

# The `bigalgebra` Package

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## 1 Introduction

The `bigalgebra` package provides arithmetic functions for double-precision valued “Big Matrices” defined by the `bigmemory` package. Infix arithmetic operators are overloaded to use `bigalgebra` functions, resulting in familiar syntax. Operations with mixed `big.matrix` and standard R numeric arguments are supported.

The package may be installed to use the native R basic linear algebra subroutine (BLAS) library (the default case), or to use a reference BLAS library configured with large index support.

When configured with large index support, the package supports operations on matrices with indices of up to about  $2^{52}$  in each dimension. Note that the usual R limit constrains objects to less than  $2^{31}$  total entries in an entire object. The package also supports computations on arrays that are larger than available RAM using `bigmemory`’s file-backed big matrix objects.

## 2 Installation

The package uses the native R linear algebra libraries (BLAS) by default to simplify installation. Operations are limited to vectors of at most  $2^{31} - 1$  elements and matrices of at most  $2^{31} - 1$  rows and  $2^{31} - 1$  columns. (Note the difference with standard R matrices, which are limited to at most  $2^{31} - 1$  total elements.) The following code block illustrates standard command-line installation of the source package:

```
R CMD INSTALL bigalgebra_0.8.1.tar.gz
```

## 2.1 Installation with Reference BLAS (with large index support)

The default installation ships with a subset of the reference BLAS and LAPACK libraries available from Netlib<sup>1</sup> compiled at installation time with support for large indices. But, the libraries are not tuned for performance. Enabling large indices supports operations on vectors and matrices with up to  $2^{52} - 1$  elements in any dimension.

Enabling the Netlib BLAS with large integer support requires installation using the `bigalgebra` source package from the command line, and is enabled by setting the environment variable `REFBLAS=1`, for example:

```
REFBLAS=1 R CMD INSTALL bigalgebra_0.8.1.tar.gz
```

The package decorates BLAS function names in a way that will not interfere with native R BLAS symbols. Reference BLAS performance (speed) will generally be worse than the native R BLAS performance. Only use the reference BLAS if you really need to work with vectors longer than  $2^{31} - 1$ .

## 3 Using the package

The `bigalgebra` package is simple to use. Load the package with:

```
> library("bigalgebra")
```

Once loaded, arithmetic functions are defined for `big.matrix`-class objects. Note that element-wise operations (like Hadamard products), and operations that recycle values are not supported.

The following listing shows a few simple examples.

```
> library("bigalgebra")
> set.seed(1)
> A <- matrix(rnorm(4), nrow=2)
> a <- as.big.matrix(A)      # A tiny, square, big.matrix
> b <- a %*% a               # returns an "anonymous" big.matrix
> c <- a + a                 # another big.matrix result
> d <- 2 * a                 # Mixing scalars and big.matrix arguments
> d <- a * 2                 # scalar multiplication commutes
> f <- a %*% A               # Mixing big.marix and matrix arguments
> g <- a %*% a - b          # Chain of operations
```

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<sup>1</sup> <http://netlib.org>

### 3.1 Returned values

The package returns a new `big.matrix` object for operations involving only `big.matrix` objects.

Operations that involve a mixture of standard R matrices, vectors, or scalars, and a `big.matrix` may return either an R matrix or a `big.matrix` depending on the setting of the package option `bigalgebra.mixed_arithmetic_returns_R_matrix`. The default value of this option is `TRUE`, which means that operations on mixed-class arguments will allocate and return a standard R matrix or vector. Set the option to `FALSE` to return results of operations on mixed matrices as new `big.matrix` objects.

```
# To obtain results as R matrices, set (the default):
options(bigalgebra.mixed_arithmetic_returns_R_matrix=TRUE)
# Here is a tiny example:
> set.seed(1)
> A <- matrix(rnorm(6), nrow=3)
> a <- as.big.matrix(A)
> a %*% t(A)      # Returns an R matrix
      [,1]      [,2]      [,3]
[1,] 2.9373652 0.4106134 -0.7853947
[2,] 0.4106134 0.1423002 -0.4238083
[3,] -0.7853947 -0.4238083 1.3714435

# To obtain results as big.matrices, set:
> options(bigalgebra.mixed_arithmetic_returns_R_matrix=FALSE)
> a %*% t(A)      # Now returns a new big.matrix (your pointer address will vary)
An object of class "big.matrix"
Slot "address":
<pointer: 0x1d101b0>
```

