RcppArmadillo: Sparse Matrix Support

Binxiang Ni[1], **Dmitriy Selivanov**[1], **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

This version was compiled on February 18, 2025

Contents

1. Introduction

The documentation is intended for the convenience of RcppArmadillo sparse matrix users based on integration of the documentation of library Matrix (Bates *et al.*, 2024) 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.*, 2024), it will be converted or mapped to CSC format, then undertaken operations on, and finally ouput as a `dgCMatrix` in R.

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

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

but do not generally show it. We recommend explicitly prefixing namespaces with `Rcpp::` or `arma::` as appropriate.

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]]
arma::sp_mat sqrt_(arma::sp_mat X) {
  return arma::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]]
arma::sp_mat symmatl_(arma::sp_mat X) {
  return arma::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]]
arma::sp_mat trimatu_(arma::sp_mat X) {
  return arma::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]]
arma::sp_mat multiply(arma::sp_mat A, arma::sp_mat B) {
  return A * B;
}

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

// [[Rcpp::export]]
int trace_(arma::sp_mat X) {
  return arma::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", ...)`
  - `code{sparseMatrix(*, triangular=TRUE, giveCsparse=FALSE)`
- Coercion
  - `as(*, "triangularMatrix")`
  - `as(*, "dtTMatrix")`

C++ Code.

```
// [[Rcpp::export]]
arma::sp_mat diag_ones(arma::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_(arma::sp_mat X) {
  return arma::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(*, "dgRatrix")

C++ Code.

```
// [[Rcpp::export]]
arma::sp_mat square_(arma::sp_mat X) {
  return arma::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]]
arma::sp_mat repmat_(arma::sp_mat X, int i, int j) {
  return arma::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]]
arma::sp_mat sign_(arma::sp_mat X) {
  return arma::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]]
arma::sp_mat multiply(arma::sp_mat A, arma::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]]
arma::sp_mat multiply(arma::sp_mat A, arma::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,]  . .  . .  .
[3,]  . .  . . 30
[4,] 90 .  . .  .
```

2.12. ddiMatrix.

Synopsis.

- Description: numeric diagonal Matrix.
- Constructor
  - `new("ddiMatrix", ...)`
  - `Diagonal(*)`

C++ Code.

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

R Code.

```
R> ddi <- Diagonal(4)
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> multiply(ddi, dgR)
4 x 4 sparse Matrix of class "dgCMatrix"

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

References

Bates D, Maechler M, Jagan M (2024). ***Matrix***: *Sparse and Dense Matrix Classes and Methods*. doi:10.32614/CRAN.package.Matrix. R package version 1.7-1, URL http://CRAN.R-Project.org/package=Matrix.

Eddelbuettel D, Francois R, Bates D, Ni B, Sanderson C (2024). ***RcppArmadillo***: *'Rcpp' Integration for the 'Armadillo' Templated Linear Algebra Library*. doi:10.32614/CRAN.package.RcppArmadillo. R package version 14.2.2-1, URL http://CRAN.R-Project.org/package=RcppArmadillo.

Eddelbuettel D, Sanderson C (2014). "RcppArmadillo: Accelerating R with high-performance C++ linear algebra." *Computational Statistics and Data Analysis*, **71**, 1054–1063. doi:10.1016/j.csda.2013.02.005. URL http://dx.doi.org/10.1016/j.csda.2013.02.005.

Sanderson C (2010). "Armadillo: An open source C++ Algebra Library for Fast Prototyping and Computationally Intensive Experiments." *Technical report*, NICTA. URL http://arma.sourceforge.net.

Sanderson C, Curtin R (2016). "Armadillo: A Template-Based C++ Library for Linear Algebra." *JOSS*, **1**(2). doi:10.21105/joss.00026. URL http://dx.doi.org/10.21105/joss.00026.