

RcppArmadillo: Sparse Matrix Support

Binxiang Ni¹, Dmitry Selivanov¹, Dirk Eddelbuettel^c, and Qiang Kou^d

^a<https://github.com/binxiangni>; ^b<https://github.com/dselivanov>; ^c<http://dirk.eddelbuettel.com>; ^d<https://github.com/thirdwing>

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1. Introduction

The documentation is intended for the convenience of RcppArmadillo sparse matrix users based on integration of the documentation of library **Matrix** (Bates and Maechler, 2017) and **Armadillo** (Sanderson, 2010; Sanderson and Curtin, 2016).

There are 31 types of sparse matrices in the **Matrix** package that can be used directly. But for now, only 12 of them are supported in RcppArmadillo: `dgCMatrix`, `dtCMatrix`, `dsCMatrix`, `dgTMatrix`, `dtTMatrix`, `dsTMatrix`, `dgRMatrix`, `dtRMatrix`, `dsRMatrix`, `indMatrix`, `pMatrix`, `ddiMatrix`.

In the **Armadillo** library, sparse matrix content is currently stored as **CSC** format. Such kind of format is quite similar to numeric column-oriented sparse matrix in the library **Matrix** (including `dgCMatrix`, `dtCMatrix` and `dsCMatrix`). When a sparse matrix from the package **Matrix** is passed through the **RcppArmadillo** package (Eddelbuettel and Sanderson, 2014; Eddelbuettel *et al.*, 2017), it will be converted or mapped to CSC format, then undertaken operations on, and finally output as a `dgCMatrix` in R.

In what follows, we will always assume this common header:

```
#include <RcppArmadillo.h>
// [[Rcpp::depends(RcppArmadillo)]]

using namespace Rcpp;
using namespace arma;
```

but not generally show it.

2. Sparse Matrix

2.1. dgCMatrix.

Synopsis.

- Description: general column-oriented numeric sparse matrix.
- Constructor
 - `new("dgCMatrix", ...)`
 - `Matrix(*, sparse = TRUE)`
 - `sparseMatrix()`
- Coercion
 - `as(*, "CsparseMatrix")`
 - `as(*, "dgCMatrix")`

C++ Code.

```
// [[Rcpp::export]]
sp_mat sqrt_(sp_mat X) {
  return sqrt(X);
}
```

R Code.

```
R> i <- c(1,3:8)
R> j <- c(2,9,6:10)
R> x <- 7 * (1:7)
R> A <- sparseMatrix(i, j, x = x)
R> sqrt_(A)
8 x 10 sparse Matrix of class "dgCMatrix"

[1,] . 2.645751 . . . . .
[2,] . . . . . . . . . .
[3,] . . . . . . 3.741657 .
[4,] . . . . 4.582576 . . . .
[5,] . . . . . 5.291503 . . . .
[6,] . . . . . . 5.91608 . . .
[7,] . . . . . . . 6.480741 .
[8,] . . . . . . . . . 7
```

2.2. dtCMatrix.

Synopsis.

- Description: triangular column-oriented numeric sparse matrix.
- Constructor
 - `new("dtCMatrix", ...)`
 - `Matrix(*, sparse = TRUE)`
 - `sparseMatrix(*, triangular=TRUE)`
- Coercion
 - `as(*, "triangularMatrix")`
 - `as(*, "dtCMatrix")`

C++ Code.

```
// [[Rcpp::export]]
sp_mat symmatl_(sp_mat X) {
  return symmatl(X);
}
```

R Code.

```
R> dtC <- 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))
R> symmatl_(dtC)
5 x 5 sparse Matrix of class "dtCMatrix"

[1,] 10 . 1 . 3
[2,] . 10 . 1 .
[3,] 1 . 10 . 1
[4,] . 1 . 10 .
[5,] 3 . 1 . 10
```

2.3. dsCMatrix.

Synopsis.

