

# Package ‘GPUmatrix’

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**Type** Package

**Title** Basic Linear Algebra with GPU

**Version** 1.0.1

**Description** GPUs are great resources for data analysis, especially in statistics and linear algebra. Unfortunately, very few packages connect R to the GPU, and none of them are transparent enough to run the computations on the GPU without substantial changes to the code. The maintenance of these packages is cumbersome: several of the earlier attempts have been removed from their respective repositories. It would be desirable to have a properly maintained R package that takes advantage of the GPU with minimal changes to the existing code. We have developed the GPUmatrix package (available on CRAN). GPUmatrix mimics the behavior of the Matrix package and extends R to use the GPU for computations. It includes single(FP32) and double(FP64) precision data types, and provides support for sparse matrices. It is easy to learn, and requires very few code changes to perform the operations on the GPU. GPUmatrix relies on either the Torch or Tensorflow R packages to perform the GPU operations. We have demonstrated its usefulness for several statistical applications and machine learning applications: non-negative matrix factorization, logistic regression and general linear models. We have also included a comparison of GPU and CPU performance on different matrix operations.

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**R topics documented:**

aperm . . . . .	2
apply . . . . .	3
as_methods . . . . .	5
cbind_rbind_methods . . . . .	7
concatenate_gpu.matrix . . . . .	8
cor_cov . . . . .	10
density . . . . .	12
det . . . . .	14
diag . . . . .	16
dim_and_names . . . . .	17
dist . . . . .	19
expmGPU . . . . .	21
extract_gpu.matrix . . . . .	22
fft . . . . .	24
gpu.matrix . . . . .	26
gpu.matrix-class . . . . .	29
GPUglm . . . . .	30
installTorch . . . . .	34
kroneker . . . . .	34
LR_GradientConjugate_gpumatrix . . . . .	35
matrix-product . . . . .	37
matrix_decomposition . . . . .	39
matrix_general_operators_methods . . . . .	41
matrix_ranges . . . . .	42
NMFgpumatrix . . . . .	46
power_of_a_matrix . . . . .	48
qr_decomposition . . . . .	49
round . . . . .	52
solve_gpu.matrix . . . . .	53
sort . . . . .	55
type of gpu.matrix . . . . .	56
<b>Index</b>	<b>59</b>

---

aperm

*Array Transposition*


---

**Description**

t returns the transpose of a gpu.matrix-class object.

**Usage**

```
## S4 method for signature 'gpu.matrix.tensorflow'  
t(x)  
## S4 method for signature 'gpu.matrix.torch'  
t(x)
```

**Arguments**

x                    a `gpu.matrix` to be transposed.

**Value**

It returns a transposed version of a. The output is also a `gpu.matrix` class object.

**See Also**

For more information: [t](#).

**Examples**

```
## Not run:  
  
a <- gpu.matrix(1:9,nrow=3,ncol=3)  
t(a) #transpose of a.  
  
## End(Not run)
```

---

apply

*Apply Functions over 'gpu.matrix-class' margins*

---

**Description**

This function mimics the 'base' function 'apply' to operate on `gpu.matrix`-class objects: It returns a vector or a list of values obtained by applying a function to margins of a `GPUmatrix`.

**Usage**

```
## S4 method for signature 'gpu.matrix.tensorflow'  
apply(X, MARGIN, FUN, ..., simplify)  
## S4 method for signature 'gpu.matrix.torch'  
apply(X, MARGIN, FUN, ..., simplify)
```

**Arguments**

X	a <code>gpu.matrix</code> object.
MARGIN	1 for rows and 2 for columns.
FUN	function to be applied in the operation.
...	general additional parameters. Optional arguments to FUN.
simplify	a logical indicating whether results should be simplified if possible. Note that some methods that can be simplified when working with 'matrix' objects may not always be simplified for <code>gpu.matrix</code> objects. See details.

**Details**

FUN is found by a call to `match.fun` as done in the base function `apply`. Internally, `apply` will use the functions implemented to work with objects from the GPUmatrix library. If the input `gpu.matrix`-class object(s) are stored on the GPU, then the operations will be performed on the GPU. See `gpu.matrix`.

As in `apply`, the arguments in ... cannot have the same name as any of the other arguments to ensure possible errors.

The parameter `simplify` indicates whether the result should be simplified if possible. If the called FUN returns a `gpu.matrix`-class object, the result cannot be simplified. In these cases, the parameter `simplify` will work as if it was set to `FALSE` and the following warning message will be returned: "If the function applied to the GPU matrix returns a tensor or another GPU matrix, then the 'simplify' argument will always be `FALSE`."

**Value**

The results of mimics the base function `apply`.

Each call to FUN will return a vector of length n. If `simplify` is `TRUE` and the result can be simplified, then `apply` will return a numeric vector of dimension `c(n, dim(x)[MARGIN])` if `n > 1`. If `n = 1`, `apply` will return a numeric vector of length `dim(x)[MARGIN]`.

If `simplify` is `FALSE`, `apply` will return a list of length `dim(x)[MARGIN]`.

Note that if `simplify` is `TRUE` and the result of FUN is an object of class `gpu.matrix`, then the result cannot be simplified, so it will return a list of length `dim(x)[MARGIN]` and each element of this list will be of class `gpu.matrix`.

For more details see `apply`

**See Also**

For more information see: `apply`

**Examples**

```
if(installTorch){
  a <- gpu.matrix(rnorm(9),3,3)
```

```

    apply(a, 1, mean) #computes the mean of each row
    apply(a, 2, mean) #computes the mean of each column
}

```

---

as\_methods

*as\_methods*


---

### Description

These functions mimic the 'base' functions of R that have the same name to operate on `gpu.matrix`-class objects:

Function `as.matrix` attempts to turn its argument into a matrix. Function `as.list` attempts to turn its argument into a list. Function `as.numeric` attempts to turn its argument into a numeric. Function `as.array` attempts to turn its argument into an array. Function `as.vector` attempts to turn its argument into a vector. Function `is.numeric` is a general test of an object being interpretable as numbers.

### Usage

```

## S4 method for signature 'gpu.matrix.tensorflow'
as.array(x,...)
## S4 method for signature 'gpu.matrix.torch'
as.array(x,...)
## S4 method for signature 'gpu.matrix.tensorflow'
as.list(x,...)
## S4 method for signature 'gpu.matrix.torch'
as.list(x,...)
## S4 method for signature 'gpu.matrix.tensorflow'
as.matrix(x,...)
## S4 method for signature 'gpu.matrix.torch'
as.matrix(x,...)
## S4 method for signature 'gpu.matrix.tensorflow'
as.numeric(x,...)
## S4 method for signature 'gpu.matrix.torch'
as.numeric(x,...)
## S4 method for signature 'gpu.matrix.tensorflow'
as.vector(x,mode)
## S4 method for signature 'gpu.matrix.torch'
as.vector(x,mode)
## S4 method for signature 'gpu.matrix.torch'
is.numeric(x)

```

```
## S4 method for signature 'gpu.matrix.tensorflow'
is.numeric(x)
```

### Arguments

`x` a `gpu.matrix` object.

`...` (generalized) vectors or matrices. These can be given as named arguments.

`mode` Argument for `as.vector`. It mimics the argument of the same name of the base function `as.vector`: character string naming an atomic mode or "list" or "expression" or (except for vector) "any".

### Details

Note that, if the input is a `gpu.matrix` with complex numbers: the function `is.numeric` will return `FALSE`, and the function `as.numeric` will only returns the real part and the following warning message: "In `asMethod(object)`: imaginary parts discarded in coercion".

The parameter `mode` of the function `as.vector` determines the storage mode of the result. For more details see [typeof](#).

### Value

Given a `gpu.matrix`-class object:

Function `as.matrix` turns the input `gpu.matrix` to a 'matrix' object.

Function `as.list` turns the input `gpu.matrix` into a list.

Function `as.numeric` turns the input `gpu.matrix` into a numeric vector.

Function `as.array` turns the input `gpu.matrix` into an array (Since the `gpu.matrix` objects are always two-dimensional, this function is equivalent to `as.matrix`).

Function `as.vector` turns the input `gpu.matrix` into a vector.

Function `is.numeric` returns `TRUE` or `FALSE` if input can be interpretable as numbers.

### See Also

[numeric](#), [array](#), [list](#), [matrix](#),

### Examples

```
## Not run:
a <- gpu.matrix(c(rnorm(8), 2+1i), nrow=3, ncol=3)
as.array(a)
as.list(a)
as.matrix(a)
as.numeric(a)
is.numeric(a)
as.character(a)
as.vector(a, mode = "list")
as.vector(a, mode = "character")
```

```

as.vector(a,mode = "logical")
as.vector(a,mode = "integer")
as.vector(a,mode = "double")
as.vector(a,mode = "complex")
as.vector(a,mode = "raw")

```

```
## End(Not run)
```

---

```
cbind_rbind_methods  cbind_rbind_methods
```

---

## Description

Mimics the 'base' functions 'cbind' and 'rbind' to operate on `gpu.matrix` objects. The 'base' functions 'cbind' and 'rbind' internally call the methods `cbind2` and `rbind2`.

Therefore, ss done in `cbind2` of the package 'Matrix', we have defined in 'GPUmatrix' the methods `cbind2` and `rbind2` to operate on `gpu.matrix` objects too.

## Usage

```

## S4 method for signature 'ANY,gpu.matrix.tensorflow'
cbind2(x,y)
## S4 method for signature 'ANY,gpu.matrix.torch'
rbind2(x,y)
## S4 method for signature 'gpu.matrix.tensorflow,ANY'
cbind2(x,y,...)
## S4 method for signature 'gpu.matrix.torch,ANY'
rbind2(x,y)

```

## Arguments

`x,y` a `gpu.matrix` object or any other matrix class.  
`...` (generalized) vectors or matrices. These can be given as named arguments.

## Value

The result of using these functions is equivalent to using the basic `cbind` and `rbind` functions. For more details see `cbind`.

Note that if one of the input values is a `gpu.matrix`-class object, then the output will also be a `gpu.matrix`-class object.

The data type of the values of the resulting `gpu.matrix`-class object (corresponding to the `dtype` parameter of the `gpu.matrix` function) is the one that allows the integration of all input values.

That is, if you call `cbind(a,b)` where `a` is a `gpu.matrix`-class object with values of "int32" and `b` is a `gpu.matrix`-class with values of "float64", the result will be a `gpu.matrix`-class with values of "float64".

### See Also

[cbind](#), [rbind](#), [cbind2](#)

### Examples

```
## Not run:

a <- gpu.matrix(1:9,nrow=3,ncol=3)

#add new row
newrow <- c(1,2,3)
a <- rbind2(a,newrow)

#add new column
newcolumn <- c(1,2,3,4)
a <- cbind(a,newcolumn)

#add new rows from other gpu.marix
b <- gpu.matrix(1:16,nrow=4,ncol=4)
d <- rbind(a,b)

#add new columns from other gpu.marix
b <- gpu.matrix(1:16,nrow=4,ncol=4)
d <- cbind(a,b)

## End(Not run)
```

---

concatenate\_gpu.matrix

*concatenate\_gpu.matrix*

---

### Description

Mimics the 'base' function 'c' to operate on `gpu.matrix` objects: function which "combines its arguments to form a vector. All arguments are coerced to a common type which is the type of the returned value." In most of the cases, the returned object is of type 'numeric'.



## Usage

```
## S4 method for signature 'gpu.matrix.tensorflow'  
c(x,...,recursive)  
## S4 method for signature 'gpu.matrix.torch'  
c(x,...,recursive)  
## S4 method for signature 'numMatrixLike'  
c(x,...,recursive)
```

## Arguments

x	A <a href="#">gpu.matrix</a> object
...	objects to be concatenated.
recursive	The same as c: Logical. If recursive = TRUE, the function recursively descends through lists (and pairlists) combining all their elements into a vector.

## Value

It will return a vector of type 'numeric' with the combined values.

## See Also

See also: [c](#).

## Examples

```
## Not run:  
  
#add new value  
a <- gpu.matrix(1:5,nrow=1,ncol=5)  
c(a,3)  
  
#add other vector  
c(a,a)  
  
#add value to a gpu.matrix  
a <- gpu.matrix(1:9,nrow=3,ncol=3)  
c(a,a)  
#it will return a vector as in original c function.  
  
## End(Not run)
```

---

cor\_cov

*Correlation, Variance and Covariance for 'GPUmatrix' objects*


---

## Description

These functions mimic the stats functions cov and cor to compute on `gpu.matrix` objects: "cov and cor compute the covariance and correlation of x and y if these are vectors. If x and y are matrices then the covariances (or correlations) between the columns of x and the columns of y are computed."

cov2cor scales a covariance matrix into the corresponding correlation matrix efficiently.

## Usage

```
## S4 method for signature 'gpu.matrix.tensorflow,ANY,ANY,ANY'
cor(x,y)
## S4 method for signature 'gpu.matrix.tensorflow,ANY,missing,character'
cor(x,y,method)
## S4 method for signature 'gpu.matrix.tensorflow,missing,missing,character'
cor(x,y,method)
## S4 method for signature 'ANY,gpu.matrix.tensorflow,ANY,ANY'
cor(x,y)
## S4 method for signature 'gpu.matrix.tensorflow,missing,ANY,ANY'
cor(x,y)

## S4 method for signature 'ANY,gpu.matrix.torch,ANY,ANY'
cor(x,y)
## S4 method for signature 'gpu.matrix.torch,ANY,ANY,ANY'
cor(x,y)
## S4 method for signature 'gpu.matrix.torch,ANY,missing,character'
cor(x,y,method)
## S4 method for signature 'gpu.matrix.torch,missing,missing,character'
cor(x,y,method)
## S4 method for signature 'gpu.matrix.torch,missing,missing,missing'
cor(x,y)
## S4 method for signature 'gpu.matrix.torch,missing,ANY,ANY'
cor(x,y)

## S4 method for signature 'gpu.matrix.tensorflow'
cov(x,y)
## S4 method for signature 'ANY,gpu.matrix.tensorflow'
cov(x,y)
## S4 method for signature 'gpu.matrix.tensorflow,ANY'
```

```

cov(x,y)
## S4 method for signature 'gpu.matrix.tensorflow,missing'
cov(x,y)

## S4 method for signature 'gpu.matrix.torch'
cov(x,y)
## S4 method for signature 'ANY,gpu.matrix.torch'
cov(x,y)
## S4 method for signature 'gpu.matrix.torch,ANY'
cov(x,y)
## S4 method for signature 'gpu.matrix.torch,missing'
cov(x,y)

## S4 method for signature 'gpu.matrix.tensorflow'
cov2cor(V)
## S4 method for signature 'gpu.matrix.torch'
cov2cor(V)

```

## Arguments

x	a <a href="#">gpu.matrix</a> .
y	NULL (default) or a vector, matrix, data frame or <a href="#">gpu.matrix</a> with compatible dimensions to x.
method	a character string indicating which correlation coefficient (or covariance) is to be computed. One of "pearson" (default) or "spearman".
V	symmetric numeric <a href="#">gpu.matrix</a> , usually positive definite such as a covariance matrix.

