nnz' only counts one "triangle"

## a random patter*n* aka boolean Matrix (no 'x' slot):
(n7 <- rsparsematrix(5, 12, nnz = 10, rand.x = NULL))

## a [T]riplet representation sparseMatrix:
T2 <- rsparsematrix(40, 12, nnz = 99, giveCsparse=FALSE)
head(T2)

---

RsparseMatrix-class  
Class "RsparseMatrix" of Sparse Matrices in Column-compressed Form

Description

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

Slots

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.

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

Extends

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

Methods

Only few methods are defined currently on purpose, since we rather use the CsparseMatrix in Matrix. Recently, more methods were added but beware that these typically do not return "RsparseMatrix" results, but rather Csparse* or Tsparse* ones.

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**  
*Schur Decomposition of a Matrix*

**Description**
Computes the Schur decomposition and eigenvalues of a square matrix; see the BACKGROUND information below.

**Usage**
```
Schur(x, vectors, ...)
```

**Arguments**
- **x**  
  numeric square Matrix (inheriting from class "Matrix") or traditional `matrix`.  
  Missing values (NAs) are not allowed.
- **vectors**  
  logical. When TRUE (the default), the Schur vectors are computed, and the result is a proper `MatrixFactorization` of class `Schur`.
- **...**  
  further arguments passed to or from other methods.

**Details**
Based on the Lapack subroutine `dgees`.

**Value**
If vectors are TRUE, as per default: If x is a `Matrix` an object of class `Schur`, otherwise, for a traditional `matrix` x, a `list` with components `T`, `Q`, and `EValues`.
If vectors are FALSE, a `list` with components
- **T**  
  the upper quasi-triangular (square) matrix of the Schur decomposition.
- **EValues**  
  the vector of numeric or complex eigen values of `T` or `A`.

**BACKGROUND**
If A is a square matrix, then $A = Q \cdot T \cdot \overline{Q}$, where $Q$ is orthogonal, and $T$ is upper block-triangular (nearly triangular with either 1 by 1 or 2 by 2 blocks on the diagonal) where the 2 by 2 blocks correspond to (non-real) complex eigenvalues. The eigenvalues of A are the same as those of T, which are easy to compute. The Schur form is used most often for computing non-symmetric eigenvalue decompositions, and for computing functions of matrices such as matrix exponentials.
References

Examples
```r
Schur(Hilbert(9))        # Schur factorization (real eigenvalues)

(A <- Matrix(round(rnorm(5*5, sd = 100)), nrow = 5))
(Sch.A <- Schur(A))

eTA <- eigen(Sch.A@T)
str(SchA <- Schur(A, vectors=FALSE))# no 'T' ==> simple list
stopifnot(all.equal(eTA$values, eigen(A)$values, tolerance = 1e-13),
  all.equal(eTA$values,
    local({z <- Sch.A@EValues
      z[order(Mod(z), decreasing=TRUE)]}, tolerance = 1e-13),
    identical(SchA$T, Sch.A@T),
    identical(SchA$EValues, Sch.A@EValues))

## For the faint of heart, we provide Schur() also for traditional matrices:

a.m <- function(M) unname(as(M, "matrix"))
a <- a.m(A)
Sch.a <- Schur(a)
stopifnot(identical(Sch.a, list(Q = a.m(Sch.A @ Q),
  T = a.m(Sch.A @ T),
  EValues = Sch.A@EValues)),
  all.equal(a, with(Sch.a, Q %*% T %*% t(Q))))
```

---

### Schur-class

#### Class “Schur” of Schur Matrix Factorizations

**Description**
Class “Schur” is the class of Schur matrix factorizations. These are a generalization of eigen value (or “spectral”) decompositions for general (possibly asymmetric) square matrices, see the `Schur()` function.

**Objects from the Class**

Objects of class "Schur" are typically created by `Schur()`.

**Slots**

"Schur" has slots

- **T**: Upper Block-triangular `Matrix` object.
- **Q**: Square orthogonal "Matrix".
EValues: numeric or complex vector of eigenvalues of T.
Dim: the matrix dimension: equal to c(n,n) of class "integer".

Extends

Class "MatrixFactorization", directly.

See Also

Schur() for object creation: MatrixFactorization.

