

# Package ‘SparseArray’

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**Title** High-performance sparse data representation and manipulation in R

**Description** The SparseArray package provides array-like containers for efficient in-memory representation of multidimensional sparse data in R (arrays and matrices). The package defines the SparseArray virtual class and two concrete subclasses: COO\_SparseArray and SVT\_SparseArray. Each subclass uses its own internal representation of the nonzero multidimensional data: the ``COO layout" and the ``SVT layout", respectively. SVT\_SparseArray objects mimic as much as possible the behavior of ordinary matrix and array objects in base R. In particular, they support most of the ``standard matrix and array API" defined in base R and in the matrixStats package from CRAN.

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read\_block\_as\_sparse.R SparseArray-dim-tuning.R  
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 SparseArray-misc-methods.R SparseMatrix-mult.R  
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COO\_SparseArray-class *COO\_SparseArray objects*


---

### Description

The COO\_SparseArray class is a container for efficient in-memory representation of multidimensional sparse arrays. It uses the *COO layout* to represent the nonzero data internally.

A COO\_SparseMatrix object is a COO\_SparseArray object of 2 dimensions.

**IMPORTANT NOTE:** COO\_SparseArray and COO\_SparseMatrix objects are now superseded by the new and more efficient [SVT\\_SparseArray](#) and SVT\_SparseMatrix objects.

### Usage

```
## Constructor function:
COO_SparseArray(dim, nzcoo=NULL, nzdata=NULL, dimnames=NULL, check=TRUE)

## Getters (in addition to dim(), length(), and dimnames()):
nzcoo(x)
nzdata(x)
```

### Arguments

dim	The dimensions (specified as an integer vector) of the COO_SparseArray or COO_SparseMatrix object to create.
nzcoo	A matrix containing the array coordinates of the nonzero elements. This must be an integer matrix of array coordinates like one returned by <code>base::arrayInd</code> or <code>S4Arrays::Lindex2Mindex</code> , that is, a matrix with <code>length(dim)</code> columns and where each row is an n-tuple representing the coordinates of an array element.
nzdata	A vector (atomic or list) of length <code>nrow(nzcoo)</code> containing the nonzero elements.
dimnames	The <i>dimnames</i> of the object to be created. Must be NULL or a list of length the number of dimensions. Each list element must be either NULL or a character vector along the corresponding dimension.
check	Should the object be validated upon construction?
x	A COO_SparseArray or COO_SparseMatrix object.

### Value

- For `COO_SparseArray()`: A COO\_SparseArray or COO\_SparseMatrix object.
- For `nzcoo()`: A matrix with one column per dimension containing the *array coordinates* of the nonzero elements.
- For `nzdata()`: A vector *parallel* to `nzcoo(x)` (i.e. with one element per row in `nzcoo(x)`) containing the nonzero elements.

**See Also**

- The new [SVT\\_SparseArray](#) class for a replacement of of the [COO\\_SparseArray](#) class.
- The [SparseArray](#) class for the virtual parent class of [COO\\_SparseArray](#) and [SVT\\_SparseArray](#).
- S4 classes [dgCMatrix](#) and [lgCMatrix](#) defined in the **Matrix** package, for the de facto standard of sparse matrix representations in the R ecosystem.
- `base::arrayInd` in the **base** package.
- `S4Arrays::Lindex2Mindex` in the **S4Arrays** package for an improved (faster) version of `base::arrayInd`.
- Ordinary [array](#) objects in base R.

**Examples**

```
## -----
## EXAMPLE 1
## -----
dim1 <- 5:3
nzcoo1 <- Lindex2Mindex(sample(60, 8), 5:3)
nzdata1 <- 11.11 * seq_len(nrow(nzcoo1))
coo1 <- COO_SparseArray(dim1, nzcoo1, nzdata1)
coo1

nzcoo(coo1)
nzdata(coo1)
type(coo1)
sparsity(coo1)

as.array(coo1) # back to a dense representation

#as.matrix(coo1) # error!

## -----
## EXAMPLE 2
## -----
m2 <- matrix(c(5:-2, rep.int(c(0L, 99L), 11)), ncol=6)
coo2 <- as(m2, "COO_SparseArray")
class(coo2)
dim(coo2)
length(coo2)
nzcoo(coo2)
nzdata(coo2)
type(coo2)
sparsity(coo2)

stopifnot(identical(as.matrix(coo2), m2))

t(coo2)
stopifnot(identical(as.matrix(t(coo2)), t(as.matrix(coo2))))

## -----
## COERCION FROM/TO dg[C|R]Matrix OR lg[C|R]Matrix OBJECTS
```

```

## -----
## dg[C|R]Matrix and lg[C|R]Matrix objects are defined in the Matrix
## package.

## dgCMatrix/dgRMatrix:

M2C <- as(coo2, "dgCMatrix")
stopifnot(identical(M2C, as(m2, "dgCMatrix")))

coo2C <- as(M2C, "COO_SparseArray")
## 'coo2C' is the same as 'coo2' except that 'nzdata(coo2C)' has
## type "double" instead of "integer":
stopifnot(all.equal(coo2, coo2C))
typeof(nzdata(coo2C)) # double
typeof(nzdata(coo2))  # integer

M2R <- as(coo2, "dgRMatrix")
stopifnot(identical(M2R, as(m2, "dgRMatrix")))
coo2R <- as(M2R, "COO_SparseArray")
stopifnot(all.equal(as.matrix(coo2), as.matrix(coo2R)))

## lgCMatrix/lgRMatrix:

m3 <- m2 == 99 # logical matrix
coo3 <- as(m3, "COO_SparseArray")
class(coo3)
type(coo3)

M3C <- as(coo3, "lgCMatrix")
stopifnot(identical(M3C, as(m3, "lgCMatrix")))
coo3C <- as(M3C, "COO_SparseArray")
identical(as.matrix(coo3), as.matrix(coo3C))

M3R <- as(coo3, "lgRMatrix")
#stopifnot(identical(M3R, as(m3, "lgRMatrix")))
coo3R <- as(M3R, "COO_SparseArray")
identical(as.matrix(coo3), as.matrix(coo3R))

## -----
## A BIG COO_SparseArray OBJECT
## -----
nzcoo4 <- cbind(sample(25000, 600000, replace=TRUE),
               sample(195000, 600000, replace=TRUE))
nzdata4 <- runif(600000)
coo4 <- COO_SparseArray(c(25000, 195000), nzcoo4, nzdata4)
coo4
sparsity(coo4)

```

## Description

`extract_sparse_array()` is an internal generic function that is the workhorse behind the default `read_block_as_sparse()` method. It is not intended to be used directly by the end user.

It is similar to the `extract_array()` internal generic function defined in the **S4Arrays** package, with the major difference that, in the case of `extract_sparse_array()`, the extracted array data is returned as a `SparseArray` object instead of an ordinary array.

## Usage

```
extract_sparse_array(x, index)
```

```
## S4 method for signature 'ANY'
extract_sparse_array(x, index)
```

## Arguments

<code>x</code>	An array-like object for which <code>is_sparse(x)</code> is TRUE.
<code>index</code>	<p>An unnamed list of integer vectors, one per dimension in <code>x</code>. Each vector is called a <i>subscript</i> and can only contain positive integers that are valid 1-based indices along the corresponding dimension in <code>x</code>.</p> <p>Empty or missing subscripts are allowed. They must be represented by list elements set to <code>integer(0)</code> or <code>NULL</code>, respectively.</p> <p>The subscripts cannot contain NAs or non-positive values.</p> <p>Individual subscripts are NOT allowed to contain duplicated indices. This is an important difference with <code>extract_array</code>.</p>

## Details

`extract_sparse_array()` should *always* be called on an array-like object `x` for which `is_sparse(x)` is TRUE. Also it should *never* be called with duplicated indices in the individual list elements of the `index` argument.

For maximum efficiency, `extract_sparse_array()` methods should:

1. NOT check that `is_sparse(x)` is TRUE.
2. NOT check that the individual list elements in `index` contain no duplicated indices.
3. NOT try to do anything with the `dimnames` on `x`.
4. always operate natively on the sparse representation of the data in `x`, that is, they should never *expand* it into a dense representation (e.g. with `as.array()`).

Like for `extract_array()`, `extract_sparse_array()` methods need to support empty or missing subscripts. For example, if `x` is an  $M \times N$  matrix-like object for which `is_sparse(x)` is TRUE, then `extract_sparse_array(x, list(NULL, integer(0)))` must return an  $M \times 0$  `SparseArray` derivative, and `extract_sparse_array(x, list(integer(0), integer(0)))` a  $0 \times 0$  `SparseArray` derivative.