## Details

These functions work in the same way as their counterparts in the 'stats' library. Note that the 'Kendal' method (implemented in the 'stats' library) is not available for working with [gpu.matrix](#)-class objects.

Notice that the inputs can be either an object of class 'matrix', 'Matrix' or 'gpu.matrix'. User must be sure that the input values must be numeric.

If the input [gpu.matrix](#)-class object(s) are stored on the GPU, then the operations will be performed on the GPU. See [gpu.matrix](#). The result will be a [gpu.matrix](#) object.

For more details see [cor](#) and [cov2cor](#).

## Value

The result obtained by applying these functions will be a [gpu.matrix](#) object. For each function the result will be:

- cor correlation between x and y (when two vectors are the input) or the correlation between the columns of x and y if x and y are a `gpu.matrix` class object. If y is empty, is equivalent to  $y=x$ .
- cov the same as cor but compute the covariance.
- cov2cor scales a covariance matrix into the corresponding correlation matrix efficiently.

### See Also

For more information: [cor](#), [cov](#), [cov2cor](#),

### Examples

```
## Not run:
a <- gpu.matrix(rnorm(10))
b <- gpu.matrix(rnorm(10))
cor(a,b)

#example taken from stats corresponding help page:
longley_matrix <- as.matrix(longley)
longley_gpu <- as.gpu.matrix(longley_matrix)
C1 <- cor(longley_gpu)
cov(longley_gpu)
cov2cor(cov(longley_gpu))

## End(Not run)
```

---

density

*Kernel Density Estimation and Histograms*

---

### Description

The function `density` mimics the function `density` of the library `stats` to operate on `gpu.matrix`-class objects: "It computes kernel density estimates. Its default method does so with the given kernel and bandwidth for univariate observations."

The function `'hist'` mimics the function `'hist'` of the library `'graphics'` to operate on `gpu.matrix`-class objects: "It computes a histogram of the given data values."

### Usage

```
## S4 method for signature 'gpu.matrix.tensorflow'
density(x)
## S4 method for signature 'gpu.matrix.torch'
density(x)
## S4 method for signature 'gpu.matrix.tensorflow'
hist(x,...)
```

```
## S4 method for signature 'gpu.matrix.torch'
hist(x,...)
```

### Arguments

**x** the `gpu.matrix` object from which the estimate density is to be computed or the histogram is desired.

**...** further arguments and graphical parameters.

### Details

The two functions (`density` and `hist`) have been programmed to call their corresponding counterpart functions with their default parameters. Therefore, the internal operations to obtain each graph are computed by the CPU, regardless of whether the input value is stored in the GPU.

For more information on these functions see [density](#), and [hist](#).

### Value

The function `density` returns the same output as its counterpart function `density` from the library `stats`: It returns "an object with class 'density' whose underlying structure is a list containing the following components.

<code>x</code>	the <code>n</code> coordinates of the points where the density is estimated.
<code>y</code>	the estimated density values. These will be non-negative, but can be zero.
<code>bw</code>	the bandwidth used.
<code>n</code>	the sample size after elimination of missing values.
<code>call</code>	the call which produced the result.
<code>data.name</code>	the deparsed name of the <code>x</code> argument.
<code>has.na</code>	logical, for compatibility (always FALSE).

The print method reports summary values on the `x` and `y` components." (taken from [density](#)).

On the other hand, the function `hist` returns the same output as its counterpart function `hist` from the library `graphics`: It returns "an object of class 'histogram' which is a list with components:

<code>breaks</code>	the <code>n+1n+1</code> cell boundaries (= <code>breaks</code> if that was a vector). These are the nominal breaks, not with the boundary fuzz.
<code>counts</code>	<code>n</code> integers; for each cell, the number of <code>x[]</code> inside.
<code>density</code>	values $\hat{f}(x_i)$ , as estimated density values. If <code>all(diff(breaks) == 1)</code> , they are the relative frequencies <code>counts/n</code> and in general satisfy $\sum_i \hat{f}(x_i)(b_{i+1} - b_i) = 1$ , where $b_i = \text{breaks}[i]$
<code>.</code>	
<code>mids</code>	the <code>n</code> cell midpoints.
<code>xname</code>	a character string with the actual <code>x</code> argument name.
<code>equidist</code>	logical, indicating if the distances between breaks are all the same."

(Taken from [hist](#))

**See Also**

For more information see: [density](#), and [hist](#)

**Examples**

```
if(installTorch){
  a <- gpu.matrix(rnorm(20*100),20,100)

  density(a[1,]) #density information
  plot(density(a[1,])) #plot the estimated density function

  hist(a[1,]) #plot the histogram
}
```

---

 det

---

*Calculate the Determinant of a 'GPUMatrix'*


---

**Description**

These functions mimic the 'base' functions `det` and `determinant` to operate on `gpu.matrix`-class objects: "`det` calculates the determinant of a matrix. `determinant` is a generic function that returns separately the modulus of the determinant, optionally on the logarithm scale, and the sign of the determinant."

**Usage**

```
## S4 method for signature 'gpu.matrix.tensorflow,logical'
determinant(x,logarithm,...)
## S4 method for signature 'gpu.matrix.tensorflow,missing'
determinant(x,logarithm,...)
## S4 method for signature 'gpu.matrix.torch,logical'
determinant(x,logarithm,...)
## S4 method for signature 'gpu.matrix.torch,missing'
determinant(x,logarithm,...)

## S4 method for signature 'gpu.matrix.tensorflow'
det(x,...)
## S4 method for signature 'gpu.matrix.torch'
det(x,...)
```

## Arguments

x	a <code>gpu.matrix</code> object.
...	Optional parameters. For more details see <a href="#">det</a>
logarithm	logical; if TRUE (default) return the logarithm of the modulus of the determinant.

## Details

The function `det` and `determinant` internally call the corresponding function of the library `torch` or `tensorflow` (depending on the type of input `gpu.matrix`-class).

If the input `gpu.matrix`-class object(s) are stored on the GPU, then the operations will be performed on the GPU. See [gpu.matrix](#).

## Value

`det` returns the same output corresponding to the base function `det`, which is the determinant of `x`. The returned value is a object of class `numeric` sotred in the `cpu`.

`determinant` returns the corresponding output of the base function `determinant`, which is an object of class `det`, that contains the following components:

modulus	a numeric value. The modulus (absolute value) of the determinant if <code>logarithm</code> is FALSE; otherwise the logarithm of the modulus.
sign	integer; either +1 or -1 according to whether the determinant is positive or negative.

## See Also

For more information see: [det](#).

## Examples

```
## Not run:  
  
x <- gpu.matrix(1:4,nrow=2, ncol = 2)  
determinant(x) #modulus of the determinant.  
det(x)#the determinant.  
  
## End(Not run)
```

---

`diag`*diag*

---

**Description**

This function mimics the base function 'diag' to operate on `gpu.matrix`-class objects: "extract or replace the diagonal of a matrix, or constructs a diagonal matrix."

**Usage**

```
## S4 method for signature 'gpu.matrix.tensorflow'  
diag(x)  
## S4 method for signature 'gpu.matrix.torch'  
diag(x)  
## S4 replacement method for signature 'gpu.matrix.tensorflow,numeric'  
diag(x) <- value  
## S4 replacement method for signature 'gpu.matrix.torch,numeric'  
diag(x) <- value
```

**Arguments**

`x` a `gpu.matrix`.  
`value` either a single value or a vector of length equal to that of the current diagonal.

**Value**

Output corresponding to the base function `diag`: If input `x` is a `gpu.matrix`-class object then `diag{x}` returns a numeric object with the diagonal of the matrix `x` (this output is not a `gpu.matrix`-class object).

The replacement form `diag(x) <- value` sets the diagonal of the matrix `x` to the given value(s).

**See Also**

For more information see: [diag](#)

**Examples**

```
if(installTorch){  
  a <- gpu.matrix(rnorm(9),nrow=3,ncol=3)  
  diag(a) #shows the diagonal of matrix a  
  diag(a) <- c(10,0,100) #set the diagonal of matrix a  
  a
```



```
}

```

---

dim\_and\_names

*Number of rows and columns and its corresponding names*

---

### Description

These functions mimic the 'base' functions rownames, colnames, dimnames, dim, length, ncol, nrow to operate on gpu.matrix-class objects.

The "dim family functions" set or get the dimension of a gpu.matrix-class object.

The "rownames and colnames family functions" set or get the corresponding names of rows and columns of a gpu.matrix-class object.

### Usage

```
## S4 method for signature 'gpu.matrix.tensorflow'
rownames(x)
## S4 method for signature 'gpu.matrix.torch'
rownames(x)
## S4 method for signature 'gpu.matrix.tensorflow'
colnames(x)
## S4 method for signature 'gpu.matrix.torch'
colnames(x)
## S4 method for signature 'gpu.matrix.tensorflow'
dim(x)
## S4 method for signature 'gpu.matrix.torch'
dim(x)
## S4 method for signature 'gpu.matrix.tensorflow'
dimnames(x)
## S4 method for signature 'gpu.matrix.torch'
dimnames(x)
## S4 method for signature 'gpu.matrix.tensorflow'
length(x)
## S4 method for signature 'gpu.matrix.torch'
length(x)
## S4 method for signature 'gpu.matrix.tensorflow'
ncol(x)
## S4 method for signature 'gpu.matrix.torch'
ncol(x)
## S4 method for signature 'gpu.matrix.tensorflow'
nrow(x)
```

```
## S4 method for signature 'gpu.matrix.torch'
nrow(x)

## S4 replacement method for signature 'gpu.matrix.tensorflow,vector'
dim(x) <- value
## S4 replacement method for signature 'gpu.matrix.torch,vector'
dim(x) <- value
## S4 replacement method for signature 'gpu.matrix.tensorflow,vector'
dimnames(x) <- value
## S4 replacement method for signature 'gpu.matrix.torch,vector'
dimnames(x) <- value
```

### Arguments

x	a <a href="#">gpu.matrix</a> .
value	For dim a numeric vector of length 2 with the number of rows and number of columns. For dimnames a character or numeric vector of length 2 with the names of the rows and names of the columns.

### Value

rownames returns the names of the rows of a `gpu.matrix`-class object. colnames returns the names of the columns of a `gpu.matrix`-class object.

dim returns the number of rows and columns of a `gpu.matrix`-class object and `dim<-` sets the number of rows and columns of a `gpu.matrix`-class object.

dimnames returns the names of the rows and columns of a `gpu.matrix`-class object and `dimnames<-` sets the names of the rows and columns of a `gpu.matrix`-class object.

length returns the length (`ncol*nrow`) of a `gpu.matrix`-class object.

ncol returns the number of columns of a `gpu.matrix`-class object.

nrow returns the number of rows of a `gpu.matrix`-class object.

### See Also

For more information: [rownames](#), [colnames](#), [dim](#), [dim<-](#), [dimnames](#), [dimnames<-](#), [length](#), [ncol](#), [nrow](#).

### Examples

```
## Not run:

a <- gpu.matrix(rnorm(9))

dim(a) <- c(3,3) #sets the number of rows and columns.
dim(a) #shows the number of rows and the number of columns
ncol(a) #shows the number of columns
nrow(a) #shows the number of rows
```

```

length(a) #shows the length of the matrix (nrow*ncol)

dimnames(a) <- list(c("r1","r2","r3"),c("c1","c2","c3")) #sets rows and column names
dimnames(a) #shows both the row and the col names

#these functions are equivalent to the following:
rownames(a) <- c("r1","r2","r3") #adds rownames to a.
colnames(a) <- c("c1","c2","c3") #adds colnames to a.
rownames(a) #shows rownames.
colnames(a) #shows colnames.

## End(Not run)

```

---

dist

*Distance Matrix Computation with GPU*


---

## Description

This function mimics the 'stats' function `dist`: 'computes and returns the distance matrix computed by using the specified distance measure to compute the distances between the rows of a data matrix.'

## Usage

```

dist(x, method = "euclidean", diag = FALSE,
     upper = FALSE, p = 2)

## S4 method for signature 'gpu.matrix.torch'
dist(x,method,diag,upper,p)

```

## Arguments

x	a <code>gpu.matrix</code> .
method	the same as the 'stats' function <code>dist</code> : the distance measure to be used. Could be "euclidean", "maximum", "manhattan" or "minkowski". Note that the "canberra", "binary" methods are not included.
diag	the same as the 'stats' function <code>dist</code> : logical value indicating if the diagonal of the distances should be printed. It is set to TRUE and cannot be changed.
upper	the same as the 'stats' function <code>dist</code> : logical value indicating whether the upper triangle of the distance matrix should be printed. It is set to TRUE and cannot be changed.
p	the same as the 'stats' function <code>dist</code> : The power of the Minkowski distance.

## Details

The function mimics the 'stat' function `dist`. The distance measures used are (taken from `dist`):

euclidean:  $\sqrt{\sum_i (x_i - y_i)^2}$

maximum: Maximum distance between two components of `x` and `y`.

manhattan: Absolute distance between the two vectors.

minkowski: the `p` norm: the `p`th root of the sum of the `p`th powers of the differences of the components.

For more details see `dist`.

The function `dist` internally calls the corresponding function of the library `torch` or `tensorflow` (depending on the type of input `gpu.matrix-class`).

If the input `gpu.matrix-class` object is stored on the GPU, then the operations will be performed on the GPU. See `gpu.matrix`.

## Value

The function returns a `gpu.matrix-class` object with the corresponding distances between the rows of the input `gpu.matrix` object.

## See Also

For more information see: `dist`, and `torch_cdist`.

## Examples

```
## Not run:

#the example compare the results with the
#'stats' function 'dist':

x <- matrix(rnorm(100), nrow = 5)

dist(x,diag = TRUE,upper = TRUE,method = "euclidean")
dist(x = as.gpu.matrix(x),method = "euclidean")

dist(x,diag = TRUE,upper = TRUE,method = "maximum")
dist(x = as.gpu.matrix(x),method = "maximum")

dist(x,diag = TRUE,upper = TRUE,method = "manhattan")
dist(x = as.gpu.matrix(x),method = "manhattan")

dist(x,diag = TRUE,upper = TRUE,method = "minkowski")
dist(x = as.gpu.matrix(x),method = "minkowski")

dist(x,diag = TRUE,upper = TRUE,method = "minkowski",p = 23)
dist(x = as.gpu.matrix(x),method = "minkowski",p = 23)
```

```
## End(Not run)
```

---

expmGPU	<i>'GPUmatrix' Exponential</i>
---------	--------------------------------

---

## Description

This function mimics the function `expm` of the library `Matrix` to operate on `gpu.matrix`-class objects: It "computes the exponential of a matrix."

