Package 'MPCR'

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Type Package

Title Multi- And Mixed-Precision Computations

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Description Designed for multi- and mixed-precision computations, accommodating 64-bit and 32-bit data structures. This flexibility enables fast execution across various applications. The package enhances performance by optimizing operations in both precision levels, which is achieved by integrating with high-speed 'BLAS' and 'LAPACK' libraries like 'MKL' and 'OpenBLAS'. Including a 32-bit option caters to applications where high precision is unnecessary, accelerating computational processes whenever feasible. The package also provides support for tile-based algorithms in three linear algebra operations: CHOL(), TRSM(), and GEMM(). The tile-based algorithm splits the matrix into smaller tiles, facilitating parallelization through a predefined Directed Acyclic Graph (DAG) for each operation. Enabling 'OpenMP' enhances the efficiency of these operations, leveraging multi-core parallelism. In this case, 'MPCR' facilitates mixed-precision execution by permitting varying precision levels for different tiles. This approach is advantageous in numerous applications, as it maintains the accuracy of the application while accelerating execution in scenarios where single-precision alone does not significantly affect the accuracy of the application.

License GPL (>= 3)

Imports methods, Rcpp (>= 1.0.9)

Depends R (>= 3.6.0)

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SystemRequirements CMake (>= 3.19.4) , C++ (>= 11) , git (>= 2.0.0)

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BugReports https://github.com/stsds/MPCR/issues

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Contents

`01-MPCR` *MPCR S4 Class*

Description

MPCR is a multi-precision vector/matrix, that enables the creation of vector/matrix with three different precisions (16-bit (half), 32-bit(single), and 64-bit(double)).

Value

MPCR object (constructor - accessors - methods)

Constructor

`new` Creates a new instance of zero values of the `MPCR` class. `new(MPCR,size, "precision")`

`size` The total number of values for which memory needs to be allocated.

`precision` String to indicate the precision of MPCR object ("half","single", or "double").

Accessors

The following accessors can be used to get the values of the slots:

`IsMatrix` Boolean to indicate whether the MPCR object is a vector or matrix.

`Size` Total number of elements inside the object, (row*col) in the case of matrix, and number of elements in the case of vector.

`Row` Number of rows.

`Col` Number of cols.

Methods

The following methods are available for objects of class `MPCR`:

PrintValues: `PrintValues()`: Prints all the values stored in the matrix or vector, along with metadata about the object.

ToMatrix: `ToMatrix(row,col)`: Changes the object representation to match the new dimensions, no memory overhead.

ToVector: `ToVector()`: Changes the MPCR matrix to vector, no memory overhead.

Examples

```
# Example usage of the class and its methods
library(MPCR)
MPCR_object <- new(MPCR,50,"single")

MPCR_object$ToMatrix(5,10)
MPCR_object$Row       #5
MPCR_object$Col       #10
MPCR_object$Size      #50
MPCR_object$IsMatrix  #TRUE

MPCR_object$PrintValues()
MPCR_object$ToVector()

MPCR_object
```

02-MPCRTile *MPCRTile S4 Class*

Description

MPCRTile is a data structure for tile matrices with mixed precision, where each tile possesses a specific precision level.

Value

MPCRTile object (constructor - accessors - methods)

Constructor

new creates a new instance of Tile-Matrix MPCRTile class.
new(MPCRTile,rows,cols,rows_per_tile,cols_per_tile,values,precisions)

rows Number of rows in the matrix.

cols Number of cols in the matrix.

rows_per_tile Number of rows in each tile.

cols_per_tile Number of cols in each tile.

values R matrix or vector containing all the values that should be in the matrix.

precisions R matrix or vector of strings, containing precision type of each tile.

Accessors

The following accessors can be used to get the values of the slots:

Size Total number of elements inside the Matrix.

Row Number of rows.

`Col` Number of cols.

`TileRow` Number of rows in each tile.

`TileCol` Number of cols in each tile.

`TileSize` Total number of elements in each tile.

Methods

The following methods are available for objects of class `MPCRTile`:

PrintTile:
`PrintTile(tile_row_idx,tile_col_idx)`: Prints all the values stored inside a specific tile plus meta-data about the tile.