Examples

showClass("Schur")
Schur(M <- Matrix(c(1:7, 10:2), 4,4))
## Trivial, of course:
str(Schur(Diagonal(5)))

## for more examples, see Schur()

solve-methods

Methods in Package Matrix for Function solve()

Description

Methods for function solve to solve a linear system of equations, or equivalently, solve for X in

\[ AX = B \]

where A is a square matrix, and X, B are matrices or vectors (which are treated as 1-column matrices), and the \texttt{R} syntax is

\[ X \leftarrow \text{solve}(A,B) \]

In solve(a,b) in the Matrix package, a may also be a MatrixFactorization instead of directly a matrix.

Usage

## S4 method for signature 'CHMfactor,ddenseMatrix'
solve(a, b,
    system = c("A", "LDLt", "LD", "DLt", "L", "Lt", "D", "P", "Pt"), ...)

## S4 method for signature 'dgCMatrix,matrix'
solve(a, b, sparse = FALSE, tol = .Machine$double.eps, ...)

    solve(a, b, ...) ## the two-argument version, almost always preferred to
# solve(a)     ## the rarely needed one-argument version
solve-methods

Arguments

a  a square numeric matrix, $A$, typically of one of the classes in Matrix. Logical matrices are coerced to corresponding numeric ones.

b  numeric vector or matrix (dense or sparse) as RHS of the linear system $Ax = b$.

system only if a is a CHMfactor: character string indicating the kind of linear system to be solved, see below. Note that the default, "A", does not solve the triangular system (but "L" does).

sparse only when a is a sparseMatrix, i.e., typically a dgCMatrix: logical specifying if the result should be a (formally) sparse matrix.

tol only used when a is sparse, in the isSymmetric(a, tol=*) test, where that applies.

... potentially further arguments to the methods.

Methods

signature(a = "ANY", b = "ANY") is simply the base package’s S3 generic solve.

signature(a = "CHMfactor", b = "..."), system= * The solve methods for a "CHMfactor" object take an optional third argument system whose value can be one of the character strings "A", "LDLt", "LD", "DLt", "L", "Lt", "D", "P" or "Pt". This argument describes the system to be solved. The default, "A", is to solve $Ax = b$ for $x$ where $A$ is sparse, positive-definite matrix that was factored to produce a. Analogously, system = "L" returns the solution $x$, of $Lx = b$; similarly, for all system codes but "P" and "Pt" where, e.g., $x \left< -solve(a, b, system="P")$ is equivalent to $x \left< - P \%*% b$.

If b is a sparseMatrix, system is used as above the corresponding sparse CHOLMOD algorithm is called.

signature(a = "d denseMatrix", b = "...") (for all b) work via as(a, "dgeMatrix"), using its methods, see below.

signature(a = "denseLU", b = "missing") basically computes uses triangular forward- and back-solve.

signature(a = "dgCMatrix", b = "matrix"), and

signature(a = "dgCMatrix", b = "d denseMatrix") with extra argument list( sparse = FALSE, tol = .Machine$double.eps)

Uses the sparse lu(a) decomposition (which is cached in a’s factor slot). By default, sparse=FALSE, returns a denseMatrix, since $U^{-1}L^{-1}B$ may not be sparse at all, even when $L$ and $U$ are.

If sparse=TRUE, returns a sparseMatrix (which may not be very sparse at all, even if a was sparse).

signature(a = "dgCMatrix", b = "d sparseMatrix"), and

signature(a = "dgCMatrix", b = "missing") with extra argument list( sparse=FALSE, tol = .Machine$double.eps)

Checks if a is symmetric, and in that case, coerces it to "symmetricMatrix", and then computes a sparse solution via sparse Cholesky factorization, independently of the sparse argument. If a is not symmetric, the sparse lu decomposition is used and the result will be sparse or dense, depending on the sparse argument, exactly as for the above (b = "d denseMatrix") case.
solve-methods

signature(a = "dgeMatrix", b = ".....") solve the system via internal LU, calling LAPACK routines dgetri or dgetrs.

signature(a = "diagonalMatrix", b = "matrix") and other bs: Of course this is trivially implemented, as \( D^{-1} \) is diagonal with entries \( 1/D[i,i] \).

signature(a = "dpoMatrix", b = ".....Matrix") , and

signature(a = "dppMatrix", b = ".....Matrix") The Cholesky decomposition of a is calculated (if needed) while solving the system.

signature(a = "dsCMatrix", b = ".....") All these methods first try Cholmod’s Cholesky factorization; if that works, i.e., typically if a is positive semi-definite, it is made use of. Otherwise, the sparse LU decomposition is used as for the “general” matrices of class "dgCMatrix".

signature(a = "dspMatrix", b = ".....") , and

signature(a = "dsyMatrix", b = ".....") all end up calling LAPACK routines dsptri, dsptrs, dsytrs and dsytri.