## Usage

```
expmGPU(x)
## S4 method for signature 'gpu.matrix.tensorflow'
expmGPU(x)
## S4 method for signature 'gpu.matrix.torch'
expmGPU(x)
```

## Arguments

`x` a `gpu.matrix`.

## Details

The exponential of a matrix is computed as:  $\sum_{k=0}^{\infty} 1/k! X^k$ .

The function `expmGPU` internally calls the corresponding function of the library `torch` or `tensorflow` (depending on the type of input `gpu.matrix`-class).

If the input `gpu.matrix`-class object(s) are stored on the GPU, then the operations will be performed on the GPU. See [gpu.matrix](#).

Please note that this function works with float numbers (either `float32` or `float64`). If the data type of `x` is integer, this function will not work. An example is shown below.

## Value

The matrix exponential of `x` as `gpu.matrix` class.

## See Also

For more information see [expm](#), and [torch\\_matrix\\_exp](#).

**Examples**

```

## Not run:
#build with a matrix that contains int number. It will not work.
x <- gpu.matrix(1:9,nrow=3,ncol = 3,dtype = "int")
x
try(expmGPU(x))

#need to be float and not int
x <- gpu.matrix(1:9,nrow=3,ncol = 3,dtype = "float64")
expmGPU(x)

## End(Not run)

```

---

extract\_gpu.matrix      *extract\_gpu.matrix*

---

**Description**

These operators mimic the base operators [, [<-, [[, and [[<- to compute on gpu.matrix-class objects.

**Usage**

```

## S4 method for signature 'gpu.matrix.tensorflow,missing'
e1 - e2
## S4 method for signature 'gpu.matrix.torch,missing'
e1 - e2
## S4 method for signature 'gpu.matrix.tensorflow,index,index'
x[i,j]
## S4 method for signature 'gpu.matrix.tensorflow,index,missing'
x[i,j,...,drop = TRUE]
## S4 method for signature 'gpu.matrix.tensorflow,matrix,missing'
x[i,j,...,drop = TRUE]
## S4 method for signature 'gpu.matrix.tensorflow,missing,index'
x[i,j]
## S4 method for signature 'gpu.matrix.torch,index,index'
x[i,j]
## S4 method for signature 'gpu.matrix.torch,index,missing'
x[i,j,...,drop = TRUE]
## S4 method for signature 'gpu.matrix.torch,matrix,missing'
x[i,j,...,drop = TRUE]
## S4 method for signature 'gpu.matrix.torch,missing,index'
x[i,j]
## S4 replacement method for signature 'gpu.matrix.tensorflow,index,index'

```

```

x[i,j] <- value
## S4 replacement method for signature 'gpu.matrix.tensorflow,index,missing'
x[i,j] <- value
## S4 replacement method for signature 'gpu.matrix.tensorflow,matrix,missing'
x[i,j] <- value
## S4 replacement method for signature 'gpu.matrix.tensorflow,missing,index'
x[i,j] <- value
## S4 replacement method for signature 'gpu.matrix.torch,index,index'
x[i,j] <- value
## S4 replacement method for signature 'gpu.matrix.torch,index,missing'
x[i,j] <- value
## S4 replacement method for signature 'gpu.matrix.torch,matrix,missing'
x[i,j] <- value
## S4 replacement method for signature 'gpu.matrix.torch,missing,index'
x[i,j] <- value
## S4 method for signature 'gpu.matrix.tensorflow,index'
x[[i,j,...]]
## S4 method for signature 'gpu.matrix.torch,index'
x[[i,j,...]]
## S4 replacement method for signature 'gpu.matrix.tensorflow,index'
x[[i]] <- value
## S4 replacement method for signature 'gpu.matrix.torch,index'
x[[i]] <- value

```

### Arguments

e1	a <a href="#">gpu.matrix</a> .
e2	a <a href="#">gpu.matrix</a> .
x	a <a href="#">gpu.matrix</a> object from which extract element(s) or in which to replace element(s)
i, j, ...	indices specifying elements to extract or replace.
value	typically an array-like R object of a similar class as x.
drop	For matrices and arrays. If TRUE the result is coerced to the lowest possible dimension

### Details

When replacing a value or values in a [gpu.matrix](#), the [gpu.matrix](#) will not change its datatype (corresponding to the parameter `dtype` of the function [gpu.matrix](#)) based on the datatype in `value`. For example, the code `x[1,1] <- value` where the array `x` is a [gpu.matrix](#) with integer values and `value` has 'double' values, only the integer part of `value` will be stored in `x[1,1]`.

### See Also

See Also [Extract](#).

## Examples

```
## Not run:

a <- gpu.matrix(1:9,nrow=3,ncol=3)
rownames(a) <- c("R1","R2","R3")
colnames(a) <- c("C1","C2","C3")

#return
a[3,3] # the element row 3 and column 3
a[6] # the 6th element
a[1,] # the first row
a[c(1,2),] # the first and second row
a[c(1,1),] # the first row twice
a[,1] # the first column
a[,c(1,2)] # the first and second column
a[,c(1,1)] # the first column twice

#replace
a[3,3] <- 100 # replace the element 3,3
a[1,] <- c(1,2,1) # replace the first row
a[,2] <- c(0,0,0) # replace the second column
a[c(1,2),] <- matrix(1:6,nrow = 2) # replace the first and second row

## End(Not run)
```

---

 fft

*Fast Discrete Fourier Transform (FFT)*


---

## Description

The function `fft` mimics the function `fft` of the library 'stats' to compute on `gpu.matrix`-class objects: it "Computes the Discrete Fourier Transform (DFT) of an array with a fast algorithm, the 'Fast Fourier Transform' (FFT)."

The function `mvfft` mimics the function `mvfft` of the library 'stats' which: "takes a real or complex matrix as argument, and returns a similar shaped matrix, but with each column replaced by its discrete Fourier transform".

## Usage

```
## S4 method for signature 'gpu.matrix.tensorflow'
fft(z)
## S4 method for signature 'gpu.matrix.torch'
fft(z)
```



```
## S4 method for signature 'gpu.matrix.torch,logical'
fft(z,inverse)

## S4 method for signature 'gpu.matrix.torch'
mvfft(z)
## S4 method for signature 'gpu.matrix.tensorflow'
mvfft(z)
## S4 method for signature 'gpu.matrix.torch,logical'
mvfft(z,inverse)
```

### Arguments

**z** a [gpu.matrix](#) object containing the values to be transformed.

**inverse** the same as in the library 'stats': "if TRUE, the unnormalized inverse transform is computed (the inverse has a + in the exponent of  $e$ , but here, we do not divide by  $1/\text{length}(x)$ ". By default is FALSE. Plea Note that this parameter only work for torch.

### Details

The function `fft` mimics the function `fft` to operate on `gpu.matrix`-class objects of one dimension. If the input `gpu.matrix` `z` has tow dimensions the function will not work, as the method for two dimensions is not implemented yet for `gpu.matrix`-class objects. In this case the function will display the following error message: "FFT in `gpu.matrix` with 2 dimensions is not allowed yet".

The function `mvfft` mimics the function `mvfft` to operate on `gpu.matrix`-class objects. This function will apply the discrete Fourier transform to each column of the input `z` matrix.

Note that the `inverse` parameter only works for 'torch' for both `fft` and `mvfft` functions.

The functions `fft` and `mvfft` internally call the corresponding function of the library `torch` or `tensorflow` (depending on the type of input `gpu.matrix`-class).

If the input `gpu.matrix`-class object(s) are stored on the GPU, then the operations will be performed on the GPU. See [gpu.matrix](#).

### Value

It returns a `gpu.matrix`-class object with the transformed values. To access the real and imaginary information use the function `Re()` for teh rea part and `Im()` for the imaginary part. Furthermore, the following code can be used: `output@gm$real` for the real part and `output@gm$imag` for the imaginary part.

### See Also

For more information see: [fft](#), [torch\\_fft\\_ifft](#), and [torch\\_fft\\_fft](#).

### Examples

```
if(installTorch){
x <- gpu.matrix(1:4,ncol = 1)
```

```

output_gpu <- fft(x)
output_matrix <- fft(z = as.matrix(x))

#check results:
Re(output_gpu)
Re(output_matrix)
Im(output_gpu)
Im(output_matrix)

x <- gpu.matrix(1:12,ncol = 3)
output_gpu <- mvfft(x)
output_matrix <- mvfft(as.matrix(x))

#check results:
Re(output_gpu)
Re(output_matrix)
Im(output_gpu)
Im(output_matrix)
}

```

---

gpu.matrix

*create and store a matrix in the GPU*


---

## Description

Mimic the base 'matrix' function to create a gpu.matrix-class object, that could be of class gpu.matrix.torch or gpu.matrix.tensorflow depending on the system installed in the computer.

The matrix created will be stored in the GPU (by default) or in the CPU. The example section explains how to be sure where the matrix is stored.

This function also mimics the function Matrix of the library 'Matrix'.

## Usage

```

gpu.matrix(data = NULL, nrow = NULL, ncol = NULL,
           byrow = FALSE, dimnames = NULL,
           dtype=NULL, sparse=NULL, colnames=c(),
           rownames=c(), device=NULL, type=NULL)

as.gpu.matrix(x,...)
## S4 method for signature 'ANY'
as.gpu.matrix(x,...)

```

**Arguments**

<code>data, x</code>	a scalar, vector or matrix (both matrix or Matrix class).
<code>nrow</code>	Number of rows of the matrix. By default the number of rows of data if data is an object of class matrix or Matrix.
<code>ncol</code>	Number of columns of the matrix. By default the number of columns of data if data is an object of class matrix or Matrix.
<code>byrow</code>	The same as function <code>matrix</code> : "logical. If FALSE (the default) the matrix is filled by columns, otherwise the matrix is filled by rows."
<code>dimnames</code>	The same as in function <code>matrix</code> : "A <code>dimnames</code> attribute for the matrix: NULL or a list of length 2 giving the row and column names respectively. An empty list is treated as NULL, and a list of length one as row names. The list can be named, and the list names will be used as names for the dimensions."
<code>dtype</code>	data type. User can indicate "float64", "float32" or "int" for "int64". if not specified, dtype will correspond to the input data type.
<code>sparse</code>	The same as in function <code>Matrix</code> of the library 'Matrix': "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."
<code>colnames</code>	A vector with the column names.
<code>rownames</code>	A vector with the row names.
<code>type</code>	If the <code>gpu.matrix</code> is 'torch' or "tensorflow". If it is NULL, <code>gpu.matrix</code> will try to create a <code>gpu.matrix.torch</code> object.
<code>device</code>	It indicates the device to load cuda. If not indicated, 'device' will be set to 'cuda' if it is available.
<code>...</code>	additional arguments to be passed to or from methods.

**Details**

The `gpu.matrix` function mimics the `Matrix` function of the 'Matrix' library and the basic `matrix` function. If `tensorflow` and/or `torch` are properly installed and the `device` parameter is set to "cuda" (by default), then the created `gpu.matrix` object will be stored on the GPU. The example shows how to check this.

The user can apply to the created `gpu.matrix`-class object -using the same operators- the basic functions that can be applied to a object of class 'matrix' and/or class 'Matrix'.

It can also work with sparse matrices as the 'Matrix' library.

**Value**

Returns a GPUmatrix object that can be either "gpu.matrix.tensorflow" or "gpu.matrix.torch". For both `torch` and `tensorflow` the functions to be applied to a matrix are the same.

If the `gpu.matrix`-class object is not sparse it will show on the console the matrix as it is. If the `gpu.matrix` is sparse, it will return to the console the position where there are number different from zero. The internal values of the matrix can be seen using the operator "@".

If the `gpu.matrix`-class object contains complex numbers, to access the real and imaginary information use the function `Re()` for the real part and `Im()` for the imaginary part. Furthermore, the

following code can be used: `output@gm$real` for the real part and `output@gm$imag` for the imaginary part.

Even if the `gpu.matrix`-class object is sparse or not, both kind of matrices works equally with all functions.

### Author(s)

Cesar Lobato and Angel Rubio.

### See Also

See [gpu.matrix](#), [Matrix](#), and [matrix](#).

For more details about the parameter `dtype` visit [dtype](#)

### Examples

```
## Not run:
## create a gpu.matrix.torch and check it is stored in the GPU.
a <- gpu.matrix(1:9,nrow=3,ncol=3)
class(a)
a@gm$is_cuda

# the output of class(a) should be:
#[1] "gpu.matrix.torch"
#attr(,"package")
#[1] "GPUmatrix"

#the output of a@gm@device should have a similar shape:
#[1] TRUE

## create a gpu.matrix.torch and check it is stored in the CPU.
a <- gpu.matrix(1:9,nrow=3,ncol=3, device="cpu")
class(a)
a@gm$is_cuda

# the output of class(a) should be:
#[1] "gpu.matrix.torch"
#attr(,"package")
#[1] "GPUmatrix"

#the output of a@gm@device should have a similar shape:
#[1] FALSE

## create a gpu.matrix.tensorflow and check it is stored in the GPU.
a <- gpu.matrix(1:9,nrow=3,ncol=3,type="tensorflow")
class(a)
a@gm$device

# the output of class(a) should be:
```

```

#[1] "gpu.matrix.tensorflow"
#attr(,"package")
#[1] "GPUmatrix"

#the output of a@gm@device should have a similar shape:
#[1] "/job:localhost/replica:0/task:0/device:GPU:0"

#create a sparse
a <- gpu.matrix(data=c(0,1,1,0,1,0),nrow = 3,ncol = 2,sparse = T)
a

#create a complex gpu.matrix
a <- gpu.matrix(data=c(0+1i,1i,1,0,1,0),nrow = 3,ncol = 2)
a

## End(Not run)

```

---

gpu.matrix-class      *Class 'gpu.matrix' for matrix stored in GPU*

---

### Description

GPU computational power is a great resource for computational biology specifically in statistics and linear algebra. the `gpu.matrix-class` is a class of the `GPUmatrix` package, that store a matrix in the GPU.

The `GPUmatrix` package is based on S4 objects in R and we have created a constructor function that acts similarly to the default `matrix` constructor in R for CPU matrices. The constructor function is [gpu.matrix](#) and accepts the same parameters as `matrix`.