`tile_row_idx` Row index of the tile.

`tile_col_idx` Col index of the tile.

ChangeTilePrecision:
`ChangeTilePrecision(tile_row_idx,tile_col_idx,precision)`: Change the precision of specific tile, this function will need to copy all the values to cast them to the new precision.

`tile_row_idx` Row index of the tile.

`tile_col_idx` Col index of the tile.

`precision` Required new precision as a string.

FillSquareTriangle:
`FillSquareTriangle(value,upper.tri,precision)`: Fills upper or lower triangle with a given value and precision, new tiles will be created, replacing the old tiles. **Note:** The input must be a square matrix

`value` A value used during matrix filling.

`upper.tri` A flag to indicate what triangle to fill. if TRUE, the upper triangle will be filled, otherwise the lower triangle.

`precision` The precision of the tiles created during matrix filling, in case it's not a diagonal tile.

Sum: `Sum()`: Get the sum of all elements in all tiles in MPCRTile Matrix.

Prod: `Prod()`: Get the product of all elements in all tiles in MPCRTile Matrix.

Examples

```
library(MPCR)
  # Example usage of the class and its methods
 a <- matrix(1:36, 6, 6)
 b <- c("double", "double", "single", "double",
        "half", "double", "half", "double",
        "single")
```

```
tile_mat <- new(MPCRTile, 6, 6, 2, 2, a, b)
tile_mat
sum <- tile_mat$Sum()
prod <- tile_mat$Prod()
tile_mat$PrintTile(1,1)
tile_mat$ChangeTilePrecision(1,1,"single")

n_rows <- tile_mat$Row
n_cols <- tile_mat$Col
total_size <- tile_mat$Size
rows_per_tile <- tile_mat$TileRow
cols_per_tile <- tile_mat$TileCol
```

`03-Converters` *Converters*

Description

Converters from R to MPCR objects and vice-versa.

Value

An MPCR or R numeric vector/matrix.

MPCR Converter

Convert R object to MPCR object.

MPCR converters:
`as.MPCR(data,nrow = 0,ncol = 0,precision)`: Converts R object to MPCR object.

`data` R matrix/vector.

`nrow` Number of rows of the new MPCR matrix, **default = zero** which means a vector will be created.

`ncol` Number of cols of the new MPCR matrix, **default = zero** which means a vector will be created.

`precision` String indicates the precision of the new MPCR object (half, single, or double).

R Converter

Convert an MPCR object to R object.

R vector converter:
`MPCR.ToNumericVector(x)`: Converts an MPCR object to a numeric R vector.

`x` MPCR object.

R matrix converter:
`MPCR.ToNumericMatrix(x)`: Converts an MPCR object to a numeric R matrix.

`x` MPCR object.

Examples

```
# Example usage of the class and its methods
library(MPCR)
a <- matrix(1:36, 6, 6)
MPCR_matrix <- as.MPCR(a,nrow=6,ncol=6,precision="single")
r_vector <- MPCR.ToNumericVector(MPCR_matrix)
r_vector
r_matrix <- MPCR.ToNumericMatrix(MPCR_matrix)
r_matrix
```

`04-Arithmetic` *Binary arithmetic numeric/MPCR objects.*

Description

Binary arithmetic for numeric/MPCR objects.

Usage

```
## S4 method for signature 'Rcpp_MPCR,Rcpp_MPCR'
e1 + e2

## S4 method for signature 'Rcpp_MPCR,Rcpp_MPCR'
e1 - e2

## S4 method for signature 'Rcpp_MPCR,Rcpp_MPCR'
e1 * e2

## S4 method for signature 'Rcpp_MPCR,Rcpp_MPCR'
e1 / e2

## S4 method for signature 'Rcpp_MPCR,Rcpp_MPCR'
e1 ^ e2

## S4 method for signature 'Rcpp_MPCR,BaseLinAlg'
e1 + e2

## S4 method for signature 'Rcpp_MPCR,BaseLinAlg'
e1 * e2

## S4 method for signature 'Rcpp_MPCR,BaseLinAlg'
e1 - e2

## S4 method for signature 'Rcpp_MPCR,BaseLinAlg'
e1 / e2

## S4 method for signature 'Rcpp_MPCR,BaseLinAlg'
```

```
e1 ^ e2
```

Arguments

e1, e2	Numeric/MPCR objects.