### 3.2 Garbage collection of anonymously-defined big matrices

Some operations performed by the `bigalgebra` package return “anonymously” allocated `big.matrix` objects. Such objects are backed by a temporary file defined by the package options `options("bigalgebra.tempdir")` and `options("bigalgebra.temp_pattern")`. These big matrices are ephemeral—their backing and descriptor files are unlinked when the corresponding R object is de-allocated by the garbage collector.

You may explicitly observe creation and removal of temporary backing files by setting the option:

```
options(bigalgebra.DEBUG=TRUE)
```

### 3.3 A practical example

We illustrate using the `bigalgebra` package together with the `irlba` package to compute a few singular values and associated singular vectors of a large, dense matrix.

The `irlba` package<sup>2</sup> (implicitly restarted Lanczos bidiagonalization algorithm) is an R implementation of a state of the art method for efficiently computing a few singular values and singular vectors of a matrix.

The `irlba` function allows users to supply a function for computing the product of a matrix or its transpose with a vector. We take advantage of this function to avoid explicitly forming the transpose of the (potentially large) `big.matrix`.

```
> library("bigalgebra")
> library("irlba")

> # Define an efficient matrix/transpose product:
> matmul <- function(A, x, transpose=FALSE)
+ {
+   if(transpose)
+     return(t( t(x) %*% A)) # i.e., t(A) %*% x
+   return (A %*% x)
+ }

# Compute a small example and compare with other methods:
> set.seed(1)
> A <- matrix(rnorm(100),10)
> a <- as.big.matrix(A)

# Compute with irlba using a big.matrix:
> La <- irlba(a, nu=2, nv=2, matmul=matmul)

# Compute with irlba using a standard matrix:
> LA <- irlba(A, nu=2, nv=2, matmul=matmul)

# Compute with svd using a standard matrix:
> S <- svd(A, nu=2, nv=2)

> rbind(La$d, LA$d, S$d[1:2])
      [,1]      [,2]
[1,] 5.154081 4.816501
```

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<sup>2</sup> <http://cran.r-project.org/web/packages/irlba/index.html>

```
[2,] 5.154081 4.816501  
[3,] 5.154081 4.816501
```

Note that the singular vectors are unique up to sign (that is, they may have different signs between the answers). Also note that we could use the same `matmul` function with both `big.matrix` and standard matrix arguments.

This simple example can be used to efficiently compute a few singular values and vectors of very large `big.matrix` objects.

### 3.4 Large-index support

The following simple example applies if the package was installed with optional large index support as outlined in Section 2. The example sums two vectors with  $2^{31}$  entries, larger than can be indexed by standard R operations. Note that the output vector  $y$  will consume approximately 16 GB of disk space.

```
> library("bigalgebra")  
> x <- big.matrix(nrow=2^31, ncol=1, type="double", backingfile="x")  
> y <- big.matrix(nrow=2^31, ncol=1, type="double", backingfile="y")  
> x[5,1] <- 5  
> y[5,1] <- 5  
> z <- x + y  
> print(z[1:10,])  
[1] 0 0 0 0 10 0 0 0 0 0
```

We remark that file-backed big matrices are block-sparse—that is they allocate space for their values in blocks (usually equal to the operating system kernel page size). Only blocks containing values are allocated. Thus, the `x` and `y` matrices in the above example each only consume one page of storage space on disk.