signature(a = "dtCMatrix", b = "CsparseMatrix") ,

signature(a = "dtMatrix", b = "dgEMatrix") , etc sparse triangular solve, in traditional S/R also known as backsolve, or forwardsolve. solve(a,b) is a sparseMatrix if b is, and hence a denseMatrix otherwise.

signature(a = "dtrMatrix", b = "ddenseMatrix") , and

signature(a = "dtpMatrix", b = "matrix") , and similar b, including "missing", and "diagonalMatrix": all use LAPACK based versions of efficient triangular backsolve, or forwardsolve.

signature(a = "Matrix", b = "diagonalMatrix") works via as(b, "CsparseMatrix").

signature(a = "sparseQR", b = "ANY") simply uses qr.coef(a, b).

signature(a = "pMatrix", b = ".....") these methods typically use crossprod(a,b), as the inverse of a permutation matrix is the same as its transpose.

signature(a = "TsparseMatrix", b = "ANY") all work via as(a, "CsparseMatrix").

See Also

solve, lu, and class documentations CHMFactor, sparseLU, and MatrixFactorization.

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 %x% Diagonal(x=c(10, rep(1, n-1))))
isSymmetric(a) # FALSE
image(drop0(skewpart(a)))
image(ia0 <- solve(a)) # checker board, dense [but really, a is singular!]
try(solve(a, sparse=TRUE))##-> error [ TODO: assertError ]
ia. <- solve(a, sparse=TRUE, tol = 1e-19)##-> *no* error
```
sparse.model.matrix

Construct Sparse Design / Model Matrices

Description

Construct a sparse model or "design" matrix, form a formula and data frame (sparse.model.matrix) or a single factor (fac2sparse).

The fac2sparse() 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,
  verbose = FALSE, ...)

fac2sparse(from, to = c("d", "i", "l", "n", "z"),
  drop.unused.levels = TRUE, giveCsparse = TRUE)
fac2sparse(from, to = c("d", "i", "l", "n", "z"),
  drop.unused.levels = TRUE, giveCsparse = TRUE,
  factorPattl2, 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.
sparse.model.matrix

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.

`verbose` logical or integer indicating if (and how much) progress output should be printed.

`...` further arguments passed to or from other methods.

`from` (for `fac2sparse()`): a `factor`.

`to` a character indicating the “kind” of sparse matrix to be returned. The default, "d" is for `double`.

`giveCsparse` (for `fac2sparse()`): logical indicating if the result must be a `CsparseMatrix`.

`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 `fac2sparse()`.

Value

a sparse matrix, extending `CsparseMatrix` (for `fac2sparse()` if `giveCsparse` is true as per default; a `TsparseMatrix` otherwise).

For `fac2Sparse()`, a list of length two, both components with the corresponding transposed model matrix, where the corresponding `factorPatt12` is true.

Note that `model.Matrix(*, sparse=TRUE)` from package `MatrixModels` may be often be preferable to `sparse.model.matrix()` nowadays, as `model.Matrix()` returns `modelMatrix` objects with additional slots assign and contrasts which relate back to the variables used.

`fac2sparse()`, the basic workhorse of `sparse.model.matrix()`, returns the `transpose` (t) of the model matrix.

Author(s)

Doug Bates and Martin Maechler, with initial suggestions from Tim Hesterberg.

See Also

`model.matrix` in standard R’s package `stats`.
`model.Matrix` which calls `sparse.model.matrix` or `model.matrix` depending on its sparse argument may be preferred to `sparse.model.matrix`.

as(f, "sparseMatrix") (see `coerce(from = "factor", ..)`) in the class doc `sparseMatrix` produces the `transpose` sparse model matrix for a single factor f (and no contrasts).
Examples

```r
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"))
```

```r
## 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)))
```

```r
(ff <- gl(3,4, , c("X","Y", "Z")))
fac2sparse(ff) # 3 x 12 sparse Matrix of class "dgCMatrix"
```

```r
## 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 decomposition of a square sparse matrix

---

**Description**

Objects of this class contain the components of the LU decomposition of a sparse square matrix.

**Objects from the Class**

Objects can be created by calls of the form `new("sparseLU", ...)` but are more commonly created by function `lu()` applied to a sparse matrix, such as a matrix of class `dgCMatrix`.  

sparseLU-class

Slots

L: Object of class "dtCMatrix", the lower triangular factor from the left.
U: Object of class "dtCMatrix", the upper triangular factor from the right.
p: Object of class "integer", permutation applied from the left.
q: Object of class "integer", permutation applied from the right.
Dim: the dimension of the original matrix; inherited from class MatrixFactorization.