### Slots

Use the `@` operator to access the different slots:

**rownames** the row names of the `gpu.matrix`

**colnames** the column names of the `gpu.matrix`

**gm** the corresponding tensor

**sparse** Logical: indicates if the `gpu.matrix` is sparse or not

**type** If it is tensorflow or torch

### See Also

See Also [gpu.matrix](#), [Matrix](#), and [matrix..](#)

## Description

These functions mimic the functions `speedglm` and `speedglm.wfit` of the library `'speedglm'` to compute on `gpu.matrix`-class objects. At the same time, these functions mimic the functions `glm`, and `glm.fit` from the library `'stats'` to compute on large data sets.

## Usage

```
glm.fit.GPU(x, y, intercept = TRUE, weights = NULL, family =
  gaussian(), start = NULL, etastart = NULL, mustart =
  NULL, offset = NULL, acc = 1e-08, maxit = 25, k = 2,
  sparse = NULL, trace = FALSE, dtype = "float64", device =
  NULL, type = NULL, ...)
```

```
GPUglm(...)
```

## Arguments

As mentioned in the description, these functions mimic `speedglm`, so almost every parameter does too. There is only three new parameters explained below.

The common parameters with `speedglm`:

<code>x</code>	the same as <code>speedglm</code> : the design matrix of dimension $n \times p$ where $n$ is the number of observations and $p$ is the number of features. <code>x</code> can be either a <code>'matrix'</code> , <code>'Matrix'</code> or <code>'gpu.matrix-class'</code> object.
<code>y</code>	the same as <code>speedglm</code> : a vector of $n$ observations. <code>y</code> can be either a <code>'matrix'</code> , <code>'Matrix'</code> or <code>'gpu.matrix-class'</code> object.
<code>intercept</code>	the same as <code>speedglm</code> : Logical. If first column of <code>x</code> should be consider as <code>'intercept'</code> (default) or not. Notice that setting this parameter <code>TRUE</code> or <code>FALSE</code> will not change the design matrix used to fit the model.
<code>weights</code>	the same as <code>speedglm</code> : an optional vector of <code>'prior weights'</code> to be used in the fitting process. Should be <code>NULL</code> (default) or a numeric vector.
<code>family</code>	the same as <code>speedglm</code> : a description of the error distribution and link function to be used in the model. For <code>glm.fit.GPU</code> this can be a character string naming a family function, a family function or the result of a call to a family function. (See <a href="#">family</a> for details of family functions.)
<code>start</code>	the same as <code>speedglm</code> : starting values for the parameters in the linear prediction.
<code>etastart</code>	the same as <code>speedglm</code> : starting values for the linear predictor.
<code>mustart</code>	the same as <code>speedglm</code> : starting values for the vector of means.

offset	the same as <code>speedglm</code> : this can be used to specify an a priori known component to be included in the linear predictor during fitting. This should be <code>NULL</code> or a numeric vector of length equal to the number of cases. One or more <code>offset</code> terms can be included in the formula instead or as well, and if more than one is specified their sum is used. See <code>model.offset</code> .
acc	the same as <code>speedglm</code> : tolerance to be used for the estimation (by default equal to: <code>1e-08</code> ).
maxit	the same as <code>speedglm</code> : maximum number of iterations.
k	the same as <code>speedglm</code> : numeric, the penalty per parameter to be used; the default <code>k = 2</code> is the classical AIC.
sparse	if matrix <code>x</code> is desired to be treated as sparse. Not yet implemented.
trace	If the user wants to see the development of the iterations. By default <code>FALSE</code>
...	For <code>GPUglm</code> : arguments to be used to form the default control argument if it is not supplied directly.

The `glm.fit.GPU` function internally initialises matrices of the 'GPUmatrix' class by calling the `gpu.matrix` function. The following parameters correspond to this function:

dtype	parameter of the function <code>gpu.matrix</code> : "data type. User can indicate "float64", "float32" or "int" for "int64"." By default it is set to 'float64'.
device	parameter of the function <code>gpu.matrix</code> : "It indicates the device to load cuda. If not indicated, 'device' will be set to 'cuda' if it is available."
type	parameter of the function <code>gpu.matrix</code> : "If <code>gpu.matrix</code> is 'torch' (by default if type is <code>NULL</code> ) or "tensorflow"."

## Details

The `GPUglm` function internally calls the `glm` function by selecting `glm.fit.GPU` as the method. The input parameters of the `GPUglm` function are equivalent to those of the `glm` function.

If the `gpu.matrix`-class object(s) are stored on the GPU, then the operations will be performed on the GPU. See `gpu.matrix`.

## Value

Both `glmGPU`, and `glm.fit.GPU` returns an object of class "GPUglm". This object can be treated as a list. This object mimics the output of the function `speedglm`:

coefficients	the estimated coefficients.
logLik	the log likelihood of the fitted model.
iter	the number of iterations of IWLS used.
tol	the maximal value of tolerance reached.
family	the maximal value of tolerance reached.
link	the link function used.
df	the degrees of freedom of the model.
XTX	the product $X'X$ (weighted, if the case).

dispersion	the estimated dispersion parameter of the model.
ok	the set of column indices of the model matrix where the model has been fitted.
rank	the rank of the model matrix.
RSS	the estimated residual sum of squares of the fitted model.
method	TODO
aic	the estimated Akaike Information Criterion.
offset	the model offset.
sparse	a logical value which indicates if the model matrix is sparse.
deviance	the estimated deviance of the fitted model.
nulldf	the degrees of freedom of the null model.
nulldev	the estimated deviance of the null model.
ngoodobs	the number of non-zero weighted observations.
n	the number of observations.
intercept	a logical value which indicates if an intercept has been used.
convergence	a logical value which indicates if convergence was reached.
terms	the terms object used.
call	the matched call.
xlevels	(where relevant) a record of the levels of the factors used in fitting.

### See Also

See also: [speedglm](#) and [glm](#).

Also of interest may be the function [LR\\_GradientConjugate\\_gpumatrix](#) for logistic regression.

### Examples

```
## Not run:
require(MASS,quietly = TRUE)
require(stats,quietly = TRUE)

# linear model (example taken from 'glm'):

utils::data(anorexia, package = "MASS")
anorex_glm <- glm(Postwt ~ Prewt + Treat + offset(Prewt),
                 family = gaussian(), data = anorexia)
summary(anorex_glm)

#Using GPUglm:
anorex_GPUglm <- GPUglm(Postwt ~ Prewt + Treat + offset(Prewt),
                      family = gaussian(), data = anorexia)
summary(anorex_GPUglm)

#linear model using glm.fit.gpu
```



```

x <- model.matrix(~Treat+Prewt,data=anorexia)
y <- as.matrix(anorexia$Postwt)
s1_glm <- glm.fit(x=x,y=y)
s1_gpu <- glm.fit.GPU(x=x,y=y)

s1_glm$coefficients
s1_gpu$coefficients

# poisson (example taken from 'glm'):
counts <- c(18,17,15,20,10,20,25,13,12)
outcome <- gl(3,1,9)
treatment <- gl(3,3)
glm.D93 <- glm(counts ~ outcome + treatment, family = poisson())
summary(glm.D93)

gpu.glm.D93 <- GPUglm(counts ~ outcome + treatment, family = poisson())
summary(gpu.glm.D93)

#logistic:
data(menarche)
glm.out <- glm(cbind(Menarche, Total-Menarche) ~ Age, family=binomial(), data=menarche)
summary(glm.out)

glm.out_gpu <- GPUglm(cbind(Menarche, Total-Menarche) ~ Age, family=binomial(), data=menarche)
summary(glm.out_gpu)

#can be also called using glm.fit.gpu:
new_menarche <- data.frame(Age=rep(menarche$Age,menarche$Total))
observations <- c()
for(i in 1:nrow(menarche)){
  observations <- c(observations,rep(c(0,1),c(menarche$Total[i]-menarche$Menarche[i],
                                             menarche$Menarche[i])))
}
new_menarche$observations <- observations
x <- model.matrix(~Age,data=new_menarche)
head(new_menarche)
glm.fit_gpu <- glm.fit.GPU(x=x,y=new_menarche$observations, family=binomial())
summary(glm.fit_gpu)

#GPUmatrix package also include the function 'LR_GradientConjugate_gpumatrix'
lr_gran_sol <- LR_GradientConjugate_gpumatrix(X = x,y = observations)

#check results
glm.out$coefficients
glm.out_gpu$coefficients
glm.fit_gpu$coefficients
lr_gran_sol

## End(Not run)

```

---

installTorch	<i>installTorch</i>
--------------	---------------------

---

**Description**

This variable checks that the torch package is installed correctly.

**Usage**

```
installTorch
```

---

kroneker	<i>kroneker Products</i>
----------	--------------------------

---

**Description**

Kroneker product of two `gpu.matrix`-class objects. This function mimics the 'base' function 'kronecker' to operate on `gpu.matrix`-class objects.

**Usage**

```
## S4 method for signature 'ANY,gpu.matrix.tensorflow'
X %% Y
## S4 method for signature 'ANY,gpu.matrix.torch'
X %% Y
## S4 method for signature 'gpu.matrix.tensorflow,ANY'
X %% Y
## S4 method for signature 'gpu.matrix.torch,ANY'
X %% Y
```

**Arguments**

X	A <code>gpu.matrix</code> .
Y	A <code>gpu.matrix</code> or a matrix or a numeric variable.

**Details**

The function `%%` internally calls the corresponding function of the library `torch` or `tensorflow` (depending on the type of input `gpu.matrix`-class).

If the input `gpu.matrix`-class object(s) are stored on the GPU, then the operations will be performed on the GPU. See `gpu.matrix`.

**See Also**

See Also `kronecker` and `torch_kron`.

## Examples

```
## Not run:  
  
a <- gpu.matrix(1:9,nrow=3,ncol=3)  
a %% diag(1,3)  
  
## End(Not run)
```

---

LR\_GradientConjugate\_gpumatrix

*Logistic Regression with Conjugate Gradient method*

---

## Description

The developed function performs the logistic regression using the Conjugate Gradient method. This method has shown to be very effective for logistic regression of big models [1]. The code is general enough to accommodate standard R matrices, sparse matrices from the 'Matrix' package and, more interestingly, `gpu.matrix`-class objects from the GPUmatrix package.

## Usage

```
LR_GradientConjugate_gpumatrix(X, y, beta = NULL,  
                               lambda = 0, iterations = 100,  
                               tol = 1e-08)
```

## Arguments

X	the design matrix. Could be either a object of class <code>gpu.matrix</code> , <code>matrix</code> , or <code>Matrix</code> .
y	vector of observations.
beta	initial solution.
lambda	numeric. Penalty factor also known as the L2 norm or L2 penalty, which is computed as the sum of the squared coefficients: $\lambda \ \beta_i\ _2^2$
iterations	maximum number of iterations.
tol	tolerance to be used for the estimation.

## Details

If the input `gpu.matrix`-class object(s) are stored on the GPU, then the operations will be performed on the GPU. See `gpu.matrix`.

**Value**

The function returns a vector containing the values of the coefficients. This returned vector will be a 'matrix', 'Matrix' or 'gpu.matrix-class' object depending on the class of the object  $X$ .

**Author(s)**

Angel Rubio and Cesar Lobato.

**References**

[1] Minka TP (2003). "A comparison of numerical optimizers for logistic regression." URL: <https://tminka.github.io/papers/logreg.pdf>.

**See Also**

See also: [GPUglm](#)

**Examples**

```
## Not run:

#toy example:
set.seed(123)
m <- 1000
n <- 100
x <- matrix(runif(m*n),m,n)
sol <- rnorm(n)
y <- rbinom(m, 1, prob = plogis(x*%sol))
s2_granConj <- LR_GradientConjugate_gpumatrix(X = x,y = y)

#the following compares LR_GradientConjugate_gpumatrix
# with glm and GPUglm:

require(MASS)
require(stats,quietly = TRUE)
#logistic:
data(menarche)
glm.out <- glm(cbind(Menarche, Total-Menarche) ~ Age, family=binomial(), data=menarche)
summary(glm.out)

glm.out_gpu <- GPUglm(cbind(Menarche, Total-Menarche) ~ Age, family=binomial(), data=menarche)
summary(glm.out_gpu)

#can be also called using glm.fit.gpu:
new_menarche <- data.frame(Age=rep(menarche$Age,menarche$Total))
observations <- c()
for(i in 1:nrow(menarche)){
  observations <- c(observations,rep(c(0,1),c(menarche$Total[i]-menarche$Menarche[i],
                                         menarche$Menarche[i])))
}
new_menarche$observations <- observations
```

```

x <- model.matrix(~Age,data=new_menarche)
head(new_menarche)
glm.fit_gpu <- glm.fit.GPU(x=x,y=new_menarche$observations, family=binomial())
summary(glm.fit_gpu)

#GPUmatrix package also include the function 'LR_GradientConjugate_gpumatrix'
lr_gran_sol <- LR_GradientConjugate_gpumatrix(X = x,y = observations)

#check results
glm.out$coefficients
glm.out_gpu$coefficients
glm.fit_gpu$coefficients
lr_gran_sol

## End(Not run)

```

---

matrix-product

*Matrix Products*


---

## Description

Mimic of the 'base' functions `%*%`, `crossprod`, `tcrossprod` to operate on `gpu.matrix`-class objects.

## Usage

```

## S4 method for signature 'gpu.matrix.tensorflow,ANY'
x %*% y
## S4 method for signature 'gpu.matrix.torch,ANY'
x %*% y

## S4 method for signature 'gpu.matrix.tensorflow,ANY'
crossprod(x, y,...)
## S4 method for signature 'gpu.matrix.tensorflow,missing'
crossprod(x, y = NULL,...)

## S4 method for signature 'gpu.matrix.tensorflow,ANY'
tcrossprod(x, y,...)
## S4 method for signature 'gpu.matrix.tensorflow,missing'
tcrossprod(x, y = NULL,...)

## S4 method for signature 'gpu.matrix.torch,ANY'
crossprod(x, y,...)
## S4 method for signature 'gpu.matrix.torch,missing'
crossprod(x, y = NULL,...)

```

```
## S4 method for signature 'gpu.matrix.torch,ANY'
tcrossprod(x, y,...)
## S4 method for signature 'gpu.matrix.torch,missing'
tcrossprod(x, y = NULL,...)
```

### Arguments

x	a <a href="#">gpu.matrix</a> .
y	a <a href="#">gpu.matrix</a> , 'matrix' or 'Matrix' object. For the functions <code>tcrossprod</code> and <code>crossprod</code> is NULL (by default), that is equivalent to <code>x=y</code> .
...	potentially more arguments passed to and from methods.