**Value**

A [SparseArray](#) derivative ([COO\\_SparseArray](#) or [SVT\\_SparseArray](#)) of the same `type()` as `x`. For example, if `x` is an object representing an  $M \times N$  sparse matrix of complex numbers (i.e. `type(x) == "complex"`), then `extract_sparse_array(x, list(NULL, 2L))` must return the 2nd column in `x` as an  $M \times 1$  [SparseArray](#) derivative of `type() "complex"`.

**See Also**

- [is\\_sparse](#) in the **S4Arrays** package to check whether an object uses a sparse representation of the data or not.
- [SparseArray](#) objects.
- `S4Arrays::type` in the **S4Arrays** package to get the type of the elements of an array-like object.
- [read\\_block\\_as\\_sparse](#) to read array blocks as [SparseArray](#) objects.
- [extract\\_array](#) in the **S4Arrays** package.
- [dgCMatrix](#) objects implemented in the **Matrix** package.

**Examples**

```
extract_sparse_array
showMethods("extract_sparse_array")

## --- On a dgCMatrix object ---

m <- matrix(0L, nrow=6, ncol=4)
m[c(1:2, 8, 10, 15:17, 24)] <- (1:8)*10L
dgcm <- as(m, "dgCMatrix")
dgcm

extract_sparse_array(dgcm, list(3:6, NULL))
extract_sparse_array(dgcm, list(3:6, 2L))
extract_sparse_array(dgcm, list(3:6, integer(0)))

## --- On a SparseArray object ---

a <- array(0L, dim=5:3, dimnames=list(letters[1:5], NULL, LETTERS[1:3]))
a[c(1:2, 8, 10, 15:17, 20, 24, 40, 56:60)] <- (1:15)*10L
svt <- as(a, "SparseArray")
svt

extract_sparse_array(svt, list(NULL, 4:2, 1L))
extract_sparse_array(svt, list(NULL, 4:2, 2:3))
extract_sparse_array(svt, list(NULL, 4:2, integer(0)))
```

---

matrixStats-methods    *SparseArray col/row summarization methods*

---

## Description

The **SparseArray** package provides memory-efficient col/row summarization methods (a.k.a. matrixStats methods) for [SparseArray](#) objects, like `colSums()`, `rowSums()`, `colMedians()`, `rowMedians()`, `colVars()`, `rowVars()`, etc...

Note that these are *S4 generic functions* defined in the **MatrixGenerics** package, with methods for ordinary matrices defined in the **matrixStats** package. This man page documents the methods defined for [SVT\\_SparseArray](#) objects.

## Usage

```
## N.B.: Showing ONLY the col*() methods (usage of row*() methods is
## the same):

## S4 method for signature 'SVT_SparseArray'
colAnyNAs(x, rows=NULL, cols=NULL, dims=1, ..., useNames=NA)

## S4 method for signature 'SVT_SparseArray'
colAnys(x, rows=NULL, cols=NULL, na.rm=FALSE, dims=1, ..., useNames=NA)

## S4 method for signature 'SVT_SparseArray'
colAlls(x, rows=NULL, cols=NULL, na.rm=FALSE, dims=1, ..., useNames=NA)

## S4 method for signature 'SVT_SparseArray'
colMins(x, rows=NULL, cols=NULL, na.rm=FALSE, dims=1, ..., useNames=NA)

## S4 method for signature 'SVT_SparseArray'
colMaxs(x, rows=NULL, cols=NULL, na.rm=FALSE, dims=1, ..., useNames=NA)

## S4 method for signature 'SVT_SparseArray'
colRanges(x, rows=NULL, cols=NULL, na.rm=FALSE, dims=1, ..., useNames=NA)

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

## S4 method for signature 'SVT_SparseArray'
colProds(x, rows=NULL, cols=NULL, na.rm=FALSE, dims=1, ..., useNames=NA)

## S4 method for signature 'SVT_SparseArray'
colMeans(x, na.rm=FALSE, dims=1)

## S4 method for signature 'SVT_SparseArray'
colVars(x, rows=NULL, cols=NULL, na.rm=FALSE, center=NULL, dims=1,
```



```

    ..., useNames=NA)

## S4 method for signature 'SVT_SparseArray'
colSds(x, rows=NULL, cols=NULL, na.rm=FALSE, center=NULL, dims=1,
    ..., useNames=NA)

## S4 method for signature 'SVT_SparseArray'
colMedians(x, rows=NULL, cols=NULL, na.rm=FALSE, ..., useNames=NA)

```

## Arguments

**x** An [SVT\\_SparseMatrix](#) or [SVT\\_SparseArray](#) object.  
 Note that the `colMedians()` and `rowMedians()` methods only support 2D objects (i.e. [SVT\\_SparseMatrix](#) objects) at the moment.

**rows, cols, ...** Not supported.

**na.rm, useNames, center**  
 See man pages for the corresponding generics in the **MatrixGenerics** package (e.g. `?MatrixGenerics::rowVars`) for a description of these arguments.  
 Note that, unlike the methods for ordinary matrices defined in the **matrixStats** package, the `center` argument of the `colVars()`, `rowVars()`, `colSds()`, and `rowSds()` methods for [SVT\\_SparseArray](#) objects can only be a *single value* (or a `NULL`). In particular, if `x` has more than one column, then `center` cannot be a vector with one value per column in `x`.

**dims** See `?base::colSums` for a description of this argument. Note that all the methods above support it, except `colMedians()` and `rowMedians()`.

## Details

All these methods operate *natively* on the [SVT\\_SparseArray](#) representation, for maximum efficiency.

Note that more col/row summarization methods might be added in the future.

## Value

See man pages for the corresponding generics in the **MatrixGenerics** package (e.g. `?MatrixGenerics::colRanges`) for the value returned by these methods.

## Note

The `matrixStats` method for [SVT\\_SparseMatrix](#) objects are multithreaded. See [set\\_SparseArray\\_nthread](#) for how to control the number of threads.

## See Also

- [SVT\\_SparseArray](#) objects.
- The man pages for the various generic functions defined in the **MatrixGenerics** package e.g. `MatrixGenerics::colVars` etc...

**Examples**

```

## -----
## 2D CASE
## -----
m0 <- matrix(0L, nrow=6, ncol=4, dimnames=list(letters[1:6], LETTERS[1:4]))
m0[c(1:2, 8, 10, 15:17, 24)] <- (1:8)*10L
m0["e", "B"] <- NA
svt0 <- SparseArray(m0)
svt0

colSums(svt0)
colSums(svt0, na.rm=TRUE)

rowSums(svt0)
rowSums(svt0, na.rm=TRUE)

colMeans(svt0)
colMeans(svt0, na.rm=TRUE)

colRanges(svt0)
colRanges(svt0, useNames=FALSE)
colRanges(svt0, na.rm=TRUE)
colRanges(svt0, na.rm=TRUE, useNames=FALSE)

colVars(svt0)
colVars(svt0, useNames=FALSE)

## Sanity checks:
stopifnot(
  identical(colSums(svt0), colSums(m0)),
  identical(colSums(svt0, na.rm=TRUE), colSums(m0, na.rm=TRUE)),
  identical(rowSums(svt0), rowSums(m0)),
  identical(rowSums(svt0, na.rm=TRUE), rowSums(m0, na.rm=TRUE)),
  identical(colMeans(svt0), colMeans(m0)),
  identical(colMeans(svt0, na.rm=TRUE), colMeans(m0, na.rm=TRUE)),
  identical(colRanges(svt0), colRanges(m0, useNames=TRUE)),
  identical(colRanges(svt0, useNames=FALSE), colRanges(m0, useNames=FALSE)),
  identical(colRanges(svt0, na.rm=TRUE),
             colRanges(m0, na.rm=TRUE, useNames=TRUE)),
  identical(colVars(svt0), colVars(m0, useNames=TRUE)),
  identical(colVars(svt0, na.rm=TRUE),
             colVars(m0, na.rm=TRUE, useNames=TRUE))
)

## -----
## 3D CASE (AND ARBITRARY NUMBER OF DIMENSIONS)
## -----
set.seed(2009)
svt <- 6L * (poissonSparseArray(5:3, density=0.35) -
            poissonSparseArray(5:3, density=0.35))
dimnames(svt) <- list(NULL, letters[1:4], LETTERS[1:3])