Extends

Class "LU", directly. Class "MatrixFactorization", by class "LU".

Methods

expand signature(x = "sparseLU") Returns a list with components P, L, U, and Q, where P and Q represent fill-reducing permutations, and L and U the lower and upper triangular matrices of the decomposition. The original matrix corresponds to the product P'LUQ.

Note

The decomposition is of the form

\[ A = P'LUQ, \]

or equivalently \( PAQ' = LU \), where all matrices are sparse and of size \( n \times n \). The matrices \( P \) and \( Q \), and their transposes \( P' \) and \( Q' \) are permutation matrices, \( L \) is lower triangular and \( U \) is upper triangular.

See Also

lu, solve, dgCMatrix

Examples

```r
## Extending the one in examples(lu), calling the matrix A,
## and confirming the factorization identities:
A <- as(readMM(system.file("external/pores_1.mtx", package = "Matrix"),
    "CsparseMatrix"))
## with dimnames(.) - to see that they propagate to L, U:
dimnames(A) <- dnA <- list(paste0("r", seq_len(nrow(A))),
    paste0("c", seq_len(ncol(A))))
str(luA <- lu(A)) # p is a 0-based permutation of the rows
# q is a 0-based permutation of the columns
xA <- expand(luA)
## which is simply doing
stopifnot(identical(xA$L, luA@L),
    identical(xA$U, luA@U),
    identical(xA$P, as(luA@p +1L, "pMatrix")),
    identical(xA$Q, as(luA@q +1L, "pMatrix")))
```
```r
P.LUQ <- with(xA, t(P) %%*% L %%*% U %%*% Q)
stopifnot(all.equal(A, P.LUQ, tolerance = 1e-12),
          identical(dimnames(P.LUQ), dnA))
## permute rows and columns of original matrix
pA <- A[luAq + 1L, luAq + 1L]
stopifnot(identical(pA, with(xA, P %%*% A %%*% t(Q))))

pLU <- drop0(luA@, %%*% luA@U) # L %%*% U -- dropping extra zeros
stopifnot(all.equal(pA, pLU, tolerance = 1e-12))
```

---

**SparseM-conversions**  
*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,

```r
as(from, Class)
```

**Methods**

- from = "matrix.csr", to = "dgRMatrix" ...  
- from = "matrix.csc", to = "dgCMatrix" ...  
- from = "matrix.coo", to = "dgTMatrix" ...  
- from = "dgRMatrix", to = "matrix.csr" ...  
- from = "dgCMatrix", to = "matrix.csc" ...  
- from = "dgTMatrix", to = "matrix.coo" ...  
- from = "sparseMatrix", to = "matrix.csr" ...  
- from = "matrix.csr", to = "dgCMatrix" ...  
- from = "matrix.coo", to = "dgCMatrix" ...  
- from = "matrix.csr", to = "Matrix" ...  
- from = "matrix.csc", to = "Matrix" ...  
- from = "matrix.coo", to = "Matrix" ...

**See Also**

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

User friendly construction of a compressed, column-oriented, sparse matrix, inheriting from class CsparseMatrix (or TsparseMatrix if giveCsparse is false), from locations (and values) of its non-zero entries.

This is the recommended user interface rather than direct `new("***Matrix", ....)` calls.

Usage

```r
sparseMatrix(i = ep, j = ep, p, x, dims, dimnames,
symmetric = FALSE, triangular = FALSE, index1 = TRUE,
giveCsparse = TRUE, check = TRUE, use.last.ij = FALSE)
```