### Details

Internally, these functions call the appropriate tensorflow or torch function to perform the matrix product (depending on the type of input `gpu.matrix-class`).

If the input `gpu.matrix-class` object(s) are stored on the GPU, then the operations will be performed on the GPU. See [gpu.matrix](#).

### Value

A `gpu.matrix-class` object with the result of the matrix product.

### Methods

```
%% signature(x = "gpu.matrix.tensorflow", y = "ANY"): Matrix multiplication
crossprod signature(x = "gpu.matrix.tensorflow", y = "ANY"): Matrix multiplication
crossprod signature(x = "gpu.matrix.tensorflow", y = "missing"): Matrix multiplication
tcrossprod signature(x = "gpu.matrix.tensorflow", y = "ANY"): Matrix multiplication
tcrossprod signature(x = "gpu.matrix.tensorflow", y = "missing"): Matrix multiplication
%% signature(x = "gpu.matrix.torch", y = "ANY"): Matrix multiplication
crossprod signature(x = "gpu.matrix.torch", y = "ANY"): Matrix multiplication
crossprod signature(x = "gpu.matrix.torch", y = "missing"): Matrix multiplication
tcrossprod signature(x = "gpu.matrix.torch", y = "ANY"): Matrix multiplication
tcrossprod signature(x = "gpu.matrix.torch", y = "missing"): Matrix multiplication
```

### See Also

`tcrossprod` in R's base, and `crossprod` and `%%`. **Matrix** package `%%` for boolean matrix product methods. Also see [torch\\_matmul](#)

## Examples

```
## Not run:
a <- gpu.matrix(rnorm(12),nrow=4,ncol=3)
b <- t(a)
b
crossprod(a,a)

b <- a
b
tcrossprod(a)

## End(Not run)
```

---

matrix\_decomposition    *Decomposition of a matrix with GPU*

---

## Description

These functions mimic the functions `eigen`, `svd`, `chol` to operate on `gpu.matrix`-class objects:

'`eigen`' mimics the base function '`eigen`' that "computes the eigenvalues and eigenvectors of a numeric (double, integer, logical) or complex matrix."

'`svd`' mimics the base function '`svd`' that "computes the singular-value decomposition of a rectangular matrix."

'`chol`' mimics the base function '`chol`' that "computes Compute the Cholesky factorization of a real symmetric positive-definite square matrix."

## Usage

```
## S4 method for signature 'gpu.matrix.tensorflow'
eigen(x)
## S4 method for signature 'gpu.matrix.torch'
eigen(x)

## S4 method for signature 'gpu.matrix.tensorflow'
svd(x)
## S4 method for signature 'gpu.matrix.torch'
svd(x)

## S4 method for signature 'gpu.matrix.tensorflow'
chol(x)
## S4 method for signature 'gpu.matrix.torch'
chol(x)
```

**Arguments**

`x` a `gpu.matrix`. `X` must fulfil certain characteristics depending on the function to be called (see details).

**Details**

These functions mimic the behaviour of their respective 'base' functions.

In the case of the `eigen` function, the input value can be a numeric or complex `gpu.matrix` class.

For `svd` function, the input value could be a numeric or complex `gpu.matrix`-class object.

For `chol` function, the input must be a positive-definite square matrix.

Internally, these functions call its corresponding function of the `tensorflow` or `torch` library depending on the type of input `gpu.matrix`-class.

If the input `gpu.matrix`-class object(s) are stored on the GPU, then the operations will be performed on the GPU. See `gpu.matrix`.

**Value**

The output of these functions correspond to their equivalent base functions:

`eigen` mimics the base function `eigen` that computes the eigenvalues and eigenvectors of a numeric (double, integer, logical) or complex matrix. It returns a list with the following items:

`values` a vector with the `P` eigenvalues of `x`

`vectors` the eigenvectors of `x`

`svd` mimics the base function `svd` that computes the singular-value decomposition of a rectangular matrix. It returns a list with the following items:

`d` a vector containing the singular values of `x`

`u` a matrix whose columns contain the left singular vectors of `x`

`v` a matrix whose columns contain the right singular vectors of `x`

`chol` mimics the base function `chol` that computes Compute the Cholesky factorization of a real symmetric positive-definite square matrix. It returns a `gpu.matrix`-class object with The upper triangular factor of the Cholesky decomposition, i.e., the matrix  $R$  such that  $R'R = X$ .

**See Also**

For more information see: `eigen`, `svd`, `chol`, `linalg_eig`, `torch_svd`, and `torch_cholesky`.

`chol` function is called by the function `chol_solve`.

For the `qr` decomposition see `qr`.



**Examples**

```
## Not run:
a <- gpu.matrix(rnorm(9),3,3)
ein <- eigen(a) #eigenvalues and eigenvectors
svd_return <- svd(a) #svd of gpu.matrix a

ata <- tcrossprod(a)
#ata is a real symmetric positive-definite square matrix.
chol(ata) #cholesky decomposition.

## End(Not run)
```

---

```
matrix_general_operators_methods
```

*Return the first or last part of a GPUmatrix object*

---

**Description**

head and tail mimic the functions head and tail from utils to operate on gpu.matrix-class objects. By default head shows the first 6 rows of a matrix or first 6 elements of a vector or list. tail shows the last 6 rows of a matrix or last 6 elements of a vector or list.

The function show mimics the function show of methods to compute on gpu.matrix-class objects: "It display the object, by printing, plotting or whatever suits its class."

The function print mimics the base function print to operate on gpu.matrix-class objects.

**Usage**

```
## S4 method for signature 'gpu.matrix.tensorflow'
tail(x,...)
## S4 method for signature 'gpu.matrix.torch'
tail(x,...)
## S4 method for signature 'gpu.matrix.tensorflow'
show(object)
## S4 method for signature 'gpu.matrix.torch'
show(object)
## S4 method for signature 'gpu.matrix.tensorflow'
head(x,...)
## S4 method for signature 'gpu.matrix.torch'
head(x,...)

## S4 method for signature 'gpu.matrix.torch'
print(x)
```

**Arguments**

x, object            a `gpu.matrix`.  
 ...                 arguments to be passed to or from other methods.

**See Also**

For more information see: [head](#), [tail](#), and [show](#).

**Examples**

```
## Not run:
a <- gpu.matrix(rnorm(20*5),20,5)
head(a) #shows the first six row of every column
tail(a) #shows the las six row of every column

show(a) #show all the object
a #equivalente to run the function show.

## End(Not run)
```

---

matrix\_ranges

*Get different statistics for a gpu.matrix-class.*


---

**Description**

Functions to summarise different values of a `gpu.matrix`-class object by rows or columns. Specifically: the maximum value, the index of the maximum value, the minimum value, the index of the minimum value, the mean, the variance, the sum of the values and the rank of the values.

These functions mimic the corresponding function of 'base', 'matrixStats' and 'Matrix' libraries.

**Usage**

```
## S4 method for signature 'gpu.matrix.tensorflow'
rowMaxs(x)
## S4 method for signature 'gpu.matrix.torch'
rowMaxs(x)
## S4 method for signature 'gpu.matrix.tensorflow'
colMaxs(x)
## S4 method for signature 'gpu.matrix.torch'
colMaxs(x)
## S4 method for signature 'gpu.matrix.tensorflow'
max(x)
## S4 method for signature 'gpu.matrix.torch'
max(x)
```

```
## S4 method for signature 'gpu.matrix.tensorflow'  
rowMins(x)  
## S4 method for signature 'gpu.matrix.torch'  
rowMins(x)  
## S4 method for signature 'gpu.matrix.tensorflow'  
colMins(x)  
## S4 method for signature 'gpu.matrix.torch'  
colMins(x)  
## S4 method for signature 'gpu.matrix.tensorflow'  
min(x)  
## S4 method for signature 'gpu.matrix.torch'  
min(x)  
  
## S4 method for signature 'gpu.matrix.tensorflow'  
rowMeans(x)  
## S4 method for signature 'gpu.matrix.torch'  
rowMeans(x)  
## S4 method for signature 'gpu.matrix.tensorflow'  
colMeans(x)  
## S4 method for signature 'gpu.matrix.torch'  
colMeans(x)  
## S4 method for signature 'gpu.matrix.tensorflow'  
mean(x)  
## S4 method for signature 'gpu.matrix.torch'  
mean(x)  
  
## S4 method for signature 'gpu.matrix.tensorflow'  
rowVars(x)  
## S4 method for signature 'gpu.matrix.torch'  
rowVars(x)  
## S4 method for signature 'gpu.matrix.tensorflow'  
colVars(x)  
## S4 method for signature 'gpu.matrix.torch'  
colVars(x)  
  
## S4 method for signature 'gpu.matrix.tensorflow'  
rowRanks(x)  
## S4 method for signature 'gpu.matrix.torch'  
rowRanks(x)  
## S4 method for signature 'gpu.matrix.tensorflow'  
colRanks(x)  
## S4 method for signature 'gpu.matrix.torch'  
colRanks(x)  
  
## S4 method for signature 'gpu.matrix.tensorflow'  
rowSums(x)
```

```
## S4 method for signature 'gpu.matrix.torch'  
rowSums(x)  
## S4 method for signature 'gpu.matrix.tensorflow'  
colSums(x)  
## S4 method for signature 'gpu.matrix.torch'  
colSums(x)  
## S4 method for signature 'gpu.matrix.tensorflow'  
sum(x)  
## S4 method for signature 'gpu.matrix.torch'  
sum(x)
```

## Arguments

x                    a [gpu.matrix](#).

## Details

The value returned by almost each function is a numeric vector stored in the CPU. Only the function `rowRanks`, `colRanks`, and `sum` return a `gpu.matrix`-class object.

These functions internally calls the corresponding function of the library `torch` or `tensorflow` (depending on the type of input `gpu.matrix`-class). If the input `gpu.matrix`-class object is stored on the GPU, then the operations will be performed on the GPU. See [gpu.matrix](#).

## Value

`max`, `rowMaxs`, `colMaxs` calculate the maximum value of a `gpu.matrix`-class object, of each row and of each column respectively. `which.max` determines the location of the maximum value.

`min`, `rowMins`, `colMins` calculate the minimum value of a `gpu.matrix`-class object, of each row and of each column respectively. `which.min` determines the location of the minimum value.

`mean`, `rowMeans`, `colMeans` calculate the mean (average) value of a `gpu.matrix`-class object, of each row and of each column respectively.

`rowVars`, `colVars` calculate the variance of each row and of each column of a `gpu.matrix`-class object respectively.

`rowRanks`, `colRanks`: given a `gpu.matrix`-class object, these functions return a `gpu.matrix` which rearranges each row and each column into ascending respectively.

`rowSums`, `colSums`, `sum` sum the value of a `gpu.matrix`-class object, of each row and of each column respectively.

## See Also

For more information:

[rowMaxs](#), [colMaxs](#), [max](#), [which.max](#), and [torch\\_max](#).

[rowMins](#), [colMins](#), [min](#), [which.min](#), and [torch\\_min](#).

[rowMeans](#), [colMeans](#), [mean](#), and [torch\\_mean](#).

[rowVars](#), [colVars](#), and [torch\\_var](#).

[rowRanks](#), [colRanks](#), and [torch\\_argsort](#).  
[rowSums](#), [colSums](#), [sum](#), and [torch\\_sum](#).

## Examples

```
## Not run:
a <- gpu.matrix(rnorm(9),3,3)

#the maximum value of a:
max(a)

#maximum of value in each row of a:
rowMaxs(a)

#maximum value in each column of a:
colMaxs(a)

#index of the maximum value of a:
which.max(a)

#minimum value of a:
min(a)

#minimum value in each row of a:
rowMins(a)

#minimum value in each column of a:
colMins(a)

#index of the minimum value in a:
which.min(a)

#mean of a:
mean(a)

#mean of each row of a:
rowMeans(a)

#mean of each column of a:
colMeans(a)

#variance of each row of a:
rowVars(a)

#variance of each column of a:
colVars(a)

#sum of all values of a:
sum(a)

#sum of each row of a:
```

```

rowSums(a)

#sum of each column of a:
colSums(a)

#ranking of each row of a:
rowRanks(a)

#ranking of each column of a:
colRanks(a)

## End(Not run)

```

---

NMFgpuMatrix

*Non negative factorization of a matrix*


---

### Description

The non-negative factorization (NMF) of a matrix is an approximate factorization where an initial matrix  $V$  is approximated by the product of two matrices  $W$  and  $H$  so that,

$$V \approx WH$$

This function operates in the same way with the 'base' matrix objects as with `gpu.matrix`-class objects, and it does not require any additional changes beyond initializing the input matrix as a `gpu.matrix`-class object.

### Usage

```

NMFgpuMatrix(V, k = 10, Winit = NULL,
             Hinit = NULL, tol = 1e-06,
             niter = 100)

```

### Arguments

<code>V</code>	a <code>gpu.matrix</code> . Values in $V$ must be $\geq 0$ .
<code>k</code>	The inner dimension of the product of the matrices $W$ and $H$ . That is, it corresponds to the number of columns in $W$ and the number of rows in $H$ .
<code>Winit</code>	Initial value for matrix $W$ . Initial values for $W$ must be $\geq 0$ .
<code>Hinit</code>	Initial value for matrix $H$ . Initial values for $H$ must be $\geq 0$ .
<code>tol</code>	tolerance to be used for the estimation.
<code>niter</code>	maximum number of iterations.

## Details

We have implemented our own non-negative matrix factorization (NMF) function using Lee and Seung[1] multiplicative update rule:

$$W_{[i,j]}^{n+1} \leftarrow W_{[i,j]}^n \frac{(V(H^{n+1})^T)_{[i,j]}}{(W^n H^{n+1} (H^{n+1})^T)_{[i,j]}}$$

and

$$H_{[i,j]}^{n+1} \leftarrow H_{[i,j]}^n \frac{((W^n)^T V)_{[i,j]}}{((W^n)^T W^n H^n)_{[i,j]}}$$

to update the  $W$  and  $H$  respectively.

Note that the values of  $V$  must be positive. If any value of  $V$  is negative, it will be set to 0. If this happens, the following warning message will be displayed: "The values of  $V$  must be positive. Negative values in  $V$  are set to 0."

If the user decides to initialise the values of  $W$  and  $H$ , they must also be positive. If there are negative values, they will be set to 0. The following warning message will be displayed: "The Winit values must be positive. Negative values in Winit are set to 0" if Winit has negative values or "The values of Hinit must be positive. Negative values in Hinit are set to 0" if Winit has negative values.