```

```

cs1 <- colSums(svt)
cs1 # cs1[j , k] is equal to sum(svt[ , j, k])

cs2 <- colSums(svt, dims=2)
cs2 # cv2[k] is equal to sum(svt[ , , k])

cv1 <- colVars(svt)
cv1 # cv1[j , k] is equal to var(svt[ , j, k])

cv2 <- colVars(svt, dims=2)
cv2 # cv2[k] is equal to var(svt[ , , k])

## Sanity checks:
k_idx <- setNames(seq_len(dim(svt)[3]), dimnames(svt)[[3]])
j_idx <- setNames(seq_len(dim(svt)[2]), dimnames(svt)[[2]])
cv1b <- sapply(k_idx, function(k)
  sapply(j_idx, function(j) var(svt[ , j, k, drop=FALSE])))
cv2b <- sapply(k_idx, function(k) var(svt[ , , k]))
stopifnot(
  identical(colSums(svt), colSums(as.array(svt))),
  identical(colSums(svt, dims=2), colSums(as.array(svt), dims=2)),
  identical(cv1, cv1b),
  identical(cv2, cv2b)
)

```

---

randomSparseArray	<i>Random SparseArray object</i>
-------------------	----------------------------------

---

## Description

randomSparseArray() and poissonSparseArray() can be used to generate a random [SparseArray](#) object efficiently.

## Usage

```

randomSparseArray(dim, density=0.05)
poissonSparseArray(dim, lambda=-log(0.95), density=NA)

## Convenience wrappers for the 2D case:
randomSparseMatrix(nrow, ncol, density=0.05)
poissonSparseMatrix(nrow, ncol, lambda=-log(0.95), density=NA)

```

## Arguments

dim	The dimensions (specified as an integer vector) of the <a href="#">SparseArray</a> object to generate.
density	The desired density (specified as a number $\geq 0$ and $\leq 1$ ) of the <a href="#">SparseArray</a> object to generate, that is, the ratio between its number of nonzero elements and its total number of elements. This is $\text{nzcount}(x)/\text{length}(x)$ or $1 - \text{sparsity}(x)$ .

Note that for `poissonSparseArray()` and `poissonSparseMatrix()` density must be  $< 1$  and the *actual* density of the returned object won't be exactly as requested but will typically be very close.

lambda	The mean of the Poisson distribution. Passed internally to the calls to <code>rpois()</code> . Only one of lambda and density can be specified. When density is requested, <code>rpois()</code> is called internally with lambda set to $-\log(1 - \text{density})$ . This is expected to generate Poisson data with the requested density. Finally note that the default value for lambda corresponds to a requested density of 0.05.
nrow, ncol	Number of rows and columns of the <code>SparseMatrix</code> object to generate.

### Details

`randomSparseArray()` mimics the `rsparsematrix()` function from the **Matrix** package but returns a `SparseArray` object instead of a `dgCMatrix` object.

`poissonSparseArray()` populates a `SparseArray` object with Poisson data i.e. it's equivalent to:

```
a <- array(rpois(prod(dim), lambda), dim)
as(a, "SparseArray")
```

but is faster and more memory efficient because intermediate dense array `a` is never generated.

### Value

A `SparseArray` derivative (of class `SVT_SparseArray` or `SVT_SparseMatrix`) with the requested dimensions and density.

The type of the returned object is "double" for `randomSparseArray()` and `randomSparseMatrix()`, and "integer" for `poissonSparseArray()` and `poissonSparseMatrix()`.

### Note

Unlike with `Matrix::rsparsematrix()` there's no limit on the number of nonzero elements that can be contained in the returned `SparseArray` object.

For example `Matrix::rsparsematrix(3e5, 2e4, density=0.5)` will fail with an error but `randomSparseMatrix(3e5, 2e4, density=0.5)` should work (even though it will take some time and the memory footprint of the resulting object will be about 18 Gb).

### See Also

- The `Matrix::rsparsematrix` function in the **Matrix** package.
- The `stats::rpois` function in the **stats** package.
- `SVT_SparseArray` objects.

**Examples**

```

## -----
## randomSparseArray() / randomSparseMatrix()
## -----
set.seed(123)
dgcM1 <- rsparsematrix(2500, 950, density=0.1)
set.seed(123)
svt1 <- randomSparseMatrix(2500, 950, density=0.1)
svt1
type(svt1) # "double"

stopifnot(identical(as(svt1, "dgCMatrix"), dgcM1))

## -----
## poissonSparseArray() / poissonSparseMatrix()
## -----
svt2 <- poissonSparseMatrix(2500, 950, density=0.1)
svt2
type(svt2) # "integer"
1 - sparsity(svt2) # very close to the requested density

set.seed(123)
svt3 <- poissonSparseArray(c(600, 1700, 80), lambda=0.01)
set.seed(123)
a3 <- array(rpois(length(svt3), lambda=0.01), dim(svt3))
stopifnot(identical(svt3, SparseArray(a3)))

## The memory footprint of 'svt3' is 10x smaller than that of 'a3':
object.size(svt3)
object.size(a3)
as.double(object.size(a3) / object.size(svt3))

```

---

readSparseCSV

*Read/write a sparse matrix from/to a CSV file*


---

**Description**

Read/write a sparse matrix from/to a CSV (comma-separated values) file.

**Usage**

```
writeSparseCSV(x, filepath, sep=",", transpose=FALSE, write.zeros=FALSE,
              chunknrow=250)
```

```
readSparseCSV(filepath, sep=",", transpose=FALSE)
```

**Arguments**

x	A matrix-like object, typically sparse. <b>IMPORTANT:</b> The object must have rownames and colnames! These will be written to the file. Another requirement is that the object must be subsettable. More precisely: it must support 2D-style subsetting of the kind <code>x[i, ]</code> and <code>x[, j]</code> where <code>i</code> and <code>j</code> are integer vectors of valid row and column indices.
filepath	The path (as a single string) to the file where to write the matrix-like object or to read it from. Compressed files are supported. If "", <code>writeSparseCSV()</code> will write the data to the standard output connection. Note that <code>filepath</code> can also be a connection.
sep	The field separator character. Values on each line of the file are separated by this character.
transpose	TRUE or FALSE. By default, rows in the matrix-like object correspond to lines in the CSV file. Set <code>transpose</code> to TRUE to transpose the matrix-like object on-the-fly, that is, to have its columns written to or read from the lines in the CSV file. Note that using <code>transpose=TRUE</code> is semantically equivalent to calling <code>t()</code> on the object before writing it or after reading it, but it will tend to be more efficient. Also it will work even if <code>x</code> does not support <code>t()</code> (not all matrix-like objects are guaranteed to be transposable).
write.zeros	TRUE or FALSE. By default, the zero values in <code>x</code> are not written to the file. Set <code>write.zeros</code> to TRUE to write them.
chunknrow	<code>writeSparseCSV()</code> uses a block-processing strategy to try to speed up things. By default blocks of 250 rows (or columns if <code>transpose=TRUE</code> ) are used. In our experience trying to increase this (e.g. to 500 or more) will generally not produce significant benefits while it will increase memory usage, so use carefully.

**Value**

`writeSparseCSV` returns an invisible NULL.

`readSparseCSV` returns a [SparseMatrix](#) object of class `SVT_SparseMatrix`.

**See Also**

- [SparseArray](#) objects.
- [dgCMatrix](#) objects implemented in the **Matrix** package.

**Examples**

```
## -----
## writeSparseCSV()
## -----

## Prepare toy matrix 'm0':
rownames0 <- LETTERS[1:6]
colnames0 <- letters[1:4]
```

```

m0 <- matrix(0L, nrow=length(rownames0), ncol=length(colnames0),
             dimnames=list(rownames0, colnames0))
m0[c(1:2, 8, 10, 15:17, 24)] <- (1:8)*10L
m0

## writeSparseCSV():
writeSparseCSV(m0, filepath="", sep="\t")
writeSparseCSV(m0, filepath="", sep="\t", write.zeros=TRUE)
writeSparseCSV(m0, filepath="", sep="\t", transpose=TRUE)

## Note that writeSparseCSV() will automatically (and silently) coerce
## non-integer values to integer by passing them thru as.integer().

## Example where type(x) is "double":
m1 <- m0 * runif(length(m0))
m1
type(m1)
writeSparseCSV(m1, filepath="", sep="\t")

## Example where type(x) is "logical":
writeSparseCSV(m0 != 0, filepath="", sep="\t")

## Example where type(x) is "raw":
m2 <- m0
type(m2) <- "raw"
m2
writeSparseCSV(m2, filepath="", sep="\t")

## -----
## readSparseCSV()
## -----

csv_file <- tempfile()
writeSparseCSV(m0, csv_file)

svt1 <- readSparseCSV(csv_file)
svt1

svt2 <- readSparseCSV(csv_file, transpose=TRUE)
svt2

## If you need the sparse data as a dgCMatrix object, just coerce the
## returned object:
as(svt1, "dgCMatrix")
as(svt2, "dgCMatrix")

## Sanity checks:
stopifnot(identical(m0, as.matrix(svt1)))
stopifnot(identical(t(m0), as.matrix(svt2)))

```

**Description**

read\_block\_as\_sparse() is an internal generic function used by S4Arrays::read\_block() when is\_sparse(x) is TRUE.