Value

An MPCR object, matching the data type of the highest precision input.

Examples

```
library(MPCR)
s1 <- as.MPCR(1:20,nrow=2,ncol=10,"single")
s2 <- as.MPCR(21:40,nrow=2,ncol=10,"double")

x <- s1 + s2
typeof(x) # A 64-bit precision (double) MPCR matrix.

s3 <- as.MPCR(1:20,nrow=2,ncol=10,"single")
x <- s1 + s3
typeof(x) # A 32-bit precision (single) MPCR matrix.
```

05-Comparison *Binary comparison operators for numeric/MPCR objects.*

Description

Binary comparison operators for numeric/MPCR objects.

Usage

```
## S4 method for signature 'Rcpp_MPCR,Rcpp_MPCR'
e1 < e2

## S4 method for signature 'Rcpp_MPCR,Rcpp_MPCR'
e1 <= e2

## S4 method for signature 'Rcpp_MPCR,Rcpp_MPCR'
e1 == e2

## S4 method for signature 'Rcpp_MPCR,Rcpp_MPCR'
e1 != e2

## S4 method for signature 'Rcpp_MPCR,Rcpp_MPCR'
e1 > e2
```

```
## S4 method for signature 'Rcpp_MPCR,Rcpp_MPCR'
e1 >= e2

## S4 method for signature 'Rcpp_MPCR,BaseLinAlg'
e1 < e2

## S4 method for signature 'Rcpp_MPCR,BaseLinAlg'
e1 <= e2

## S4 method for signature 'Rcpp_MPCR,BaseLinAlg'
e1 == e2

## S4 method for signature 'Rcpp_MPCR,BaseLinAlg'
e1 != e2

## S4 method for signature 'Rcpp_MPCR,BaseLinAlg'
e1 > e2

## S4 method for signature 'Rcpp_MPCR,BaseLinAlg'
e1 >= e2
```

Arguments

e1, e2	Numeric/MPCR objects.

Value

A vector/matrix of logicals.

Examples

```
library(MPCR)
s1 <- as.MPCR(1:20,nrow=2,ncol=10,"single")
s2 <- as.MPCR(21:40,nrow=2,ncol=10,"double")

x <- s1 > s2
```

06-Extract-Replace *Extract or replace elements from an MPCR object.*

Description

Extract or replace elements from an MPCR object using the '[', '[[', '[<-', and '[[<-' operators. When extracting values, they will be converted to double precision. However, if you update a single object, the double value will be cast down to match the precision. If the MPCR object is a matrix

and you access it using the 'i' index, the operation is assumed to be performed in column-major order, or using 'i' and 'j' index.

Usage

```
  ## S4 method for signature 'Rcpp_MPCR'
x[i, j, drop = TRUE]
  ## S4 replacement method for signature 'Rcpp_MPCR'
x[i, j, ...] <- value
  ## S4 method for signature 'Rcpp_MPCR'
x[[i, drop = TRUE]]
  ## S4 replacement method for signature 'Rcpp_MPCR'
x[[i, ...]] <- value
```

Arguments

x	An MPCR object.
i	Row index or indices.
j	Column index or indices.
...	ignored.
drop	ignored.
value	A value to replace the selected elements with.

Examples

```
library(MPCR)
  x <-as.MPCR(1:50,precision="single")
  ext <- x[5]
  x[5] <- 0
  x$ToMatrix(5,10)
  x[2,5]
  x[3,5] <- 100
```

07-Dimensions *dimensions*

Description

Returns the number of rows or cols in an MPCR object.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
nrow(x)

## S4 method for signature 'Rcpp_MPCR'
ncol(x)
```

Arguments

x	An MPCR object.

Value

The number of rows/cols in an MPCR object.

Examples