- Description: symmetric column-oriented numeric sparse matrix.
- Constructor
 - new("dsCMatrix", ...)
 - Matrix(*, sparse = TRUE)
 - sparseMatrix(*, symmetric = TRUE)
- Coercion
 - as(*, "symmetricMatrix")
 - as(*, "dsCMatrix")

C++ Code.

```
// [[Rcpp::export]]
sp_mat trimatu_(sp_mat X) {
  return trimatu(X);
}
```

R Code.

```
R> i <- c(1,3:8)
R> j <- c(2,9,6:10)
R> x <- 7 * (1:7)
R> dsC <- sparseMatrix(i, j, x = x, symmetric = TRUE)
R> trimatu_(dsC)
10 x 10 sparse Matrix of class "dgCMatrix"

[1,] . 7 . . . . . . .
[2,] . . . . . . . . .
```

```
[3,] . . . . . . . . . 14 .
[4,] . . . . . 21 . . . . .
[5,] . . . . . . 28 . . . . .
[6,] . . . . . . . 35 . . . . .
[7,] . . . . . . . . 42 . . . . .
[8,] . . . . . . . . . 49 . . . . .
[9,] . . . . . . . . . . . . . . .
[10,] . . . . . . . . . . . . . . .
```

2.4. dgTMatrix.

Synopsis.

- Description: general numeric sparse matrix in triplet form.
- Constructor
 - `new("dgTMatrix", ...)`
 - `sparseMatrix(*, giveCsparse=FALSE)`
 - `spMatrix()`
- Coercion
 - `as(*, "TsparseMatrix")`
 - `as(*, "dgTMatrix")`

C++ Code.

```
// [[Rcpp::export]]
sp_mat multiply(sp_mat A, sp_mat B) {
  return A * B;
}

// [[Rcpp::export]]
sp_mat trans_(sp_mat X) {
  return trans(X);
}

// [[Rcpp::export]]
int trace_(sp_mat X) {
  return trace(X);
}
```

R Code.

```
R> dgT <- new("dgTMatrix",
             i = c(1L,1L,0L,3L,3L),
             j = c(2L,2L,4L,0L,0L),
             x=10*1:5, Dim=4:5)
R> dgT_t <- trans_(dgT)
R> prod <- multiply(dgT, dgT_t)
R> trace_(prod)
[1] 9900
```

2.5. dtTMatrix.

Synopsis.

- Description: triangular numeric sparse matrix in triplet form.
- Constructor
 - `new("dtTMatrix", ...)`
 - `sparseMatrix(*, triangular=TRUE, giveCsparse=FALSE)`
- Coercion
 - `as(*, "triangularMatrix")`
 - `as(*, "dtTMatrix")`

C++ Code.

```
// [[Rcpp::export]]
sp_mat diag_ones(sp_mat X) {
  X.diag().ones();
  return X;
}
```

R Code.

```
R> dtT <- new("dtTMatrix", x= c(3,7),
             i= 0:1, j=3:2, Dim= as.integer(c(4,4)))
R> diag_ones(dtT)
4 x 4 sparse Matrix of class "dgCMatrix"

[1,] 1 . . 3
[2,] . 1 7 .
[3,] . . 1 .
[4,] . . . 1
```

2.6. dsTMatrix.

Synopsis.

- Description: symmetric numeric sparse matrix in triplet form.
- Constructor
 - `new("dsTMatrix", ...)`
 - `sparseMatrix(*, symmetric=TRUE, giveCsparse=FALSE)`
- Coercion
 - `as(*, "symmetricMatrix")`
 - `as(*, "dsTMatrix")`

C++ Code.

```
// [[Rcpp::export]]
int trace_(sp_mat X) {
  return trace(X);
}
```

R Code.

```
R> mm <- Matrix(toeplitz(c(10, 0, 1, 0, 3)),
                sparse = TRUE)
R> mT <- as(mm, "dgTMatrix")
R> dsT <- as(mT, "symmetricMatrix")
R> trace_(dsT)
[1] 50
```

2.7. dgRMatrix.

Synopsis.