**Usage**

```
read_block_as_sparse(x, viewport)
```

```
## S4 method for signature 'ANY'
read_block_as_sparse(x, viewport)
```

**Arguments**

x	An array-like object for which <code>is_sparse(x)</code> is TRUE.
viewport	An <code>ArrayViewport</code> object compatible with x, that is, such that <code>refdim(viewport)</code> is identical to <code>dim(x)</code> .

**Details**

Like `read_block_as_dense()` in the **S4Arrays** package, `read_block_as_sparse()` is not meant to be called directly by the end user. The end user should always call the higher-level user-facing `read_block()` function instead. See `?read_block` in the **S4Arrays** package for more information.

Also, like `extract_sparse_array()`, `read_block_as_sparse()` should *always* be called on an array-like object x for which `is_sparse(x)` is TRUE.

For maximum efficiency, `read_block_as_sparse()` methods should:

1. NOT check that `is_sparse(x)` is TRUE.
2. NOT try to do anything with the `dimnames` on x (`read_block()` takes care of that).
3. always operate natively on the sparse representation of the data in x, that is, they should never *expand* it into a dense representation (e.g. with `as.array()`).

**Value**

A block of data as a `SparseArray` derivative (`COO_SparseArray` or `SVT_SparseArray`) of the same type() as x.

**See Also**

- `read_block` in the **S4Arrays** package for the higher-level user-facing function for reading array blocks.
- `ArrayGrid` in the **S4Arrays** package for `ArrayGrid` and `ArrayViewport` objects.
- `is_sparse` in the **S4Arrays** package to check whether an object uses a sparse representation of the data or not.
- `SparseArray` objects.
- `S4Arrays::type` in the **S4Arrays** package to get the type of the elements of an array-like object.



- [extract\\_sparse\\_array](#) for the workhorse behind the default `read_block_as_sparse()` method.
- [dgCMatrix](#) objects implemented in the **Matrix** package.

---

rowsum-methods

*rowsum() methods for sparse matrices*


---

## Description

The **SparseArray** package provides memory-efficient `rowsum()` methods for [SparseMatrix](#) and [dgCMatrix](#) objects.

Note that `colsum()` also works on these objects via the default method defined in the **S4Arrays** package.

## Usage

```
## S4 method for signature 'SVT_SparseMatrix'
rowsum(x, group, reorder=TRUE, ...)
```

```
## S4 method for signature 'dgCMatrix'
rowsum(x, group, reorder=TRUE, ...)
```

## Arguments

<code>x</code>	An <a href="#">SVT_SparseMatrix</a> or <a href="#">dgCMatrix</a> object.
<code>group, reorder</code>	See <code>?base::rowsum</code> for a description of these arguments.
<code>...</code>	Like the default S3 <code>rowsum()</code> method defined in the <b>base</b> package, the methods documented in this man page support additional argument <code>na.rm</code> , set to <code>FALSE</code> by default. If <code>TRUE</code> , missing values (NA or NaN) are omitted from the calculations.

## Value

An *ordinary* matrix, like the default `rowsum()` method. See `?base::rowsum` for how the matrix returned by the default `rowsum()` method is obtained.

## See Also

- `rowsum` in base R.
- `S4Arrays::rowsum` in the **S4Arrays** package for the `rowsum()` and `colsum()` S4 generic functions.
- [SVT\\_SparseMatrix](#) objects.
- [dgCMatrix](#) objects implemented in the **Matrix** package.

**Examples**

```

svt0 <- randomSparseMatrix(7e5, 100, density=0.15)
dgcm0 <- as(svt0, "dgCMatrix")
m0 <- as.matrix(svt0)

group <- sample(10, nrow(m0), replace=TRUE)

## Calling rowsum() on the sparse representations is usually faster
## than on the dense representation:
rs1 <- rowsum(m0, group)
rs2 <- rowsum(svt0, group) # about 3x faster
rs3 <- rowsum(dgcm0, group) # also about 3x faster

## Sanity checks:
stopifnot(identical(rs1, rs2))
stopifnot(identical(rs1, rs3))

```

---

SparseArray

*SparseArray objects*


---

**Description**

The **SparseArray** package defines the SparseArray virtual class whose purpose is to be extended by other S4 classes that aim at representing in-memory multidimensional sparse arrays.

It has currently two concrete subclasses, [COO\\_SparseArray](#) and [SVT\\_SparseArray](#), both also defined in this package. Each subclass uses its own internal representation for the nonzero multidimensional data, the *COO layout* for [COO\\_SparseArray](#), and the *SVT layout* for [SVT\\_SparseArray](#). The two layouts are described in the [COO\\_SparseArray](#) and [SVT\\_SparseArray](#) man pages, respectively.

Finally, the package also defines the SparseMatrix virtual class, as a subclass of the SparseArray class, for the specific 2D case.

**Usage**

```

## Constructor function:
SparseArray(x, type=NA)

```

**Arguments**

x	An ordinary matrix or array, or a dg[CIR]Matrix object, or an lg[CIR]Matrix object, or any matrix-like or array-like object that supports coercion to <a href="#">SVT_SparseArray</a> .
type	A single string specifying the requested type of the object. Normally, the SparseArray object returned by the constructor function has the same type() as x but the user can use the type argument to request a different type. Note that doing:

```
sa <- SparseArray(x, type=type)
```

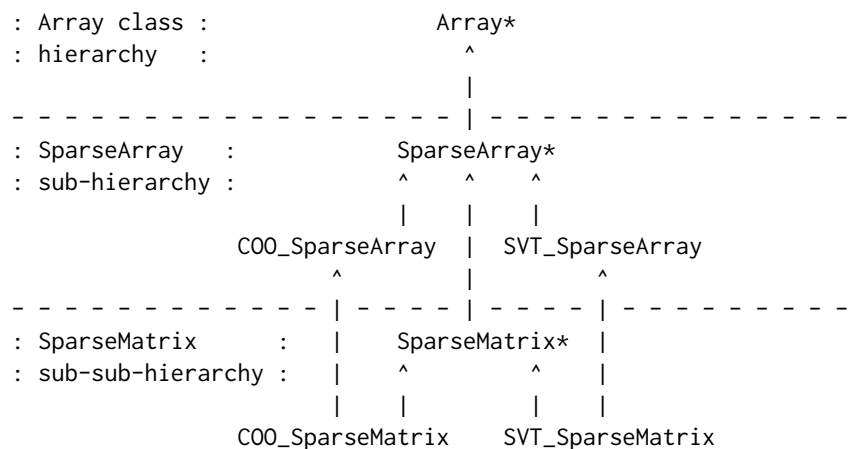
is equivalent to doing:

```
sa <- SparseArray(x)
type(sa) <- type
```

but the former is more convenient and will generally be more efficient. Supported types are all R atomic types plus "list".

## Details

The SparseArray class extends the [Array](#) virtual class defined in the **S4Arrays** package. Here is the full SparseArray sub-hierarchy as defined in the **SparseArray** package (virtual classes are marked with an asterisk):



Any object that belongs to a class that extends SparseArray e.g. (a [SVT\\_SparseArray](#) or [SVT\\_SparseMatrix](#) object) is called a *SparseArray derivative*.

Most of the *standard matrix and array API* defined in base R should work on SparseArray derivatives, including `dim()`, `length()`, `dimnames()`, ``dimnames<-`()`, `[`, `drop()`, ``[<-`` (subassignment), `t()`, `rbind()`, `cbind()`, etc...

SparseArray derivatives also support `type()`, ``type<-`()`, `is_sparse()`, `nzcount()`, `nzwhich()`, `nzvals()`, `sparsity()`, `arbind()`, and `acbind()`.