In addition, Winit and Hinit must also have the correct dimensions. Winit must fulfil two conditions:  $nrow(Winit) == nrow(V)$  and  $ncol(Winit) == k$ . If not, the function will stop with the following error message: "The dimensions of the Winit matrix are incorrect. Please check that  $nrow(Winit) == nrow(V)$  and that  $ncol(Winit) == k$ ". On the other hand, Hinit must fulfil two conditions:  $nrow(Winit) == nrow(V)$  and that  $ncol(Winit) == k$ . If not, the function will stop with the following error message: "The dimensions of the Winit matrix are incorrect. Please check that  $nrow(Winit) == nrow(V)$  and that  $ncol(Winit) == k$ ".

If the input `gpu.matrix`-class object is stored on the GPU, then the operations will be performed on the GPU. See `gpu.matrix`.

## Value

The function returns a list that contains the corresponding matrix  $W$  and  $H$ . If the input  $V$  matrix is a `gpu.matrix`-class object, then both  $W$  and  $H$  are also `gpu.matrix`-class objects.

## Author(s)

Angel Rubio and Cesar Lobato.

## References

[1] Lee, D., Seung, H. Learning the parts of objects by non-negative matrix factorization. Nature 401, 788–791 (1999). <https://doi.org/10.1038/44565>

## Examples

```
## Not run:
library(Matrix)
set.seed(1)
a1 <- gpu.matrix(runif(90), nrow=30, ncol=3)
a2 <- gpu.matrix(runif(30), nrow=3, ncol=10)
```

```
V <- a1 %*% a2
b <- NMFgpmatrix(V = V, k=3, tol = 1e-6)

#check result:
image(Matrix(as.matrix(V)))
image(Matrix(as.matrix(b$W %*% b$H)))

## End(Not run)
```

---

power\_of\_a\_matrix      *Compute the kth power of a matrix.*

---

### Description

Compute the kth power of a square matrix, i.e., multiply the `gpu.matrix`-class object by itself as many times as user indicates.

### Usage

```
## S4 method for signature 'gpu.matrix.tensorflow,numeric'
x %^^ k
## S4 method for signature 'gpu.matrix.torch,numeric'
x %^^ k
```

### Arguments

x                    a `gpu.matrix`.

k                    the power of the matrix.

### Details

The input `x` `gpu.matrix`-class needs to be square. This function internally call the method `%^^` as many times as required. If the input `gpu.matrix`-class object is stored on the GPU, then the operations will be performed on the GPU. See [gpu.matrix](#).

### Value

the `n`th power of the input `gpu.matrix`-class object. The returned matrix is also a `gpu.matrix`-class object.

### See Also

See also: `%*%`.



**Examples**

```
## Not run:

a <- gpu.matrix(rnorm(9),nrow=3,ncol=3)
a %^^ 5

## End(Not run)
```

---

qr\_decomposition

*The QR Decomposition of a GPUmatrix object*


---

**Description**

These functions mimic the base qr family functions to operate on gpu.matrix-class objects.

**Usage**

```
## S4 method for signature 'gpu.matrix.tensorflow'
qr(x,...)
## S4 method for signature 'gpu.matrix.torch'
qr(x,...)

## S4 method for signature 'list'
qr.Q(qr,complete,Dvec)
## S4 method for signature 'list'
qr.R(qr,complete)
## S4 method for signature 'list'
qr.X(qr,complete)

## S4 method for signature 'list'
qr.coef(qr,y)
## S4 method for signature 'list'
qr.qy(qr,y)
## S4 method for signature 'list'
qr.qty(qr,y)
## S4 method for signature 'list'
qr.resid(qr,y)
## S4 method for signature 'ANY,gpu.matrix.tensorflow'
qr.solve(a,b)
## S4 method for signature 'ANY,gpu.matrix.torch'
qr.solve(a,b)
## S4 method for signature 'gpu.matrix.tensorflow,ANY'
qr.solve(a,b)
```

```

## S4 method for signature 'gpu.matrix.tensorflow,gpu.matrix.tensorflow'
qr.solve(a,b)
## S4 method for signature 'gpu.matrix.torch,ANY'
qr.solve(a,b)
## S4 method for signature 'gpu.matrix.torch,gpu.matrix.torch'
qr.solve(a,b)
## S4 method for signature 'list,ANY'
qr.solve(a,b)

```

### Arguments

x	a <a href="#">gpu.matrix</a> .
y,b	a <a href="#">gpu.matrix</a> corresponding to the right-hand side of equations $ax=b$ or $ax=y$ .
...	further arguments passed to or from other methods.
qr	a list resulting from the application of the function qr.
complete	The same as in 'base' function <code>qr.Q</code> , and <code>qr.X</code>
Dvec	The same as in 'base' function <code>qr.Q</code>
a	a <a href="#">gpu.matrix</a> corresponding to the left-hand side of equations $ax=b$ or $ax=y$ .

### Details

The function `qr` internally calls the corresponding function of the library `torch` or `tensorflow` (depending on the type of input `gpu.matrix-class`).

The QR decomposition can be used to solve the equation  $Ax=b$  for a given matrix  $A$ , and a vector of observations  $b$ . In this context, the functions `qr.coef`, and `qr.resid` return the coefficients, and residuals values. Moreover, the functions `qr.qy`, and `qr.qty` returns  $Q \%* \% y$  and  $Q \%* \% t(y)$ . Note that if parameter `complete` is `TRUE` then an arbitrary orthogonal completion of the  $X$  and  $Q$  matrix or whether the  $R$  matrix is to be completed by binding zero-value rows beneath the square upper triangle.

The function `solve.qr` solves the system of equations  $Ax=b$  via the QR decomposition. This function internally calls the corresponding function of the library `torch` or `tensorflow` (depending on the type of input `gpu.matrix-class`).

If the input `gpu.matrix-class` object(s) are stored on the GPU, then the operations will be performed on the GPU. See [gpu.matrix](#).

### Value

The function `qr` returns a list with the following items:

q	The corresponding complete matrix $Q$ resulting from the application of the QR decomposition to $a$ . It is a <code>gpu.matrix-class</code> object.
r	The corresponding complete matrix $R$ resulting from the application of the QR decomposition to $a$ . It is a <code>gpu.matrix-class</code> object.
x	The matrix $a$ . It is a <code>gpu.matrix-class</code> object.

Please note that the output returned by this function is different from the 'base' function `qr`, which returns an object of the 'qr' class.

After performing a QR decomposition on a matrix  $A$ , given the resulting object, the functions `qr.X`, `qr.Q`, and `qr.R` return the original matrix  $A$ , the matrix  $Q$ , and the matrix  $R$  respectively. The returned matrices are `gpu.matrix`-class objects.

The functions `qr.coef` and `qr.resid` return the coefficients and residuals when fitting the equation  $Ax=b$ . In this context, the functions `qr.qy`, and `qr.qty` returns  $Q^{*}y$  and  $Q^{*}t(y)$ . The resulting vectors are objects of the class `gpu.matrix`.

The function `qr.solve` returns a `gpu.matrix`-class object containing the coefficients of the solution of the system of equations  $Ax=b$  by QR decomposition.

### See Also

See [qr](#), [linalg\\_qr](#), [torch\\_triangular\\_solve](#)

### Examples

```
## Not run:
## overdetermined system
A <- gpu.matrix(runif(12),nrow = 4)
b <- gpu.matrix(rnorm(4),ncol=1)
qr.solve(a = A, b)
qr_gpu <- qr(A)
qr.solve(a=qr_gpu,b)
qr.coef(qr = qr_gpu,b)
qr.resid(qr = qr_gpu,b)
qr.qty(qr = qr_gpu,b)
qr.qy(qr = qr_gpu,b)
qr.X(qr = qr_gpu,complete = T)
qr.Q(qr = qr_gpu,complete = T)
qr.R(qr = qr_gpu,complete = T)

## underdetermined system
A <- gpu.matrix(runif(12),nrow = 3)
b <- gpu.matrix(rnorm(3),ncol=1)
qr.solve(a = A, b)
qr_gpu <- qr(A)
qr.solve(a=qr_gpu,b)
qr.coef(qr = qr_gpu,b)
qr.resid(qr = qr_gpu,b)
qr.qty(qr = qr_gpu,b)
qr.qy(qr = qr_gpu,b)
qr.X(qr = qr_gpu,complete = T)
qr.Q(qr = qr_gpu,complete = T)
qr.R(qr = qr_gpu,complete = T)

## End(Not run)
```

---

round	<i>rounding of numbers</i>
-------	----------------------------

---

### Description

It mimics the base function 'round' to operate on `gpu.matrix`-class objects. This function rounds the values in its first argument to the specified number of decimal places (default 0).

### Usage

```
## S4 method for signature 'gpu.matrix.tensorflow,ANY'  
round(x)  
## S4 method for signature 'gpu.matrix.torch,missing'  
round(x,digits)  
## S4 method for signature 'gpu.matrix.torch,numeric'  
round(x,digits)  
## S4 method for signature 'gpu.matrix.tensorflow,missing'  
round(x,digits)  
## S4 method for signature 'gpu.matrix.tensorflow,numeric'  
round(x,digits)
```

### Arguments

x	a <code>gpu.matrix</code> .
digits	integer indicating the number of decimal places (round) or significant digits (signif) to be used.

### Details

The function `round` internally calls the corresponding function of the library `torch` or `tensorflow` (depending on the type of input `gpu.matrix`-class).

The behaviour of the function mimics the 'base' function `round`. Note that for rounding off a 5, the function will consider "go to the even digit". Therefore, `round(2.5) = 2` and `round(3.5) = 4`. For more details see [round](#), and [torch\\_round](#).

If the input `gpu.matrix`-class object is stored on the GPU, then the operations will be performed on the GPU. See [gpu.matrix](#).

### Value

The function will return a `gpu.matrix`-class object with the rounded values.

### See Also

[round](#), and [torch\\_round](#).

**Examples**

```
## Not run:

a <- gpu.matrix(rnorm(9),3,3)
round(a,digits = 3) #round to the third digit

## End(Not run)
```

---

solve_gpu.matrix	<i>Solve a System of Equations</i>
------------------	------------------------------------

---

**Description**

The function `solve` mimics of the 'base' function `solve` to operate on `gpu.matrix`-class objects: it "solves the equation  $a \cdot x = b$ ."

The function `ginv` mimics the function `ginv` of package 'MASS' to operate on `gpu.matrix`-class objects: it "Calculates the Moore-Penrose generalized inverse of a matrix X."

The function `chol_solve` is a GPUmatrix own function. This function uses the Cholesky decomposition to solve a system of equations.

**Usage**

```
## S4 method for signature 'ANY,gpu.matrix.tensorflow'
solve(a,b)
## S4 method for signature 'ANY,gpu.matrix.torch'
solve(a,b)
## S4 method for signature 'gpu.matrix.tensorflow,ANY'
solve(a,b)
## S4 method for signature 'gpu.matrix.tensorflow,missing'
solve(a)
## S4 method for signature 'gpu.matrix.torch,ANY'
solve(a,b)
## S4 method for signature 'gpu.matrix.torch,missing'
solve(a)

## S4 method for signature 'gpu.matrix.torch'
ginv(X,tol)
## S4 method for signature 'gpu.matrix.tensorflow'
ginv(X,tol)

## S4 method for signature 'ANY,gpu.matrix.torch'
chol_solve(x,y)
```

```

## S4 method for signature 'ANY,gpu.matrix.tensorflow'
chol_solve(x,y)
## S4 method for signature 'gpu.matrix.torch,ANY'
chol_solve(x,y)
## S4 method for signature 'gpu.matrix.tensorflow,ANY'
chol_solve(x,y)

```

## Arguments

These inputs correspond to the solve function:

- a a square numeric or complex [gpu.matrix](#) containing the coefficients of the linear system.
- b a numeric or complex vector or matrix giving the right-hand side(s) of the linear system. If b missing, solve will return the inverse of a.

These inputs correspond to the chol\_solve function:

- x Given the equation  $Ax=b$ , x must be the transposed of the cholesky decomposition of matrix A if A is a real symmetric positive-definite square matrix.
- y a numeric or complex vector or matrix giving the right-hand side(s) of the linear system.

These inputs correspond to the ginv function:

- X Matrix for which the Moore-Penrose inverse is required.
- tol A relative tolerance to detect zero singular values.

## Details

The functions solve, and ginv internally calls the corresponding function of the library torch or tensorflow (depending on the type of input [gpu.matrix-class](#)).

If the input [gpu.matrix-class](#) object(s) are stored on the GPU, then the operations will be performed on the GPU. See [gpu.matrix](#).

## Value

The result of these functions is an object of the class [gpu.matrix](#).

## See Also

See also [solve](#), [ginv](#), [torch\\_inverse](#), and [torch\\_pinverse](#).

For cholesky decomposition see [chol](#) from base or [matrix\\_decomposition](#) from GPUmatrix.

Also see [qr.solve](#).

## Examples

```
## Not run:

#solve a system of equations:
a <- gpu.matrix(rnorm(9),nrow=3,ncol=3)
b <- c(1,1,1)
betas <- solve(a,b)
a %*% betas

#the inverse matrix
inv <- solve(a)
a %*% inv

#inverse using ginv
inv_2 <- ginv(a)
a %*% inv_2

#chol_solve: it can be applies only if
# in the equation Ax=b A is real symmetric positive-definite square matrix.
a <- gpu.matrix(rnorm(9),3,3)
A <- tcrossprod(a) #A is symmetrix positive-definite
b <- gpu.matrix(rnorm(3))

x_solve <- solve(A,b) #using solve to compare results
x_chol_solve <- chol_solve(t(chol(A)),b) #using chol_solve
#NOTE: notice that the input for chol_solve is the Cholesky decomposition
# of matrix A.

## End(Not run)
```

---

sort

*sort*

---

## Description

This function mimics the 'base' function `sort` to operate on `gpu.matrix`-class objects. This function sort the input matrix into ascending or descending order.

## Usage

```
## S4 method for signature 'gpu.matrix.tensorflow,logical'
sort(x,decreasing)
## S4 method for signature 'gpu.matrix.torch,logical'
sort(x,decreasing)
```

**Arguments**

`x` a `gpu.matrix`.  
`decreasing` Logical. Should the sort be increasing or decreasing?

**Details**

The function internally calls the corresponding function of the library `torch` or `tensorflow` (depending on the type of input `gpu.matrix`-class).

If the input `gpu.matrix`-class object(s) are stored on the GPU, then the operations will be performed on the GPU. See `gpu.matrix`.

**Value**

Returns a `gpu.matrix`-class object that is a vector (or a matrix with one column) with the values sorted.

**See Also**

`sort`, `torch_sort`.

