

Package ‘GPUmatrix’

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Type Package

Title Basic Linear Algebra with GPU

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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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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 gpu.matrix 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 gpu.matrix .
y	NULL (default) or a vector, matrix, data frame or gpu.matrix 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 gpu.matrix , 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(1:10)
b <- gpu.matrix(11:20)
cor(a,b)

#example taken from stats corresponding help page:
longley_gpu <- gpu.matrix(longley, type="tensorflow")
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 <code>gpu.matrix</code> 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.

x	the n coordinates of the points where the density is estimated.
y	the estimated density values. These will be non-negative, but can be zero.
bw	the bandwidth used.
n	the sample size after elimination of missing values.
call	the call which produced the result.
data.name	the deparsed name of the x argument.
has.na	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:

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

```

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 int32

#by default, gpu.matrix work with float64
x <- gpu.matrix(1:9,nrow=3,ncol = 3)
try(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 gpu.matrix .
e2	a gpu.matrix .
x	a gpu.matrix 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

This function 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)."

Usage

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

Arguments

`z` a `gpu.matrix` object containing the values to be transformed.

Details

This function mimics the function `fft` to operate on `gpu.matrix`-class objects.

The function `fft` 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

It returns a `gpu.matrix`-class object with the transformed values. To access the real and imaginary information, the following code must be executed: `output@gm$real` for the real part and `output@gm$imag` for the imaginary part.

See Also

For more information see: `fft` and `torch_fft_ifft`.

Examples

```
if(installTorch){  
  x <- gpu.matrix(1:4)  
  output <- fft(x)  
  output@gm$real  
  output@gm$imag  
}
```

`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

data, x	a scalar, vector or matrix (both matrix or Matrix class).
nrow	Number of rows of the matrix. By default the number of rows of data if data is an object of class matrix or Matrix.
ncol	Number of columns of the matrix. By default the number of columns of data if data is an object of class matrix or Matrix.
byrow	The same as function matrix: "logical. If FALSE (the default) the matrix is filled by columns, otherwise the matrix is filled by rows."
dimnames	The same as in function matrix: "A dimnames 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."
dtype	data type. User can indicate "float64", "float32" or "int" for "int64". if not specified, dtype will correspond to the input data type.
sparse	The same as in function Matrix 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."
colnames	A vector with the column names.
rownames	A vector with the row names.
type	If the gpu.matrix is 'torch' or "tensorflow". If it is NULL, gpu.matrix will try to create a gpu.matrix.torch object.
device	It indicates the device to load cuda. If not indicated, 'device' will be set to 'cuda' if it is available.
...	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, use the @gm\$real and @gm\$imag operators to access the corresponding real and imaginary values.

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..](#)

GPUglm

Fitting Generalized Linear Models using GPUmatrix objects

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 = NULL, 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 seting 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 family 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.
<code>offset</code>	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> .
<code>acc</code>	the same as <code>speedglm</code> : tolerance to be used for the estimation (by default equal to: <code>1e-08</code>).
<code>maxit</code>	the same as <code>speedglm</code> : maximum number of iterations.
<code>k</code>	the same as <code>speedglm</code> : numeric, the penalty per parameter to be used; the default <code>k = 2</code> is the classical AIC.
<code>sparse</code>	if matrix <code>x</code> is desired to be treated as sparse. Not yet implemented.
<code>trace</code>	If the user wants to see the development of the iterations. By default <code>FALSE</code>
<code>...</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:

<code>dtype</code>	parameter of the function <code>gpu.matrix</code> : "data type. User can indicate "float64", "float32" or "int" for "int64". if not specified, dtype will correspond to the input data type."
<code>device</code>	parameter of the function <code>gpu.matrix</code> : "Only for type = "torch". It indicates de devide to load cuda. If not indicated, 'device' will be set to 'cuda' if <code>torch::cuda_is_available()</code> "
<code>type</code>	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`:

<code>coefficients</code>	the estimated coefficients.
<code>logLik</code>	the log likelihood of the fitted model.
<code>iter</code>	the number of iterations of IWLS used.
<code>tol</code>	the maximal value of tolerance reached.
<code>family</code>	the maximal value of tolerance reached.
<code>link</code>	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](#).

Examples

```
## Not run:
# These examples show that the way to call
# and work with these functions is the same
# as with the corresponding functions
# of the 'speedglm' library.

# linear model:
x <- matrix(rnorm(100*50),nrow = 100)
y <- x
s1 <- glm.fit.GPU(x=Matrix(x),y=as.gpu.matrix(y))

#poisson and binomial:

m <- 1000
n <- 100
x <- matrix(runif(m*n),m,n)
```

```

sol <- rnorm(n)
y <- rbinom(m, 1, prob = plogis(x
s1 <- glm.fit.GPU(x,y,family = binomial(),dtype="float32")
s2 <- glm.fit.GPU(x,y,family = poisson(),dtype="float64", device = "cpu")

## 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 %x% Y
## S4 method for signature 'ANY,gpu.matrix.torch'
X %x% Y
## S4 method for signature 'gpu.matrix.tensorflow,ANY'
X %x% Y
## S4 method for signature 'gpu.matrix.torch,ANY'
X %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 [gpu.matrix](#), [matrix](#), or [Matrix](#).

`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/lologreg.pdf>.

Examples

```
## Not run:
x <- gpu.matrix(rnorm(100*3),nrow=100,ncol=3)
y <- sample(c(0,1),size=100,replace = T)
a <- LR_GradientConjugate_gpumatrix(X = x,y = y)

## 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 gpu.matrix .
y	a gpu.matrix , 'matrix' or 'Matrix' object. For the functions tcrossprod and crossprod is NULL (by default), that is equivalent to $x=y$.
...	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(9),nrow=3,ncol=3)
b <- a%*%a

b <- tcrossprod(a)

b <- crossprod(a,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:

<code>values</code>	a vector with the <code>P</code> eigenvalues of <code>x</code>
<code>vectors</code>	the eigenvectors of <code>x</code>

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

<code>d</code>	a vector containing the singular values of <code>x</code>
----------------	---

`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](#).

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
qr_return <- qr(a) #qr decompostion

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

#for an example of how to use the cholesky decomposition see
#the corresponding help for the function chol_solve.

## 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 apply function show.  
  
## End(Not run)
```

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`, `rankMatrix` get the rank of a `gpu.matrix-class` object, of each row and of each column 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](#).

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> .
<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 .
<code>Hinit</code>	Initial value for matrix H .
<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

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

to update the W and H respectively.

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:
#toy exapmle
a1 <- gpu.matrix(rnorm(9),nrow=3,ncol=3)
a2 <- gpu.matrix(rnorm(9),nrow=3,ncol=3)
V <- a1 %*% a2
b <- NMFgpuatrix(V = V)
#check result:
V - 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 nth 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(1:9,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

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

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

rounding of numbers

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 gpu.matrix .
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 *Solve a System of Equations*

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 <- GPUmatrix::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 symmetric 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

`x` a `gpu.matrix`.
`value` type of `gpu.matrix` 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 original matrix A:
A
```

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


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