`sparsity(x)` returns the ratio between the number of zero-valued elements in array-like object `x` and its total number of elements (`length(x)` or `prod(dim(x))`). More precisely, `sparsity(x)` is  $1 - \text{nzcount}(x) / \text{length}(x)$ .

## Value

A *SparseArray derivative*, that is a [SVT\\_SparseArray](#), [COO\\_SparseArray](#), [SVT\\_SparseMatrix](#), or [COO\\_SparseMatrix](#) object.

The `type()` of the input object is preserved, except if a different one was requested via the `type` argument.

What is considered a zero depends on the `type()`:

- "logical" zero is FALSE;

- "integer" zero is 0L;
- "double" zero is 0;
- "complex" zero is 0+0i;
- "raw" zero is raw(1);
- "character" zero is "" (empty string);
- "list" zero is NULL.

### See Also

- The [COO\\_SparseArray](#) and [SVT\\_SparseArray](#) classes.
- [SparseArray\\_subsetting](#) for subsetting a SparseArray object.
- [SparseArray\\_subassignment](#) for SparseArray subassignment.
- [SparseArray\\_abind](#) for combining multidimensional SparseArray objects.
- [SparseArray\\_summarization](#) for SparseArray summarization methods.
- [SparseArray\\_Ops](#) for operations from the Ops group on SparseArray objects.
- [SparseArray\\_Math](#) for operations from the Math and Math2 groups on SparseArray objects.
- [SparseArray\\_Complex](#) for operations from the Complex group on SparseArray objects.
- [SparseArray\\_misc](#) for miscellaneous operations on a SparseArray object.
- [SparseMatrix\\_mult](#) for SparseMatrix multiplication and cross-product.
- [matrixStats\\_methods](#) for SparseArray col/row summarization methods.
- [rowsum\\_methods](#) for rowsum() methods for sparse matrices.
- [randomSparseArray](#) to generate a random SparseArray object.
- [readSparseCSV](#) to read/write a sparse matrix from/to a CSV (comma-separated values) file.
- S4 classes [dgCMatrix](#), [dgRMatrix](#), and [lgCMatrix](#) defined in the **Matrix** package, for the de facto standard for sparse matrix representations in the R ecosystem.
- [is\\_sparse](#) in the **S4Arrays** package.
- The [Array](#) class defined in the **S4Arrays** package.
- Ordinary [array](#) objects in base R.
- `base::which` in base R.

### Examples

```
## -----
## Display details of class definition & known subclasses
## -----

showClass("SparseArray")

## -----
## The SparseArray() constructor
## -----

a <- array(rpois(9e6, lambda=0.3), dim=c(500, 3000, 6))
```

```

SparseArray(a) # an SVT_SparseArray object

m <- matrix(rpois(9e6, lambda=0.3), ncol=500)
SparseArray(m) # an SVT_SparseMatrix object

dgc <- sparseMatrix(i=c(4:1, 2:4, 9:12, 11:9), j=c(1:7, 1:7),
                   x=runif(14), dims=c(12, 7))
class(dgc)
SparseArray(dgc) # an SVT_SparseMatrix object

dgr <- as(dgc, "RsparseMatrix")
class(dgr)
SparseArray(dgr) # a COO_SparseMatrix object

## -----
## nzcount(), nzwhich(), nzvals()
## -----
x <- SparseArray(a)

## Get the number of nonzero array elements in 'x':
nzcount(x)

## nzwhich() returns the indices of the nonzero array elements in 'x'.
## Either as an integer (or numeric) vector of length 'nzcount(x)'
## containing "linear indices":
nzidx <- nzwhich(x)
length(nzidx)
head(nzidx)

## Or as an integer matrix with 'nzcount(x)' rows and one column per
## dimension where the rows represent "array indices" (a.k.a. "array
## coordinates"):
Mnzidx <- nzwhich(x, arr.ind=TRUE)
dim(Mnzidx)

## Each row in the matrix is an n-tuple representing the "array
## coordinates" of a nonzero element in 'x':
head(Mnzidx)
tail(Mnzidx)

## Extract the values of the nonzero array elements in 'x' and return
## them in a vector "parallel" to 'nzwhich(x)':
#nzvals <- nzvals(x) # NOT READY YET!
#length(nzvals)      # NOT READY YET!
#head(nzvals)        # NOT READY YET!

## Sanity checks:
stopifnot(identical(nzidx, which(a != 0)))
stopifnot(identical(Mnzidx, which(a != 0, arr.ind=TRUE, useNames=FALSE)))
#stopifnot(identical(nzvals, a[nzidx])) # NOT READY YET!
#stopifnot(identical(nzvals, a[Mnzidx])) # NOT READY YET!

```

---

SparseArray-abind      *Combine multidimensional SparseArray objects*

---

## Description

Like ordinary matrices and arrays in base R, [SparseMatrix](#) derivatives can be combined by rows or columns, with `rbind()` or `cbind()`, and multidimensional [SparseArray](#) derivatives can be bound along any dimension with `abind()`.

Note that `arbind()` can also be used to combine the objects along their first dimension, and `acbind()` can be used to combine them along their second dimension.

## See Also

- [cbind](#) in base R.
- [abind](#) in the **S4Arrays** package.
- [SparseArray](#) objects.
- Ordinary [array](#) objects in base R.

## Examples

```
## -----
## COMBINING SparseMatrix OBJECTS
## -----

m1a <- matrix(1:15, nrow=3, ncol=5,
              dimnames=list(NULL, paste0("M1y", 1:5)))
m1b <- matrix(101:135, nrow=7, ncol=5,
              dimnames=list(paste0("M2x", 1:7), paste0("M2y", 1:5)))
sm1a <- SparseArray(m1a)
sm1b <- SparseArray(m1b)

rbind(sm1a, sm1b)

## -----
## COMBINING SparseArray OBJECTS WITH 3 DIMENSIONS
## -----

a2a <- array(1:105, dim=c(5, 7, 3),
             dimnames=list(NULL, paste0("A1y", 1:7), NULL))
a2b <- array(1001:1105, dim=c(5, 7, 3),
             dimnames=list(paste0("A2x", 1:5), paste0("A2y", 1:7), NULL))
sa2a <- SparseArray(a2a)
sa2b <- SparseArray(a2b)

abind(sa2a, sa2b)           # same as 'abind(sa2a, sa2b, along=3)'
abind(sa2a, sa2b, rev.along=0) # same as 'abind(sa2a, sa2b, along=4)'

a3a <- array(1:60, dim=c(3, 5, 4),
```

```

      dimnames=list(NULL, paste0("A1y", 1:5), NULL))
a3b <- array(101:240, dim=c(7, 5, 4),
      dimnames=list(paste0("A2x", 1:7), paste0("A2y", 1:5), NULL))
sa3a <- SparseArray(a3a)
sa3b <- SparseArray(a3b)

arbind(sa3a, sa3b) # same as 'abind(sa3a, sa3b, along=1)'

## -----
## Sanity checks
## -----

sm1 <- rbind(sm1a, sm1b)
m1 <- rbind(m1a, m1b)
stopifnot(identical(as.array(sm1), m1), identical(sm1, SparseArray(m1)))

sa2 <- abind(sa2a, sa2b)
stopifnot(identical(sa2, abind(sa2a, sa2b, along=3)))
a2 <- abind(a2a, a2b, along=3)
stopifnot(identical(as.array(sa2), a2), identical(sa2, SparseArray(a2)))

sa2 <- abind(sa2a, sa2b, rev.along=0)
stopifnot(identical(sa2, abind(sa2a, sa2b, along=4)))
a2 <- abind(a2a, a2b, along=4)
stopifnot(identical(as.array(sa2), a2), identical(sa2, SparseArray(a2)))

sa3 <- arbind(sa3a, sa3b)
a3 <- arbind(a3a, a3b)
stopifnot(identical(as.array(sa3), a3), identical(sa3, SparseArray(a3)))

```

---

SparseArray-aperm      *SparseArray transposition*

---

## Description

Transpose a [SparseArray](#) object by permuting its dimensions.

WORK-IN-PROGRESS

## Value

COMING SOON...

## See Also

- [aperm\(\)](#) in base R.
- [SparseArray](#) objects.
- Ordinary [array](#) objects in base R.

**Examples**

```
## COMING SOON...
```

---

SparseArray-Complex-methods  
*'Complex' methods for SparseArray objects*

---

**Description**

WORK-IN-PROGRESS

**Value**

COMING SOON...