Arguments

- `i, j` integer vectors of the same length specifying the locations (row and column indices) of the non-zero (or non-TRUE) entries of the matrix. Note that for repeated pairs \((i_k, j_k)\), when `x` is not missing, the corresponding `x_k` are added, in consistency with the definition of the "TsparseMatrix" class, unless `use.last.ij` is true, in which case only the last of the corresponding \((i_k, j_k, x_k)\) triplet is used.
- `p` numeric (integer valued) 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` or `p` must be missing.
- `x` optional values of the matrix entries. If specified, must be of the same length as `i` / `j`, or of length one where it will be recycled to full length. If missing, the resulting matrix will be a 0/1 pattern matrix, i.e., extending class nsparseMatrix.
- `dims` optional, non-negative, integer, dimensions vector of length 2. Defaults to `c(max(i), max(j))`.
- `dimnames` optional list of `dimnames`; if not specified, none, i.e., `NULL` ones, are used.
- `symmetric` logical indicating if the resulting matrix should be symmetric. In that case, only the lower or upper triangle needs to be specified via `(i/j/p)`.
- `triangular` logical indicating if the resulting matrix should be triangular. In that case, the lower or upper triangle needs to be specified via `(i/j/p)`.
- `index1` logical scalar. If `TRUE`, the default, the index vectors `i` and/or `j` are 1-based, as is the convention in R. That is, counting of rows and columns starts at 1. If `FALSE` the index vectors are 0-based so counting of rows and columns starts at 0; this corresponds to the internal representation.
- `giveCsparse` logical indicating if the result should be a CsparseMatrix or a TsparseMatrix. The default, `TRUE` is very often more efficient subsequently, but not always.
- `check` logical indicating if a validity check is performed; do not set to `FALSE` unless you know what you’re doing!
- `use.last.ij` logical indicating if in the case of repeated, i.e., duplicated pairs \((i_k, j_k)\) only the last one should be used. The default, `FALSE`, corresponds to the "TsparseMatrix" definition.
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 \( \text{singular} \) and \( \text{triangular} \) to true; rather use \( \text{Diagonal()} \) (or its alternatives, see there).

The values of \( i \), \( j \), \( p \) and \( \text{index1} \) are used to create 1-based index vectors \( i \) and \( j \) from which a \( \text{TsparseMatrix} \) 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 "\( \text{TsparseMatrix} \)" class, unless \( \text{use.last.ij} \) is set to true.

By default, when giveCsparse is true, the \( \text{CsparseMatrix} \) derived from this triplet form is returned.

The reason for returning a \( \text{CsparseMatrix} \) 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 \( \text{CsparseMatrix} \) is a unique representation of the sparse matrix.

Value

A sparse matrix, by default (see giveCsparse) in compressed, column-oriented form, as an \( R \) object inheriting from both \( \text{CsparseMatrix} \) and \( \text{generalMatrix} \).

Note

You \textit{do} need to use \( \text{index1} = \text{FALSE} \) (or add + 1 to \( i \) and \( j \)) if you want use the 0-based \( i \) (and \( j \)) slots from existing sparse matrices.

See Also

\( \text{Matrix}(*, \text{sparse=TRUE}) \) 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 \( \text{sparseMatrix}() \) is needed. Further \( \text{bdiag} \) and \( \text{Diagonal} \) for (block-)diagonal and \( \text{bandSparse} \) for banded sparse matrix constructors.

Random sparse matrices via \( \text{rsparsematrix}() \).

The standard \( \text{R xtabs}(*, \text{sparse=TRUE}) \), for sparse tables and \( \text{sparse.model.matrix}() \) for building sparse model matrices.

Consider \( \text{CsparseMatrix} \) 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)
m
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' --> patter*n* matrix:
(n <- sparseMatrix(i=1:6, j=rev(2:7)))# -> ngCMatrix

## an empty sparse matrix:
```
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"): Returns an object of S3 class "sparseSummary" which is basically a `data.frame` with columns (i,j,x) (or just (i,j) for `nspmatrix` 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

```r
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); dim(CAex) # 72 x 72 matrix
determinant(CAex) # works via sparse lu(.)

## factor -> t( <sparse design matrix> ):
(fact <- gl(5, 3, 30, labels = LETTERS[1:5]))
(Xt <- as(fact, "sparseMatrix")) # indicator rows

## missing values --> all-0 columns:
f.mis <- fact
i.mis <- c(3:5, 17)
is.mis(f.mis) <- i.mis
Xt != (X. <- as(f.mis, "sparseMatrix")] # differ only in columns 3:5,17
stopifnot(all(X.[,i.mis] == 0), all(Xt[,-i.mis] == X.[,-i.mis]))

### SparseQR-class

**Sparse QR decomposition of a sparse matrix**

**Description**

Objects class "SparseQR" represent a QR decomposition of a sparse $m \times n$ ("long": $m \geq n$) rectangular matrix $A$, typically resulting from `qr(.)`, see ‘Details’ notably about row and column permutations for pivoting.

**Details**

For a sparse $m \times n$ ("long": $m \geq n$) rectangular matrix $A$, the sparse QR decomposition is either of the form $PA = QR$ with a (row) permutation matrix $P$, (encoded in the p slot of the result) if the q slot is of length 0, or of the form $PAP^* = QR$ with an extra (column) permutation matrix $P^*$ (encoded in the q slot). Note that the row permutation $PA$ in R is simply $A[p+1, ]$ where p is the p-slot, a 0-based permutation of 1:m applied to the rows of the original matrix.