**Examples**

```
## Not run:
a <- gpu.matrix(rnorm(9),nrow=3,ncol=3)
sort(a) #returns a vector with the data sorted.

## End(Not run)
```

---

type of `gpu.matrix`      *Spicify type of 'GPUmatrix'*

---

**Description**

`dtype` and `dtype<-` are functions that show or set the number of bits to use to store the number. The possible options are "float64" for float64 (default), "float32" for float32 and "int" for int64. float64 uses 64 bits, that means that float64's take up twice as much memory than float32, thus doing operations on them may be slower in some machine architectures. However, float64's can represent numbers much more accurately than 32 bit floats. They also allow much larger numbers to be stored.

`to_dense` is a function that transforms a sparse matrix to a dense matrix. On the other hand, `to_sparse` transforms a dense matrix to a sparse matrix.



**Usage**

```
## S4 method for signature 'gpu.matrix.torch'  
to_dense(x)  
## S4 method for signature 'gpu.matrix.tensorflow'  
to_dense(x)  
## S4 method for signature 'gpu.matrix.torch'  
to_sparse(x)  
## S4 method for signature 'gpu.matrix.tensorflow'  
to_sparse(x)  
  
## S4 method for signature 'gpu.matrix.torch'  
dtype(x)  
## S4 method for signature 'gpu.matrix.tensorflow'  
dtype(x)  
## S4 replacement method for signature 'gpu.matrix.torch'  
dtype(x) <- value  
## S4 replacement method for signature 'gpu.matrix.tensorflow'  
dtype(x) <- value
```

**Arguments**

<code>x</code>	a <a href="#">gpu.matrix</a> .
<code>value</code>	type of <code>gpu.matrix</code> object

**Value**

`dtype` and `dtype <-` show or set the number of bits to use to store the number.

`to_dense` returns a dense `gpu.matrix`-class object while the function `to_sparse` returns a sparse `gpu.matrix`-class object.

**See Also**

See also [gpu.matrix](#).

**Examples**

```
## Not run:  
  
a <- gpu.matrix(rnorm(9),3,3)  
  
dtype(a) #bits used to store the numbers: it is float64 by default.  
  
b <- a  
dtype(b) <- "float32" #change to float32  
b
```

```
b <- a
dtype(b) <- "int" #change to integer64 (int64)
b

#sparse or dense matrices
A <- gpu.matrix(data=c(1,1,1,0,0,1,0,1,0),3,3)
A #A is a dense gpu.matrix

A_sparse <- to_sparse(A) #transform A to a sparse matrix.
A_sparse #this matrix stores the where number different to 0 were placed.

to_dense(A_sparse) #transform A_sparse to a dense matrix and we obtain the orginal matrix A:
A

## End(Not run)
```



- %x%,gpu.matrix.torch,ANY-method (kroneker), 34
- %x%-methods (kroneker), 34
- %\*%, 38, 48
- %&&, 38
  
- aperm, 2
- apply, 3, 4
- apply,gpu.matrix.tensorflow-method (apply), 3
- apply,gpu.matrix.torch-method (apply), 3
- apply-methods (apply), 3
- array, 6
- as.array (as\_methods), 5
- as.array,gpu.matrix.tensorflow-method (as\_methods), 5
- as.array,gpu.matrix.torch-method (as\_methods), 5
- as.array-methods (as\_methods), 5
- as.gpu.matrix (gpu.matrix), 26
- as.gpu.matrix,ANY-method (gpu.matrix), 26
- as.gpu.matrix-methods (gpu.matrix), 26
- as.list (as\_methods), 5
- as.list,gpu.matrix.tensorflow-method (as\_methods), 5
- as.list,gpu.matrix.torch-method (as\_methods), 5
- as.list-methods (as\_methods), 5
- as.matrix (as\_methods), 5
- as.matrix,gpu.matrix.tensorflow-method (as\_methods), 5
- as.matrix,gpu.matrix.torch-method (as\_methods), 5
- as.matrix-methods (as\_methods), 5
- as.numeric (as\_methods), 5
- as.numeric,gpu.matrix.tensorflow-method (as\_methods), 5
- as.numeric,gpu.matrix.torch-method (as\_methods), 5
- as.numeric-methods (as\_methods), 5
- as.vector (as\_methods), 5
- as.vector,gpu.matrix.tensorflow-method (as\_methods), 5
- as.vector,gpu.matrix.torch-method (as\_methods), 5
- as.vector-methods (as\_methods), 5
- as\_methods, 5
  
- c, 9
- c,gpu.matrix.tensorflow-method (concatenate\_gpu.matrix), 8
- c,gpu.matrix.torch-method (concatenate\_gpu.matrix), 8
- c,numMatrixLike-method (concatenate\_gpu.matrix), 8
- c-methods (concatenate\_gpu.matrix), 8
- cbind, 7, 8
- cbind2, 7, 8
- cbind2 (cbind\_rbind\_methods), 7
- cbind2,ANY,gpu.matrix.tensorflow-method (cbind\_rbind\_methods), 7
- cbind2,ANY,gpu.matrix.torch-method (cbind\_rbind\_methods), 7
- cbind2,gpu.matrix.tensorflow,ANY-method (cbind\_rbind\_methods), 7
- cbind2,gpu.matrix.torch,ANY-method (cbind\_rbind\_methods), 7
- cbind2-methods (cbind\_rbind\_methods), 7
- cbind\_rbind\_methods, 7
- chol, 40, 54
- chol (matrix\_decomposition), 39
- chol,gpu.matrix.tensorflow-method (matrix\_decomposition), 39
- chol,gpu.matrix.torch-method (matrix\_decomposition), 39
- chol-methods (matrix\_decomposition), 39
- chol\_solve, 40
- chol\_solve (solve\_gpu.matrix), 53
- chol\_solve,ANY,gpu.matrix.tensorflow-method (solve\_gpu.matrix), 53
- chol\_solve,ANY,gpu.matrix.torch-method (solve\_gpu.matrix), 53
- chol\_solve,gpu.matrix.tensorflow,ANY-method (solve\_gpu.matrix), 53
- chol\_solve,gpu.matrix.torch,ANY-method (solve\_gpu.matrix), 53
- chol\_solve-methods (solve\_gpu.matrix), 53
- colMaxs, 44
- colMaxs (matrix\_ranges), 42
- colMaxs,gpu.matrix.tensorflow-method (matrix\_ranges), 42
- colMaxs,gpu.matrix.torch-method (matrix\_ranges), 42
- colMaxs-methods (matrix\_ranges), 42
- colMeans, 44

- colMeans (matrix\_ranges), 42
- colMeans, gpu.matrix.tensorflow-method (matrix\_ranges), 42
- colMeans, gpu.matrix.torch-method (matrix\_ranges), 42
- colMeans-methods (matrix\_ranges), 42
- colMins, 44
- colMins (matrix\_ranges), 42
- colMins, gpu.matrix.tensorflow-method (matrix\_ranges), 42
- colMins, gpu.matrix.torch-method (matrix\_ranges), 42
- colMins-methods (matrix\_ranges), 42
- colnames, 18
- colnames (dim\_and\_names), 17
- colnames, gpu.matrix.tensorflow-method (dim\_and\_names), 17
- colnames, gpu.matrix.torch-method (dim\_and\_names), 17
- colnames-methods (dim\_and\_names), 17
- colRanks, 45
- colRanks (matrix\_ranges), 42
- colRanks, gpu.matrix.tensorflow-method (matrix\_ranges), 42
- colRanks, gpu.matrix.torch-method (matrix\_ranges), 42
- colRanks-methods (matrix\_ranges), 42
- colSums, 45
- colSums (matrix\_ranges), 42
- colSums, gpu.matrix.tensorflow-method (matrix\_ranges), 42
- colSums, gpu.matrix.torch-method (matrix\_ranges), 42
- colSums-methods (matrix\_ranges), 42
- colVars, 44
- colVars (matrix\_ranges), 42
- colVars, gpu.matrix.tensorflow-method (matrix\_ranges), 42
- colVars, gpu.matrix.torch-method (matrix\_ranges), 42
- colVars-methods (matrix\_ranges), 42
- concatenate\_gpu.matrix, 8
- cor, 11, 12
- cor (cor\_cov), 10
- cor, ANY, gpu.matrix.tensorflow, ANY, ANY-method (cor\_cov), 10
- cor, ANY, gpu.matrix.torch, ANY, ANY-method (cor\_cov), 10
- cor, gpu.matrix.tensorflow, ANY, ANY, ANY-method (cor\_cov), 10
- cor, gpu.matrix.tensorflow, ANY, missing, character-method (cor\_cov), 10
- cor, gpu.matrix.tensorflow, missing, ANY, ANY-method (cor\_cov), 10
- cor, gpu.matrix.tensorflow, missing, missing, character-method (cor\_cov), 10
- cor, gpu.matrix.torch, ANY, ANY, ANY-method (cor\_cov), 10
- cor, gpu.matrix.torch, ANY, missing, character-method (cor\_cov), 10
- cor, gpu.matrix.torch, missing, ANY, ANY-method (cor\_cov), 10
- cor, gpu.matrix.torch, missing, missing, character-method (cor\_cov), 10
- cor, gpu.matrix.torch, missing, missing, missing-method (cor\_cov), 10
- cor-methods (cor\_cov), 10
- cor\_cov, 10
- cov, 12
- cov (cor\_cov), 10
- cov, ANY, gpu.matrix.tensorflow-method (cor\_cov), 10
- cov, ANY, gpu.matrix.torch-method (cor\_cov), 10
- cov, gpu.matrix.tensorflow, ANY-method (cor\_cov), 10
- cov, gpu.matrix.tensorflow, missing-method (cor\_cov), 10
- cov, gpu.matrix.tensorflow-method (cor\_cov), 10
- cov, gpu.matrix.torch, ANY-method (cor\_cov), 10
- cov, gpu.matrix.torch, missing-method (cor\_cov), 10
- cov, gpu.matrix.torch-method (cor\_cov), 10
- cov-methods (cor\_cov), 10
- cov2cor, 11, 12
- cov2cor (cor\_cov), 10
- cov2cor, gpu.matrix.tensorflow-method (cor\_cov), 10
- cov2cor, gpu.matrix.torch-method (cor\_cov), 10
- cov2cor-methods (cor\_cov), 10
- crossprod, 38
- crossprod (matrix-product), 37

- crossprod,ANY,gpu.matrix.tensorflow-method (matrix-product), 37
- crossprod,ANY,gpu.matrix.torch-method (matrix-product), 37
- crossprod,gpu.matrix.tensorflow,ANY-method (matrix-product), 37
- crossprod,gpu.matrix.tensorflow,missing-method (matrix-product), 37
- crossprod,gpu.matrix.torch,ANY-method (matrix-product), 37
- crossprod,gpu.matrix.torch,missing-method (matrix-product), 37
- crossprod-methods (matrix-product), 37
  
- density, 12, 13, 14
- density,gpu.matrix.tensorflow-method (density), 12
- density,gpu.matrix.torch-method (density), 12
- density-methods (density), 12
- det, 14, 15
- det,gpu.matrix.tensorflow-method (det), 14
- det,gpu.matrix.torch-method (det), 14
- det-methods (det), 14
- determinant (det), 14
- determinant,gpu.matrix.tensorflow,logical-method (det), 14
- determinant,gpu.matrix.tensorflow,missing-method (det), 14
- determinant,gpu.matrix.torch,logical-method (det), 14
- determinant,gpu.matrix.torch,missing-method (det), 14
- determinant-methods (det), 14
- diag, 16, 16
- diag,gpu.matrix.tensorflow-method (diag), 16
- diag,gpu.matrix.torch-method (diag), 16
- diag-methods (diag), 16
- diag<- (diag), 16
- diag<-,gpu.matrix.tensorflow,numeric-method (diag), 16
- diag<-,gpu.matrix.torch,numeric-method (diag), 16
- diag<--methods (diag), 16
- dim, 18
- dim (dim\_and\_names), 17
- dim,gpu.matrix.tensorflow-method (dim\_and\_names), 17
- dim,gpu.matrix.torch-method (dim\_and\_names), 17
- dim-methods (dim\_and\_names), 17
- dim<- (dim\_and\_names), 17
- dim<-,gpu.matrix.tensorflow,vector-method (dim\_and\_names), 17
- dim<-,gpu.matrix.torch,vector-method (dim\_and\_names), 17
- dim<--methods (dim\_and\_names), 17
- dim\_and\_names, 17
- dimnames, 18
- dimnames (dim\_and\_names), 17
- dimnames,gpu.matrix.tensorflow-method (dim\_and\_names), 17
- dimnames,gpu.matrix.torch-method (dim\_and\_names), 17
- dimnames-methods (dim\_and\_names), 17
- dimnames<- (dim\_and\_names), 17
- dimnames<-,gpu.matrix.tensorflow,vector-method (dim\_and\_names), 17
- dimnames<-,gpu.matrix.torch,vector-method (dim\_and\_names), 17
- dimnames<--methods (dim\_and\_names), 17
- dist, 19, 20
- dist,gpu.matrix.torch-method (dist), 19
- dist-methods (dist), 19
- dtype, 28
- dtype (type of gpu.matrix), 56
- dtype,gpu.matrix.tensorflow-method (type of gpu.matrix), 56
- dtype,gpu.matrix.torch-method (type of gpu.matrix), 56
- dtype-methods (type of gpu.matrix), 56
- dtype<- (type of gpu.matrix), 56
- dtype<-,gpu.matrix.tensorflow-method (type of gpu.matrix), 56
- dtype<-,gpu.matrix.torch-method (type of gpu.matrix), 56
- dtype<--methods (type of gpu.matrix), 56
- eigen, 40
- eigen (matrix\_decomposition), 39
- eigen,gpu.matrix.tensorflow-method (matrix\_decomposition), 39
- eigen,gpu.matrix.torch-method (matrix\_decomposition), 39
- eigen-methods (matrix\_decomposition), 39

- expm, [21](#)
- expmGPU, [21](#)
- expmGPU, gpu.matrix.tensorflow-method (expmGPU), [21](#)
- expmGPU, gpu.matrix.torch-method (expmGPU), [21](#)
- expmGPU-methods (expmGPU), [21](#)
- Extract, [23](#)
- extract\_gpu.matrix, [22](#)
  
- family, [30](#)
- fft, [24, 25](#)
- fft, gpu.matrix.tensorflow, missing-method (fft), [24](#)
- fft, gpu.matrix.tensorflow-method (fft), [24](#)
- fft, gpu.matrix.torch, logical-method (fft), [24](#)
- fft, gpu.matrix.torch, missing-method (fft), [24](#)
- fft, gpu.matrix.torch-method (fft), [24](#)
- fft-methods (fft), [24](#)
  