**See Also**

- [S4groupGeneric](#) in the **methods** package.
- [SparseArray](#) objects.
- Ordinary [array](#) objects in base R.

**Examples**

```
## COMING SOON...
```

---

SparseArray-dim-tuning  
*Add/drop ineffective dims to/from a SparseArray object*

---

**Description**

The *ineffective dimensions* of an array-like object are its dimensions that have an extent of 1.

Drop all *ineffective dimensions* from [SparseArray](#) object `x` with `drop(x)`.

Add and/or drop arbitrary *ineffective dimensions* to/from [SparseArray](#) object `x` with the `dim()` setter.



## Details

The *ineffective dimensions* of an array-like object are its dimensions that have an extent of 1. For example, for a 1 x 1 x 15 x 1 x 6 array, the *ineffective dimensions* are its 1st, 2nd, and 4th dimensions.

Note that *ineffective dimensions* can be dropped or added from/to an array-like object `x` without changing its length (`prod(dim(x))`) or altering its content.

`drop(x)`: Drop all *ineffective dimensions* from `SparseArray` derivative `x`. If `x` has at most one effective dimension, then the result is returned as an ordinary vector. Otherwise it's returned as a `SparseArray` derivative.

`dim(x) <- value`: Add and/or drop arbitrary *ineffective dimensions* to/from `SparseArray` derivative `x`. `value` must be a vector of dimensions compatible with `dim(x)`, that is, it must preserve all the effective dimensions in their original order.

## See Also

- `drop()` in base R.
- The `dim()` getter and setter in base R.
- `SparseArray` objects.
- Ordinary `array` objects in base R.

## Examples

```
## An array with ineffective 1st and 4th dimensions:
a <- array(0L, dim=c(1, 1, 5, 4, 1, 3))
dimnames(a) <- list(NULL, NULL, letters[1:5], NULL, NULL, LETTERS[1:3])
a[c(1:2, 8, 10, 15:17, 20, 24, 40, 56:60)] <- (1:15)*10L
svt <- SparseArray(a)
dim(svt)

## Drop ineffective dims:
dim(drop(svt)) # the 1st, 2nd, and 5th dimensions were dropped

## Drop some ineffective dims and adds new ones:
svt2 <- svt
dim(svt2) <- c(1, 5, 4, 1, 1, 3, 1)
dim(svt2)

## Sanity check:
stopifnot(identical(as.array(drop(svt)), drop(a)))
a2 <- `dim<-`(a, c(1, 5, 4, 1, 1, 3, 1))
dimnames(a2)[c(2, 6)] <- dimnames(a)[c(3, 6)]
stopifnot(identical(as.array(svt2), a2))
```

---

 SparseArray-Math-methods

*'Math' and 'Math2' methods for SparseArray objects*


---

## Description

[SparseArray](#) derivatives support a *subset* of operations from the `Math` and `Math2` groups. See [?S4groupGeneric](#) in the `methods` package for more information about the `Math` and `Math2` group generics.

### IMPORTANT NOTES:

- Only operations from these groups that preserve sparsity are supported. For example, `sqrt()`, `trunc()`, `log1p()`, and `sin()` are supported, but `cumsum()`, `log()`, `cos()`, or `gamma()` are not.
- Only [SVT\\_SparseArray](#) objects are supported at the moment. Support for [COO\\_SparseArray](#) objects might be added in the future.
- `Math` and `Math2` operations only support [SVT\\_SparseArray](#) objects of `type()` "double" at the moment.

## Value

A [SparseArray](#) derivative of the same dimensions as the input object.

## See Also

- [S4groupGeneric](#) in the `methods` package.
- [SparseArray](#) objects.
- Ordinary `array` objects in base R.

## Examples

```
m <- matrix(0, nrow=15, ncol=6)
m[c(2, 6, 12:17, 22:33, 55, 59:62, 90)] <-
  c(runif(22)*1e4, Inf, -Inf, NA, NaN)
svt <- SparseArray(m)

svt2 <- trunc(sqrt(svt))
svt2

## Sanity check:
m2 <- suppressWarnings(trunc(sqrt(m)))
stopifnot(identical(as.matrix(svt2), m2))
```

---

SparseArray-misc-methods

*Miscellaneous operations on a SparseArray object*

---

## Description

This man page documents various base array operations that are supported by [SparseArray](#) derivatives, and that didn't belong to any of the groups of operations documented in the other man pages of the **SparseArray** package.

Note that only [COO\\_SparseArray](#) objects support these operations at the moment.

## Usage

```
## S4 method for signature 'COO_SparseArray'
is.na(x)

## S4 method for signature 'COO_SparseArray'
is.infinite(x)

## S4 method for signature 'COO_SparseArray'
is.nan(x)

## S4 method for signature 'COO_SparseArray'
tolower(x)

## S4 method for signature 'COO_SparseArray'
toupper(x)

## S4 method for signature 'COO_SparseArray'
nchar(x, type="chars", allowNA=FALSE, keepNA=NA)
```

## Arguments

`x` An [COO\\_SparseArray](#) object.  
`type`, `allowNA`, `keepNA`  
See `?base::nchar` for a description of these arguments.

## Details

More operations will be added in the future. For example [SVT\\_SparseArray](#) objects also need to support `is.na()`, `is.infinite()`, and `is.nan()`.

## Value

See man pages for the corresponding default methods in the **base** package (e.g. `?base::is.na`, `?base::nchar`, etc..) for the value returned by these methods.

**See Also**

- `base::is.na` and `base::is.infinite` in base R.
- `base::tolower` in base R.
- `base::nchar` in base R.
- `SparseArray` objects.
- Ordinary `array` objects in base R.

**Examples**

```
## COMING SOON...
#a <- array(FALSE, dim=5:3)
#nzidx <- c(1:2, 8, 10, 15:17, 20, 24, 40, 56:60)
#a[nzidx] <- TRUE
#coo <- as(a, "COO_SparseArray")
```

---

SparseArray-Ops-methods

*'Ops' methods for SparseArray objects*

---

**Description**

`SparseArray` derivatives support operations from the Arith, Compare, and Logic groups, with some restrictions. All together, these groups are referred to as the Ops group. See `?S4groupGeneric` in the **methods** package for more information about the Ops group generic.

IMPORTANT NOTES:

- Only `SVT_SparseArray` objects are supported at the moment. Support for `COO_SparseArray` objects might be added in the future.
- Arith operations don't support `SVT_SparseArray` objects of `type()` "complex" at the moment.

**Details**

Two forms of operations are supported:

1. Between an `SVT_SparseArray` object `svt` and a single value `y`:

```
svt op y
y op svt
```

The operations from the Arith group that support this form are: `*`, `/`, `^`, `%/%`. Note that, except for `*` (for which both `svt * y` and `y * svt` are supported), single value `y` must be on the right e.g. `svt ^ 3`.

All operations from the Compare group support this form, with single value `y` either on the left or the right. However, there are some operation-dependent restrictions on the value of `y`.

2. Between two `SVT_SparseArray` objects `svt1` and `svt2` of same dimensions (a.k.a. *conformable arrays*):

```
svt1 op svt2
```

The operations from the `Arith` group that support this form are: `+`, `-`, `*`.

The operations from the `Compare` group that support this form are: `!=`, `<`, `>`.

### Value

A [SparseArray](#) derivative of the same dimensions as the input object(s).

### See Also

- [S4groupGeneric](#) in the `methods` package.
- [SparseArray](#) objects.
- Ordinary `array` objects in base R.

### Examples

```
m <- matrix(0L, nrow=15, ncol=6)
m[c(2, 6, 12:17, 22:33, 55, 59:62, 90)] <- 101:126
svt <- SparseArray(m)

## Can be 5x or 10x faster than with a dgCMatrix object on a big
## SVT_SparseMatrix object!
svt2 <- (svt^1.5 + svt)
svt2

## Sanity check:
m2 <- (m^1.5 + m)
stopifnot(identical(as.matrix(svt2), m2))
```

---

SparseArray-subassignment

*SparseArray subassignment*

---

### Description

Like ordinary arrays in base R, [SparseArray](#) derivatives support subassignment via the `[<-` operator.

### See Also

- `[<-` in base R.
- [SparseArray](#) objects.
- Ordinary `array` objects in base R.