- Description: general row-oriented numeric sparse matrix.
- Constructor
 - new("dgRMatrix", ...)
- Coercion
 - as(*, "RsparseMatrix")
 - as(*, "dgRMatrix")

C++ Code.

```
// [[Rcpp::export]]
sp_mat square_(sp_mat X) {
  return square(X);
}
```

R Code.

```
R> dgR <- new("dgRMatrix", j=c(0L,2L,1L,3L),
             p=c(0L,2L,3L,3L,4L),
             x=c(3,1,2,1),
             Dim=rep(4L,2))
R> square_(dgR)
4 x 4 sparse Matrix of class "dgCMatrix"

[1,] 9 . 1 .
[2,] . 4 . .
[3,] . . . .
[4,] . . . 1
```

2.8. dtRMatrix.

Synopsis.

- Description: triangular row-oriented numeric sparse matrix.
- Constructor
 - new("dtRMatrix", ...)

C++ Code.

```
// [[Rcpp::export]]
sp_mat repmat_(sp_mat X, int i, int j) {
  return repmat(X, i, j);
}
```

R Code.

```
R> dtR <- new("dtRMatrix", Dim = c(2L,2L),
             x = c(5, 1:2), p = c(0L,2:3), j= c(0:1,1L))
R> repmat_(dtR, 2, 2)
4 x 4 sparse Matrix of class "dgCMatrix"

[1,] 5 1 5 1
[2,] . 2 . 2
[3,] 5 1 5 1
[4,] . 2 . 2
```

2.9. dsRMatrix.

Synopsis.

- Description: symmetric row-oriented numeric sparse matrix.
- Constructor
 - new("dsRMatrix", ...)
- Coercion
 - as("dsCMatrix", "dsRMatrix")

C++ Code.

```
// [[Rcpp::export]]
sp_mat sign_(sp_mat X) {
  return sign(X);
}
```

R Code.

```
R> dsR <- new("dsRMatrix", Dim = c(2L,2L),
             x = c(-3,1), j = c(1L,1L), p = 0:2)
R> sign_(dsR)
2 x 2 sparse Matrix of class "dgCMatrix"

[1,] . -1
[2,] -1 1
```

2.10. indMatrix.

Synopsis.

- Description: index matrix.
- Constructor
 - new("indMatrix", ...)

- Coercion
 - `as(*, "indMatrix")`

C++ Code.

```
// [[Rcpp::export]]
sp_mat multiply(sp_mat A, sp_mat B) {
  return A * B;
}
```

R Code.

```
R> ind <- as(2:4, "indMatrix")
R> dgT <- new("dgTMatrix",
             i = c(1L,1L,0L,3L,3L),
             j = c(2L,2L,4L,0L,0L),
             x=10*1:5, Dim=4:5)
R> multiply(ind, dgT)
3 x 5 sparse Matrix of class "dgCMatrix"

[1,] . . 30 . .
[2,] . . . . .
[3,] 90 . . . .
```

2.11. pMatrix.

Synopsis.

- Description: permutation matrix.
- Constructor
 - `new("pMatrix", ...)`
- Coercion
 - `as(*, "pMatrix")`

C++ Code.

```
// [[Rcpp::export]]
sp_mat multiply(sp_mat A, sp_mat B) {
  return A * B;
}
```

R Code.

```
R> pM <- as(c(2,3,1,4), "pMatrix")
R> dgT <- new("dgTMatrix",
             i = c(1L,1L,0L,3L,3L),
             j = c(2L,2L,4L,0L,0L),
             x=10*1:5, Dim=4:5)
R> multiply(pM, dgT)
4 x 5 sparse Matrix of class "dgCMatrix"

[1,] . . 30 . .
[2,] . . . . .
```


References

- Bates D, Maechler M (2017). *Matrix: Sparse and Dense Matrix Classes and Methods*. R package version 1.2-11, URL <http://CRAN.R-Project.org/package=Matrix>.
- Eddelbuettel D, François R, Bates D, Ni B (2017). *RcppArmadillo: Rcpp integration for Armadillo templated linear algebra library*. R package version 0.7.960.1.2, URL <http://CRAN.R-Project.org/package=RcppArmadillo>.
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- Sanderson C (2010). "Armadillo: An open source C++ Algebra Library for Fast Prototyping and Computationally Intensive Experiments." *Technical report*, NICTA. URL <http://arma.sf.net>.
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