If the q slot has length n it is a 0-based permutation of 1:n applied to the columns of the original matrix to reduce the amount of “fill-in” in the matrix $R$, and $AP^*$ in R is simply $A[, q+1]$.

$R$ is an $m \times n$ matrix that is zero below the main diagonal, i.e., upper triangular $(m \times m)$ with $m - n$ extra zero rows.

The matrix $Q$ is a "virtual matrix". It is the product of $n$ Householder transformations. The information to generate these Householder transformations is stored in the V and beta slots. Note however that `qr.Q(.)` returns the row permuted matrix $Q^* := P^{-1}Q = P^*Q$ as permutation matrices are orthogonal; and $Q^*$ is orthogonal itself because $Q$ and $P$ are. This is useful because then, as in the dense matrix and **base R** matrix `qr` case, we have the mathematical identity

$$PA = Q^* R,$$

in R as

$$A[p+1, ] == qr.Q(*) \%\% R.$$
The "sparseQR" methods for the qr.* functions return objects of class "dgeMatrix" (see dgeMatrix). Results from qr.coef, qr.resid and qr.fitted (when k == ncol(R)) are well-defined and should match those from the corresponding dense matrix calculations. However, because the matrix Q is not uniquely defined, the results of qr.qy and qr.qty do not necessarily match those from the corresponding dense matrix calculations.

Also, the results of qr.qy and qr.qty apply to the permuted column order when the q slot has length n.

**Objects from the Class**

Objects can be created by calls of the form new("sparseQR", ...) but are more commonly created by function qr applied to a sparse matrix such as a matrix of class dgCMatrix.

**Slots**

V: Object of class "dgCMatrix". The columns of V are the vectors that generate the Householder transformations of which the matrix Q is composed.

beta: Object of class "numeric", the normalizing factors for the Householder transformations.

p: Object of class "integer": Permutation (of 0:(n-1)) applied to the rows of the original matrix.

R: Object of class "dgCMatrix": An upper triangular matrix of the same dimension as X.

q: Object of class "integer": Permutation applied from the right, i.e., to the columns of the original matrix. Can be of length 0 which implies no permutation.

**Methods**

qr.R signature(qr = "sparseQR"): compute the upper triangular R matrix of the QR decomposition. Note that this currently warns because of possible permutation mismatch with the classical qr.R() result, and you can suppress these warnings by setting options() either "Matrix.qutet.qr.R" or (the more general) either "Matrix.qutet" to TRUE.

qr.Q signature(qr = "sparseQR"): compute the orthogonal Q matrix of the QR decomposition.

qr.coef signature(qr = "sparseQR", y = "ddenseMatrix"): ...

qr.coef signature(qr = "sparseQR", y = "matrix"): ...

qr.qty signature(qr = "sparseQR", y = "ddenseMatrix"): ...

qr.qty signature(qr = "sparseQR", y = "matrix"): ...

qr.qty signature(qr = "sparseQR", y = "numeric"): ...

qr.fitted signature(qr = "sparseQR", y = "ddenseMatrix"): ...

qr.fitted signature(qr = "sparseQR", y = "matrix"): ...

qr.fitted signature(qr = "sparseQR", y = "numeric"): ...

qr.resid signature(qr = "sparseQR", y = "ddenseMatrix"): ...
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

```r
str(sv <- sparseVector(x = 1:10, i = sample(999, 10), length=1000))

sx <- c(0,0,3, 3.2, 0,0,0,-3:1,0,2,0,0,5,0,0)
ss <- as(sx, "sparseVector")
stopifnot(identical(ss,
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))))
```

Description

Sparse Vector Classes: The virtual mother class "sparseVector" has the five actual daughter classes "dsparseVector", "isparsiveVector", "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 >= 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 x n Toeplitz matrix from x, where n = length(x).

rep signature(x = "sparseVector") repeat x, with the same argument list (x, times, length.out, each,...) 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 = ...): 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("xsparsesVector") # those with an 'x' slot
sx <- c(0,0,3, 3.2, 0,0,0,-3:1,0,2,0,0,5,0)
(ss <- as(sx, "sparseVector"))
ix <- as.integer(round(sx))
(is <- as(ix, "sparseVector")) ## an "isparseVector" (!)
(ns <- sparseVector(i= c(7, 3, 2), length = 10)) # "n sparseVector"
## 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, "C sparseMatrix")))))

## 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(); 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))
spMatrix

## 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

```r
spMatrix(nrow, ncol, i = integer(), j = integer(), x = numeric())
```

## 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.
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{spMatrix} 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 \texttt{Matrix}' \texttt{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)
```
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

coerce signature(from = "ddiMatrix", to = "symmetricMatrix"): and many other coercion methods, some of which are particularly optimized.

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, dims = c(7,7),
         symmetric=TRUE, dimnames = list(NULL, letters[1:7]))
sy # shows symmetrical dimnames
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**

**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**

- `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).
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, i.e., 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**

```r
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

Unique (Sorted) TsparseMatrix Representations

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` constructors for "dgTMatrix" (and other "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`.