**Examples**

```

a <- array(0L, dim=5:3)
a[c(1:2, 8, 10, 15:17, 20, 24, 40, 56:60)] <- (1:15)*10L
svt <- SparseArray(a)
svt

svt[5:3, c(4,2,4), 2:3] <- -99L

## Sanity checks:
a[5:3, c(4,2,4), 2:3] <- -99L
stopifnot(identical(as.array(svt), a), identical(svt, SparseArray(a)))

```

---

SparseArray-subsetting

*Subsetting a SparseArray object*

---

**Description**

Like ordinary arrays in base R, [SparseArray](#) derivatives support subsetting via the single bracket operator (`[]`).

**See Also**

- `[]` in base R.
- `SparseArray::drop` to drop *ineffective dimensions*.
- [SparseArray](#) objects.
- Ordinary `array` objects in base R.

**Examples**

```

a <- array(0L, dim=5:3)
a[c(1:2, 8, 10, 15:17, 20, 24, 40, 56:60)] <- (1:15)*10L
svt <- SparseArray(a)
svt

svt[5:3, c(4,2,4), 2:3]

svt[ , c(4,2,4), 2:3]

svt[ , c(4,2,4), -1]

svt[ , c(4,2,4), 1]

svt2 <- svt[ , c(4,2,4), 1, drop=FALSE]
svt2

## Ineffective dimensions can always be dropped as a separate step:
drop(svt2)

```

```

svt[ , c(4,2,4), integer(0)]

dimnames(a) <- list(letters[1:5], NULL, LETTERS[1:3])
svt <- SparseArray(a)

svt[c("d", "a"), c(4,2,4), "C"]

svt2 <- svt["e", c(4,2,4), , drop=FALSE]
svt2

drop(svt2)

## Sanity checks:
svt2 <- svt[5:3, c(4,2,4), 2:3]
a2 <- a [5:3, c(4,2,4), 2:3]
stopifnot(identical(as.array(svt2), a2), identical(svt2, SparseArray(a2)))
svt2 <- svt[ , c(4,2,4), 2:3]
a2 <- a [ , c(4,2,4), 2:3]
stopifnot(identical(as.array(svt2), a2), identical(svt2, SparseArray(a2)))
svt2 <- svt[ , c(4,2,4), -1]
a2 <- a [ , c(4,2,4), -1]
stopifnot(identical(as.array(svt2), a2), identical(svt2, SparseArray(a2)))
svt2 <- svt[ , c(4,2,4), 1]
a2 <- a [ , c(4,2,4), 1]
stopifnot(identical(as.array(svt2), a2), identical(svt2, SparseArray(a2)))
svt2 <- svt[ , c(4,2,4), 1, drop=FALSE]
a2 <- a [ , c(4,2,4), 1, drop=FALSE]
stopifnot(identical(as.array(svt2), a2), identical(svt2, SparseArray(a2)))
svt2 <- drop(svt2)
a2 <- drop(a2)
stopifnot(identical(as.array(svt2), a2), identical(svt2, SparseArray(a2)))
svt2 <- svt[ , c(4,2,4), integer(0)]
a2 <- a [ , c(4,2,4), integer(0)]
stopifnot(identical(as.array(svt2), a2),
           identical(unname(svt2), unname(SparseArray(a2))))
svt2 <- svt[c("d", "a"), c(4,2,4), "C"]
a2 <- a [c("d", "a"), c(4,2,4), "C"]
stopifnot(identical(as.array(svt2), a2), identical(svt2, SparseArray(a2)))
svt2 <- svt["e", c(4,2,4), , drop=FALSE]
a2 <- a ["e", c(4,2,4), , drop=FALSE]
stopifnot(identical(as.array(svt2), a2), identical(svt2, SparseArray(a2)))
svt2 <- drop(svt2)
a2 <- drop(a2)
stopifnot(identical(as.array(svt2), a2), identical(svt2, SparseArray(a2)))

```

## Description

The **SparseArray** package provides memory-efficient summarization methods for [SparseArray](#) objects. The following methods are supported at the moment: `anyNA()`, `any()`, `all()`, `min()`, `max()`, `range()`, `sum()`, `prod()`, `mean()`, `var()`, `sd()`.

More might be added in the future.

Note that these are *S4 generic functions* defined in base R and in the **BiocGenerics** package, with default methods defined in base R. This man page documents the methods defined for [SparseArray](#) objects.

## Details

All these methods operate *natively* on the [COO\\_SparseArray](#) or [SVT\\_SparseArray](#) representation, for maximum efficiency.

## Value

See man pages for the corresponding default methods in the **base** package (e.g. `?base::range`, `?base::mean`, etc...) for the value returned by these methods.

## See Also

- [SparseArray](#) objects.
- The man pages for the various default methods defined in the **base** package e.g. `base::range`, `base::mean`, `base::anyNA`, etc...

## Examples

```
m0 <- matrix(0L, nrow=6, ncol=4)
m0[c(1:2, 8, 10, 15:17, 24)] <- (1:8)*10L
m0[5, 2] <- NA
svt0 <- as(m0, "SVT_SparseMatrix")
svt0

anyNA(svt0)

range(svt0)

range(svt0, na.rm=TRUE)

sum(svt0, na.rm=TRUE)

sd(svt0, na.rm=TRUE)

## Sanity checks:
stopifnot(
  identical(anyNA(svt0), anyNA(m0)),
  identical(range(svt0), range(m0)),
  identical(range(svt0, na.rm=TRUE), range(m0, na.rm=TRUE)),
  identical(sum(svt0), sum(m0)),
  identical(sum(svt0, na.rm=TRUE), sum(m0, na.rm=TRUE)),
```



```

    all.equal(sd(svt0, na.rm=TRUE), sd(m0, na.rm=TRUE))
  )

```

---

SparseMatrix-mult      *SparseMatrix multiplication and cross-product*

---

### Description

Like ordinary matrices in base R, [SparseMatrix](#) derivatives can be multiplied with the `%%` operator. They also support `crossprod()` and `tcrossprod()`.

### Value

The `%%`, `crossprod()` and `tcrossprod()` methods for [SparseMatrix](#) objects always return an *ordinary* matrix of type() "double".

### Note

Matrix multiplication and cross-product of [SVT\\_SparseMatrix](#) objects are multithreaded. See [set\\_SparseArray\\_nthread](#) for how to control the number of threads.

### See Also

- `%%` and `crossprod` in base R.
- [SparseMatrix](#) objects.
- `S4Arrays::type` in the [S4Arrays](#) package to get the type of the elements of an array-like object.
- Ordinary [matrix](#) objects in base R.

### Examples

```

m1 <- matrix(0L, nrow=15, ncol=6)
m1[c(2, 6, 12:17, 22:33, 55, 59:62, 90)] <- 101:126
svt1 <- as(m1, "SVT_SparseMatrix")

set.seed(333)
svt2 <- poissonSparseMatrix(nrow=6, ncol=7, density=0.2)

svt1 %% svt2
m1   %% svt2

## Unary crossprod() and tcrossprod():
crossprod(svt1)           # same as t(svt1) %% svt1
tcrossprod(svt1)         # same as svt1 %% t(svt1)

## Binary crossprod() and tcrossprod():
crossprod(svt1[1:6, ], svt2) # same as t(svt1[1:6, ]) %% svt2
tcrossprod(svt1, t(svt2))   # same as svt1 %% svt2

```

```
## Sanity checks:
m12 <- m1 %*% as.matrix(svt2)
stopifnot(
  identical(svt1 %*% svt2, m12),
  identical(m1 %*% svt2, m12),
  identical(crossprod(svt1), t(svt1) %*% svt1),
  identical(tcrossprod(svt1), svt1 %*% t(svt1)),
  identical(crossprod(svt1[1:6, ], svt2), t(svt1[1:6, ]) %*% svt2),
  identical(tcrossprod(svt1, t(svt2)), m12)
)
```

---

sparseMatrix-utils      *Internal utilities to handle sparseMatrix derivatives*

---

### Description

The **SparseArray** package defines some utilities to handle sparseMatrix derivatives (e.g. dgCMa-trix and lgCMa-trix objects) from the **Matrix** package. These are for internal use only.

### See Also

- [dgCMa-trix](#) objects implemented in the **Matrix** package.

---

SVT\_SparseArray-class      *SVT\_SparseArray objects*

---

### Description

The SVT\_SparseArray class is a new container for efficient in-memory representation of multidimensional sparse arrays. It uses the *SVT layout* to represent the nonzero multidimensional data internally.

An SVT\_SparseMatrix object is an SVT\_SparseArray object of 2 dimensions.

Note that SVT\_SparseArray and SVT\_SparseMatrix objects replace the older and less efficient [COO\\_SparseArray](#) and [COO\\_SparseMatrix](#) objects.