- ginv, [54](#)
- ginv (solve\_gpu.matrix), [53](#)
- ginv, gpu.matrix.tensorflow-method (solve\_gpu.matrix), [53](#)
- ginv, gpu.matrix.torch-method (solve\_gpu.matrix), [53](#)
- ginv-methods (solve\_gpu.matrix), [53](#)
- glm, [32](#)
- glm.fit.GPU (GPUglm), [30](#)
- gpu.matrix, [3, 4, 6–11, 13, 15, 16, 18–21, 23, 25, 26, 28, 29, 31, 34, 35, 38, 40, 42, 44, 46–48, 50, 52, 54, 56, 57](#)
- gpu.matrix-class, [29](#)
- GPUglm, [30, 36](#)
  
- head, [42](#)
- head
  - (matrix\_general\_operators\_methods), [41](#)
- head, gpu.matrix.tensorflow-method (matrix\_general\_operators\_methods), [41](#)
- head, gpu.matrix.torch-method (matrix\_general\_operators\_methods), [41](#)
  
- head-methods
  - (matrix\_general\_operators\_methods), [41](#)
- hist, [13, 14](#)
- hist (density), [12](#)
- hist, gpu.matrix.tensorflow-method (density), [12](#)
- hist, gpu.matrix.torch-method (density), [12](#)
- hist-methods (density), [12](#)
  
- installTorch, [34](#)
- is.numeric (as\_methods), [5](#)
- is.numeric, gpu.matrix.tensorflow-method (as\_methods), [5](#)
- is.numeric, gpu.matrix.torch-method (as\_methods), [5](#)
- is.numeric-methods (as\_methods), [5](#)
  
- kronecker, [34](#)
- kroneker, [34](#)
  
- length, [18](#)
- length (dim\_and\_names), [17](#)
- length, gpu.matrix.tensorflow-method (dim\_and\_names), [17](#)
- length, gpu.matrix.torch-method (dim\_and\_names), [17](#)
- length-methods (dim\_and\_names), [17](#)
- linalg\_eig, [40](#)
- linalg\_qr, [51](#)
- list, [6](#)
- LR\_GradientConjugate\_gpumatrix, [32, 35](#)
  
- match.fun, [4](#)
- Matrix, [28, 29, 35](#)
- matrix, [6, 28, 29, 35](#)
- matrix-product, [37](#)
- matrix\_decomposition, [39, 54](#)
- matrix\_general\_operators\_methods, [41](#)
- matrix\_ranges, [42](#)
- max, [44](#)
- max, gpu.matrix.tensorflow-method (matrix\_ranges), [42](#)
- max, gpu.matrix.torch-method (matrix\_ranges), [42](#)
- max-methods (matrix\_ranges), [42](#)
- mean, [44](#)
- mean (matrix\_ranges), [42](#)

- mean, gpu.matrix.tensorflow-method (matrix\_ranges), 42
- mean, gpu.matrix.torch-method (matrix\_ranges), 42
- mean-methods (matrix\_ranges), 42
- min, 44
- min (matrix\_ranges), 42
- min, gpu.matrix.tensorflow-method (matrix\_ranges), 42
- min, gpu.matrix.torch-method (matrix\_ranges), 42
- min-methods (matrix\_ranges), 42
- model.offset, 31
- mvfft, 25
- mvfft (fft), 24
- mvfft, gpu.matrix.tensorflow, missing-method (fft), 24
- mvfft, gpu.matrix.tensorflow-method (fft), 24
- mvfft, gpu.matrix.torch, logical-method (fft), 24
- mvfft, gpu.matrix.torch, missing-method (fft), 24
- mvfft, gpu.matrix.torch-method (fft), 24
- mvfft-methods (fft), 24
- ncol, 18
- ncol (dim\_and\_names), 17
- ncol, gpu.matrix.tensorflow-method (dim\_and\_names), 17
- ncol, gpu.matrix.torch-method (dim\_and\_names), 17
- ncol-methods (dim\_and\_names), 17
- NMFgpumatrix, 46
- nrow, 18
- nrow (dim\_and\_names), 17
- nrow, gpu.matrix.tensorflow-method (dim\_and\_names), 17
- nrow, gpu.matrix.torch-method (dim\_and\_names), 17
- nrow-methods (dim\_and\_names), 17
- numeric, 6
- offset, 31
- power\_of\_a\_matrix, 48
- print
  - (matrix\_general\_operators\_methods), 41
  - print, gpu.matrix.torch-method (matrix\_general\_operators\_methods), 41
  - print-methods (matrix\_general\_operators\_methods), 41
- qr, 40, 51
- qr (qr\_decomposition), 49
- qr, gpu.matrix.tensorflow-method (qr\_decomposition), 49
- qr, gpu.matrix.torch-method (qr\_decomposition), 49
- qr-methods (qr\_decomposition), 49
- qr.coef (qr\_decomposition), 49
- qr.coef, list-method (qr\_decomposition), 49
- qr.coef-methods (qr\_decomposition), 49
- qr.Q (qr\_decomposition), 49
- qr.Q, list-method (qr\_decomposition), 49
- qr.Q-methods (qr\_decomposition), 49
- qr.qty (qr\_decomposition), 49
- qr.qty, list-method (qr\_decomposition), 49
- qr.qty-methods (qr\_decomposition), 49
- qr.qy (qr\_decomposition), 49
- qr.qy, list-method (qr\_decomposition), 49
- qr.qy-methods (qr\_decomposition), 49
- qr.R (qr\_decomposition), 49
- qr.R, list-method (qr\_decomposition), 49
- qr.R-methods (qr\_decomposition), 49
- qr.resid (qr\_decomposition), 49
- qr.resid, list-method (qr\_decomposition), 49
- qr.resid-methods (qr\_decomposition), 49
- qr.solve, 54
- qr.solve (qr\_decomposition), 49
- qr.solve, ANY, gpu.matrix.tensorflow-method (qr\_decomposition), 49
- qr.solve, ANY, gpu.matrix.torch-method (qr\_decomposition), 49
- qr.solve, gpu.matrix.tensorflow, ANY-method (qr\_decomposition), 49
- qr.solve, gpu.matrix.tensorflow, gpu.matrix.tensorflow-method (qr\_decomposition), 49
- qr.solve, gpu.matrix.torch, ANY-method (qr\_decomposition), 49
- qr.solve, gpu.matrix.torch, gpu.matrix.torch-method (qr\_decomposition), 49



- qr.solve,list,ANY-method  
(qr\_decomposition), 49
- qr.solve-methods (qr\_decomposition), 49
- qr.X (qr\_decomposition), 49
- qr.X,list-method (qr\_decomposition), 49
- qr.X-methods (qr\_decomposition), 49
- qr\_decomposition, 49
- rbind, 8
- rbind2 (cbind\_rbind\_methods), 7
- rbind2,ANY,gpu.matrix.tensorflow-method  
(cbind\_rbind\_methods), 7
- rbind2,ANY,gpu.matrix.torch-method  
(cbind\_rbind\_methods), 7
- rbind2,gpu.matrix.tensorflow,ANY-method  
(cbind\_rbind\_methods), 7
- rbind2,gpu.matrix.torch,ANY-method  
(cbind\_rbind\_methods), 7
- rbind2-methods (cbind\_rbind\_methods), 7
- round, 52, 52
- round,gpu.matrix.tensorflow,ANY-method  
(round), 52
- round,gpu.matrix.tensorflow,missing-method  
(round), 52
- round,gpu.matrix.tensorflow,numeric-method  
(round), 52
- round,gpu.matrix.torch,missing-method  
(round), 52
- round,gpu.matrix.torch,numeric-method  
(round), 52
- round-methods (round), 52
- rowMaxs, 44
- rowMaxs (matrix\_ranges), 42
- rowMaxs,gpu.matrix.tensorflow-method  
(matrix\_ranges), 42
- rowMaxs,gpu.matrix.torch-method  
(matrix\_ranges), 42
- rowMaxs-methods (matrix\_ranges), 42
- rowMeans, 44
- rowMeans (matrix\_ranges), 42
- rowMeans,gpu.matrix.tensorflow-method  
(matrix\_ranges), 42
- rowMeans,gpu.matrix.torch-method  
(matrix\_ranges), 42
- rowMeans-methods (matrix\_ranges), 42
- rowMins, 44
- rowMins (matrix\_ranges), 42
- rowMins,gpu.matrix.tensorflow-method  
(matrix\_ranges), 42
- rowMins,gpu.matrix.torch-method  
(matrix\_ranges), 42
- rowMins-methods (matrix\_ranges), 42
- rowNames, 18
- rowNames (dim\_and\_names), 17
- rowNames,gpu.matrix.tensorflow-method  
(dim\_and\_names), 17
- rowNames,gpu.matrix.torch-method  
(dim\_and\_names), 17
- rowNames-methods (dim\_and\_names), 17
- rowRanks, 45
- rowRanks (matrix\_ranges), 42
- rowRanks,gpu.matrix.tensorflow-method  
(matrix\_ranges), 42
- rowRanks,gpu.matrix.torch-method  
(matrix\_ranges), 42
- rowRanks-methods (matrix\_ranges), 42
- rowSums, 45
- rowSums (matrix\_ranges), 42
- rowSums,gpu.matrix.tensorflow-method  
(matrix\_ranges), 42
- rowSums,gpu.matrix.torch-method  
(matrix\_ranges), 42
- rowSums-methods (matrix\_ranges), 42
- rowVars, 44
- rowVars (matrix\_ranges), 42
- rowVars,gpu.matrix.tensorflow-method  
(matrix\_ranges), 42
- rowVars,gpu.matrix.torch-method  
(matrix\_ranges), 42
- rowVars-methods (matrix\_ranges), 42
- show, 42
- show  
(matrix\_general\_operators\_methods),  
41
- show,gpu.matrix.tensorflow-method  
(matrix\_general\_operators\_methods),  
41
- show,gpu.matrix.torch-method  
(matrix\_general\_operators\_methods),  
41
- show-methods  
(matrix\_general\_operators\_methods),  
41
- solve, 54
- solve (solve\_gpu.matrix), 53
- solve,ANY,gpu.matrix.tensorflow-method  
(solve\_gpu.matrix), 53

- solve,ANY,gpu.matrix.torch-method  
(solve\_gpu.matrix), 53
- solve,gpu.matrix.tensorflow,ANY-method  
(solve\_gpu.matrix), 53
- solve,gpu.matrix.tensorflow,missing-method  
(solve\_gpu.matrix), 53
- solve,gpu.matrix.torch,ANY-method  
(solve\_gpu.matrix), 53
- solve,gpu.matrix.torch,missing-method  
(solve\_gpu.matrix), 53
- solve-methods (solve\_gpu.matrix), 53
- solve\_gpu.matrix, 53
- sort, 55, 56
- sort,gpu.matrix.tensorflow,logical-method  
(sort), 55
- sort,gpu.matrix.tensorflow-method  
(sort), 55
- sort,gpu.matrix.torch,logical-method  
(sort), 55
- sort,gpu.matrix.torch-method (sort), 55
- sort-methods (sort), 55
- speedglm, 30–32
- sum, 45
- sum (matrix\_ranges), 42
- sum,gpu.matrix.tensorflow-method  
(matrix\_ranges), 42
- sum,gpu.matrix.torch-method  
(matrix\_ranges), 42
- sum-methods (matrix\_ranges), 42
- svd, 40
- svd (matrix\_decomposition), 39
- svd,gpu.matrix.tensorflow-method  
(matrix\_decomposition), 39
- svd,gpu.matrix.torch-method  
(matrix\_decomposition), 39
- svd-methods (matrix\_decomposition), 39
  
- t, 3
- t (aperm), 2
- t,gpu.matrix.tensorflow-method (aperm),  
2
- t,gpu.matrix.torch-method (aperm), 2
- t-methods (aperm), 2
- tail, 42
- tail  
(matrix\_general\_operators\_methods),  
41
- tail,gpu.matrix.tensorflow-method  
(matrix\_general\_operators\_methods),  
41
- tail-methods  
(matrix\_general\_operators\_methods),  
41
- tcrossprod, 38
- tcrossprod (matrix-product), 37
- tcrossprod,ANY,gpu.matrix.tensorflow-method  
(matrix-product), 37
- tcrossprod,ANY,gpu.matrix.torch-method  
(matrix-product), 37
- tcrossprod,gpu.matrix.tensorflow,ANY-method  
(matrix-product), 37
- tcrossprod,gpu.matrix.tensorflow,missing-method  
(matrix-product), 37
- tcrossprod,gpu.matrix.torch,ANY-method  
(matrix-product), 37
- tcrossprod,gpu.matrix.torch,missing-method  
(matrix-product), 37
- tcrossprod-methods (matrix-product), 37
- to\_dense (type of gpu.matrix), 56
- to\_dense,gpu.matrix.tensorflow-method  
(type of gpu.matrix), 56
- to\_dense,gpu.matrix.torch-method (type  
of gpu.matrix), 56
- to\_dense-methods (type of gpu.matrix),  
56
- to\_sparse (type of gpu.matrix), 56
- to\_sparse,gpu.matrix.tensorflow-method  
(type of gpu.matrix), 56
- to\_sparse,gpu.matrix.torch-method  
(type of gpu.matrix), 56
- to\_sparse-methods (type of gpu.matrix),  
56
- torch\_argsort, 45
- torch\_cdist, 20
- torch\_cholesky, 40
- torch\_fft\_fft, 25
- torch\_fft\_ifft, 25
- torch\_inverse, 54
- torch\_kron, 34
- torch\_matmul, 38
- torch\_matrix\_exp, 21
- torch\_max, 44
- torch\_mean, 44
- torch\_min, 44

- torch\_pinverse, [54](#)
- torch\_round, [52](#)
- torch\_sort, [56](#)
- torch\_sum, [45](#)
- torch\_svd, [40](#)
- torch\_triangular\_solve, [51](#)
- torch\_var, [44](#)
- type of gpu.matrix, [56](#)
- typeof, [6](#)
  
- which.max, [44](#)
- which.max, gpu.matrix.tensorflow-method  
    (matrix\_ranges), [42](#)
- which.max, gpu.matrix.torch-method  
    (matrix\_ranges), [42](#)
- which.max-methods (matrix\_ranges), [42](#)
- which.min, [44](#)
- which.min (matrix\_ranges), [42](#)
- which.min, gpu.matrix.tensorflow-method  
    (matrix\_ranges), [42](#)
- which.min, gpu.matrix.torch-method  
    (matrix\_ranges), [42](#)
- which.min-methods (matrix\_ranges), [42](#)