Extends

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

Methods

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

Note

Most operations with sparse matrices are performed using the compressed, column-oriented or `CsparseMatrix` representation. The triplet representation is convenient for creating a sparse matrix or for reading and writing such matrices. Once it is created, however, the matrix is generally coerced to a `CsparseMatrix` for further operations.

Note that all `new(.)`, `spMatrix` and `sparseMatrix(*, giveCsparse=FALSE)` constructors for "TsparseMatrix" classes implicitly add \(x_k\)'s that belong to identical \((i_k,j_k)\) pairs, see, the example below, or also "dgTMatrix".

For convenience, methods for some operations such as `%*%` and `crossprod` are defined for `TsparseMatrix` objects. These methods simply coerce the `TsparseMatrix` object to a `CsparseMatrix` object then perform the operation.

See Also

its superclass, `sparseMatrix`, and the `dgTMatrix` class, for the links to other classes.

Examples

```r
showClass("TsparseMatrix")
## or just the subclasses' names
names(getClass("TsparseMatrix"))@subclasses

T3 <- spMatrix(3,4, i=c(1,3:1), j=c(2,4:2), x=1:4)
T3 # only 3 non-zero entries, 5 = 1+4
```

---

uniqTsparse

Unique (Sorted) TsparseMatrix Representations

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` constructors for "dgTMatrix" (and other "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

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 1:TM matrix and n:TMatrix:
(L2 <- T2 > 0)
validObject(L2u <- uniqTsparse(L2))
(N2 <- as(L2, "nMatrix"))
validObject(NZu <- uniqTsparsen(Z(NZ))
stopifnot(NZ@i <- L2u@i, L2u@i <- T2u@i, NZ@j <- L2@j, L2@j <- T2@j,
        NZ@j <- L2u@j)
# now with a nasty NA [partly failed in Matrix 1.1-5]:
validObject(L2.N)
(mZN <- as.matrix((L2.N))) # looks "ok"
iL <- as.integer(mZN)
stopifnot(identical(10L, which(is.na(match(iL, 0:1)))))
symnum(mZN)

unpack Representation of Packed and Unpacked (Dense) Matrices

Description

“Packed” matrix storage here applies to dense matrices (denseMatrix) only, and there is available only for symmetric (symmetricMatrix) or triangular (triangularMatrix) matrices, where only one triangle of the matrix needs to be stored.

unpack() unpacks “packed” matrices, where pack() produces “packed” matrices.

Usage

pack(x, ...)
## S4 method for signature 'matrix'
pack(x, symmetric = NA, upperTri = NA, ...)

unpack(x, ...)

Arguments

x for unpack(): a matrix stored in packed form, e.g., of class "d?pMatrix" where "?" is "t" for triangular or "s" for symmetric.

for pack(): a (symmetric or triangular) matrix stored in full storage.
symmetric logical (including NA) for optionally specifying if x is symmetric (or rather triangular).
upperTri (for the triangular case only) logical (incl. NA) indicating if x is upper (or lower) triangular.
...

further arguments passed to or from other methods.

Details

These are generic functions with special methods for different types of packed (or non-packed) symmetric or triangular dense matrices. Use showMethods("unpack") to list the methods for unpack(), and similarly for pack().
Value

for unpack(): A **Matrix** object containing the full-storage representation of \( x \).

for pack(): A packed **Matrix** (i.e. of class ".pMatrix") representation of \( x \).

Examples

```r
showMethods("unpack")
(cp4 <- chol(Hilbert(4))) # is triangular
tp4 <- as(cp4,"dtpMatrix") # tiangular [p]acked
str(tp4)
(unpack(tp4))
stopifnot(identical(tp4, pack(unpack(tp4))))

(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))
showMethods("pack")
```

---

**Unused-classes**  
**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**

```r
showClass("iMatrix")
showClass("zMatrix")
```

---

**Updown**  
**Up- and Down-Dating a Cholesky Decomposition**

**Description**

Compute the up- or down-dated Cholesky decomposition

**Usage**

```r
updown(update, C, L)
```
Arguments

update logical (TRUE or FALSE) or "+" or "-" indicating if an up- or a down-date is to be computed.