### Usage

```
## Constructor function:
SVT_SparseArray(x, type=NA)
```

**Arguments**

- x** An ordinary matrix or array, or a dgCMatrix/lgCMatrix object, or any matrix-like or array-like object that supports coercion to SVT\_SparseArray.
- type** A single string specifying the requested type of the object. Normally, the SVT\_SparseArray object returned by the constructor function has the same type() as x but the user can use the type argument to request a different type. Note that doing:
- ```
svt <- SVT_SparseArray(x, type=type)
```
- is equivalent to doing:
- ```
svt <- SVT_SparseArray(x)
type(svt) <- type
```
- but the former is more convenient and will generally be more efficient. Supported types are all R atomic types plus "list".

**Details**

SVT\_SparseArray is a concrete subclass of the [SparseArray](#) virtual class. This makes SVT\_SparseArray objects SparseArray derivatives.

The nonzero data in a SVT\_SparseArray object is stored in a *Sparse Vector Tree*. We'll refer to this internal data representation as the *SVT layout*. See the "SVT layout" section below for more information.

The SVT layout is similar to the CSC layout (compressed, sparse, column-oriented format) used by CsparseMatrix derivatives from the **Matrix** package, like dgCMatrix or lgCMatrix objects, but with the following improvements:

- The SVT layout supports sparse arrays of arbitrary dimensions.
- With the SVT layout, the sparse data can be of any type. Whereas CsparseMatrix derivatives only support sparse data of type "double" or "logical" at the moment.
- The SVT layout imposes no limit on the number of nonzero elements that can be stored. With dgCMatrix/lgCMatrix objects, this number must be  $< 2^{31}$ .
- Overall, the SVT layout allows more efficient operations on SVT\_SparseArray objects.

**Value**

An SVT\_SparseArray or SVT\_SparseMatrix object.

**SVT layout**

An SVT (Sparse Vector Tree) is a tree of depth  $N - 1$  where  $N$  is the number of dimensions of the sparse array.

The leaves in the tree can only be of two kinds: NULL or *leaf vector*. Leaves that are leaf vectors can only be found at the deepest level in the tree (i.e. at depth  $N - 1$ ). All leaves found at a lower depth must be NULLs.

A leaf vector represents a sparse vector of length equal to the first dimension of the sparse array. This is done using a set of offset/value pairs sorted by strictly ascending offset. More precisely, a leaf vector is represented by an ordinary list of 2 parallel vectors:

1. an integer vector of offsets (i.e. 0-based positions);
2. a vector (atomic or list) of nonzero values.

The 2nd vector determines the type of the leaf vector i.e. "double", "integer", "logical", etc... All the leaf vectors in the SVT have the type of the sparse array.

Examples:

- An SVT\_SparseArray object with 1 dimension has its nonzero data stored in an SVT of depth 0. Such SVT is represented by a single "leaf vector".
- An SVT\_SparseArray object with 2 dimensions has its nonzero data stored in an SVT of depth 1. Such SVT is represented by a list of length the extend of the 2nd dimension (number of columns). Each list element is an SVT of depth 0 (as described above), or a NULL if the corresponding column is empty (i.e. has no nonzero data).

For example, the nonzero data of an 8-column sparse matrix will be stored in an SVT that looks like this:

```

.-----list-of-length-8-----.
 /      /      /      |      |      \      \      \
 |      |      |      |      |      |      |      |
leaf  leaf  NULL  leaf  leaf  leaf  leaf  NULL
vector vector          vector vector vector vector

```

The NULL leaves represent the empty columns (i.e. the columns with no nonzero elements).

- An SVT\_SparseArray object with 3 dimensions has its nonzero data stored in an SVT of depth 2. Such SVT is represented by a list of length the extend of the 3rd dimension. Each list element must be an SVT of depth 1 (as described above) that stores the nonzero data of the corresponding 2D slice, or a NULL if the 2D slice is empty (i.e. has no nonzero data).

### See Also

- The [SparseArray](#) class for the virtual parent class of COO\_SparseArray and SVT\_SparseArray.
- S4 classes [dgCMatrix](#) and [lgCMatrix](#) defined in the **Matrix** package, for the de facto standard of sparse matrix representations in the R ecosystem.
- Virtual class [CsparseMatrix](#) defined in the **Matrix** package for the parent class of all classes that use the "CSC layout".
- Ordinary [array](#) objects in base R.

### Examples

```

## -----
## EXAMPLE 1
## -----
m0 <- matrix(0L, nrow=6, ncol=4)
m0[c(1:2, 8, 10, 15:17, 24)] <- (1:8)*10L
m0

svt0 <- as(m0, "SVT_SparseMatrix")
svt0

```

```

## CSC (Compressed sparse column) layout vs SVT layout:

dgcm <- as(m0, "dgCMatrix")
dgcm@x
dgcm@i
dgcm@p

str(svt0)

## -----
## EXAMPLE 2
## -----
m1 <- matrix(rpois(54e6, lambda=0.4), ncol=1200)

## Note that 'SparseArray(m1)' can also be used for this:
svt1 <- SVT_SparseArray(m1)
svt1

dgcm1 <- as(m1, "dgCMatrix")

## Compare type and memory footprint:
type(svt1)
object.size(svt1)
type(dgcm1)
object.size(dgcm1)

## Transpose:
system.time(svt <- t(t(svt1)))
system.time(dgcm <- t(t(dgcm1)))
identical(svt, svt1)
identical(dgcm, dgcm1)

## rbind():
m2 <- matrix(rpois(45e6, lambda=0.4), ncol=1200)
svt2 <- SVT_SparseArray(m2)
dgcm2 <- as(m2, "dgCMatrix")

system.time(rbind(svt1, svt2))
system.time(rbind(dgcm1, dgcm2))

```

---

thread-control

*Number of threads used by SparseArray operations*


---

## Description

Use `get_SparseArray_nthread` or `set_SparseArray_nthread` to get or set the number of threads to use by the multithreaded operations implemented in the **SparseArray** package.

**Usage**

```
get_SparseArray_nthread()
set_SparseArray_nthread(nthread=NULL)
```

**Arguments**

**nthread**            The number of threads to use by multithreaded operations implemented in the **SparseArray** package.

On systems where OpenMP is available, this must be NULL or an integer value  $\geq 1$ . When NULL (the default), a "reasonable" value will be used that never exceeds one third of the number of logical cpus available on the machine.

On systems where OpenMP is not available, the supplied **nthread** is ignored and `set_SparseArray_nthread()` is a no-op.

**Details**

Multithreaded operations in the **SparseArray** package are implemented in C with OpenMP (<https://www.openmp.org/>).

Note that OpenMP is not available on all systems. On systems where it's available, `get_SparseArray_nthread()` is guaranteed to return a value  $\geq 1$ . On systems where it's not available (e.g. macOS), `get_SparseArray_nthread()` returns 0 and `set_SparseArray_nthread()` is a no-op.

**IMPORTANT:** The portable way to disable multithreading is by calling `set_SparseArray_nthread(1)`, NOT `set_SparseArray_nthread(0)` (the latter returns an error on systems where OpenMP is available).

**Value**

`get_SparseArray_nthread()` returns an integer value  $\geq 1$  on systems where OpenMP is available, and 0 on systems where it's not.

`set_SparseArray_nthread()` returns the *previous* **nthread** value, that is, the value returned by `get_SparseArray_nthread()` before the call to `set_SparseArray_nthread()`. Note that the value is returned invisibly.

**See Also**

- [SparseMatrix\\_mult](#) for SparseMatrix multiplication and cross-product.
- [matrixStats\\_methods](#) for SparseArray col/row summarization methods.
- [SparseArray](#) objects.

**Examples**

```
get_SparseArray_nthread()

if (get_SparseArray_nthread() != 0) { # multithreading is available
  svt1 <- poissonSparseMatrix(77000L, 15000L, density=0.01)

  ## 'user' time is typically N x 'elapsed' time where N is roughly the
  ## number of threads that was effectively used:
```

```
system.time(cv1 <- colVars(svt1))

svt2 <- poissonSparseMatrix(77000L, 300L, density=0.3) * 0.77
system.time(cp12 <- crossprod(svt1, svt2))

prev_nthread <- set_SparseArray_nthread(1) # disable multithreading
system.time(cv1 <- colVars(svt1))
system.time(cp12 <- crossprod(svt1, svt2))

## Restore previous 'nthread' value:
set_SparseArray_nthread(prev_nthread)
}
```

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