C any R object, coercable to a sparse matrix (i.e., of subclass of \texttt{sparseMatrix}).

L a Cholesky factor, specifically, of class \"CHMfactor\".

Value

an updated Cholesky factor, of the same dimension as \texttt{L}. Typically of class \"dCHMsimpl\" (a subclass of \"CHMfactor\").

Methods

signature(update = "character", C = "mMatrix", L = "CHMfactor") ..

signature(update = "logical", C = "mMatrix", L = "CHMfactor") ..

Author(s)

Contributed by Nicholas Nagle, University of Tennessee, Knoxville, USA

References

CHOLMOD manual, currently beginning of chapter~18. ...

See Also

Cholesky.

Examples

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)
cA <- Cholesky(A <- crossprod(m) + Diagonal(5))
166 * as(cA,"Matrix") ^ 2
uc1 <- updown("+", Diagonal(5), cA)
# Hmm: this loses positive definiteness:
uc2 <- updown("-", 2*Diagonal(5), cA)
image(show(as(cA, "Matrix")))
image(show(c2 <- as(uc2,"Matrix")))# severely negative entries
#---> Warning
USCounties

USCounties Contiguity Matrix

Description

This matrix represents the contiguouses of 3111 US counties using the Queen criterion of at least a single shared boundary point. The representation is as a row standardised spatial weights matrix transformed to a symmetric matrix (see Ord (1975), p. 125).

Usage

data(USCounties)

Format

A $3111^2$ symmetric sparse matrix of class dsCMatrix with 9101 non-zero entries.

Details

The data were read into R using read_gal, and row-standardised and transformed to symmetry using nb2listw and similar.listw. This spatial weights object was converted to class dsCMatrix using as_dsTMatrix_listw and coercion.

Source

The data were retrieved from http://sal.uiuc.edu/weights/zips/usc.zip, files “usc.txt” and “usc\_q.GAL”, with permission for use and distribution from Luc Anselin.

References


Examples

data(USCounties)
(n <- ncol(USCounties))
IM <- .symDiagonal(n)
nn <- 50
set.seed(1)
rho <- runif(nn, 0, 1)
system.time(MJ <- sapply(rho, function(x)
determinant(IM - x * USCounties, logarithm = TRUE)$modulus))

## can be done faster, by update()ing the Cholesky factor:
nWC <- USCounties
C1 <- Cholesky(nWC, Imult = 2)
system.time(M1 <- n * log(rho) +
sapply(rho, function(x)
Methods for 
"[": Extraction or Subsetting in Package 'Matrix'

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)
```
Methods for "[<-", i.e., extraction or subsetting mostly of matrices, in package \texttt{Matrix}.

\textbf{Note}: Contrary to standard matrix assignment in base \texttt{R}, in \texttt{x[..] <- val} it is typically an error (see \texttt{stop}) when the \texttt{type} or \texttt{class} of \texttt{val} would require the class of \texttt{x} to be changed, e.g., when \texttt{x} is logical, say \texttt{lsparseMatrix}, and \texttt{val} is numeric. In other cases, e.g., when \texttt{x} is a \texttt{nsparseMatrix} and \texttt{val} is not TRUE or FALSE, a warning is signalled, and \texttt{val} is “interpreted” as \texttt{logical}, and (logical) \texttt{NA} is interpreted as \texttt{TRUE}.

\section*{Methods}

There are many more than these:

- \texttt{x = "Matrix", i = "missing", j = "missing", value= "ANY"} is currently a simple fallback method implementation which ensures “readable” error messages.
- \texttt{x = "Matrix", i = "ANY", j = "ANY", value= "ANY"} currently gives an error
- \texttt{x = "denseMatrix", i = "index", j = "missing", value= "numeric"} ...
- \texttt{x = "denseMatrix", i = "index", j = "index", value= "numeric"} ...

\section*{See Also}

\texttt{[<-methods} for subsetting "Matrix" objects; the \texttt{index} class; \texttt{Extract} about the standard subset assignment (and extraction).

\section*{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)
m
```
Boolean Arithmetic Matrix Products: %&% and Methods

### 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 = "nMatrix")`
- `signature(x = "nsparseMatrix", 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

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

```r
## 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")
```
Examples

```r
set.seed(7)
L <- Matrix(rnorm(20) > 1, 4, 5)
(N <- as(L, "nMatrix"))
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"
```
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