```
library(MPCR)
x <- as.MPCR(1:16,4,4,"single")
y <- as.MPCR(1:20,4,5,"double")
rows_x <- nrow(x)
cols_y <- ncol(y)
```

08-Copy *copy*

Description

Functions for copying MPCR objects.

Value

An MPCR copy from the input object.

MPCR deep copy

Create a copy of an MPCR object. Typically, using 'equal' creates a new pointer for the object, resulting in any modifications made to object one affecting object two as well.

copy:
`MPCR.copy(x)`: Create a new copy of an MPCR object.

`x` MPCR object.

MPCRTile deep copy

Create a duplicate of an MPCRTile object. Usually, using 'equal' creates a new pointer for the object, causing any modifications made to object one to affect object two as well.

copy:
`MPCRTile.copy(x)`: Create a new copy of an MPCRTile matrix.

`x` MPCRTile matrix.

Examples

```
library(MPCR)
# Example usage of the class and its methods
a <- matrix(1:36, 6, 6)
MPCR_matrix <- as.MPCR(a,nrow=6,ncol=6,precision="single")

# Normal equal '=' will create a new pointer of the object, so any change in object A
# will affect object B
temp_MPCR_matrix = MPCR_matrix
temp_MPCR_matrix[2,2] <- 500
MPCR_matrix[2,2]           #500


MPCR_matrix_copy <- MPCR.copy(MPCR_matrix)
MPCR_matrix[2,2] <-100
MPCR_matrix_copy[2,2] <- 200

MPCR_matrix[2,2]           #100
MPCR_matrix_copy[2,2]      #200
```

`09-Concatenate` *concatenate*

Description

`c()` function for MPCR objects.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
MPCR.Concatenate(x)
```

Arguments

`x`	List of MPCR objects.

Value

MPCR object containing values from all objects in the list.

Examples

```
library(MPCR)
x <- as.MPCR(1:20,precision="single")
y <- as.MPCR(1:20,precision="single")
list <- c(x,y)
new_obj <- MPCR.Concatenate(list)
```

10-Bind *bind*

Description

rbind() and cbind() for MPCR objects.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
MPCR.rbind(x,y)

## S4 method for signature 'Rcpp_MPCR'
MPCR.cbind(x,y)
```

Arguments

x	An MPCR object.
y	An MPCR object.

Value

An MPCR object, matching the data type of the highest precision input.

Examples

```
library(MPCR)
# create 2 MPCR matrix a,b
a <- as.MPCR(1:20,nrow=2,ncol=10,"single")
b <- as.MPCR(21:40,nrow=2,ncol=10,"double")

x <- MPCR.rbind(a,b)
y <- MPCR.cbind(a,b)
```

11-Diagonal *diag*

Description

Returns the diagonal of an MPCR matrix.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
diag(x)
```

Arguments

x	An MPCR matrix.

Value

An MPCR vector contains the main diagonal of the matrix.

Examples

```
library(MPCR)
x <- as.MPCR(1:16,4,4,"single")
diag_vals <- diag(x)
```

12-Extremes *Min-Max Functions*

Description

Min-Max functions for MPCR objects values and indices, all NA values are disregarded.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
min(x)

## S4 method for signature 'Rcpp_MPCR'
max(x)

## S4 method for signature 'Rcpp_MPCR'
which.min(x)

## S4 method for signature 'Rcpp_MPCR'
which.max(x)
```

Arguments

x	An MPCR object.

Value

Min/max value/index.

Examples

```
library(MPCR)

x <- as.MPCR(1:20,precision="double")
min <-min(x)
min_idx <-which.min(x)
```

13-Log *Logarithms and Exponentials*

Description

exp/log functions.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
exp(x)

## S4 method for signature 'Rcpp_MPCR'
expm1(x)

## S4 method for signature 'Rcpp_MPCR'
log(x, base = 1)

## S4 method for signature 'Rcpp_MPCR'
log10(x)

## S4 method for signature 'Rcpp_MPCR'
log2(x)
```

Arguments

x	An MPCR object.
base	The logarithm base. If base = 1, exp(1) is assumed, only base 1,2, and 10 available.

Value

An MPCR object of the same dimensions as the input.

Examples

```
library(MPCR)

x <- as.MPCR(1:20,precision="double")
log(x)
```

14-Mathis *Finite, infinite, and NaNs*

Description

Finite, infinite, and NaNs.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
is.finite(x)

## S4 method for signature 'Rcpp_MPCR'
is.infinite(x)

## S4 method for signature 'Rcpp_MPCR'
is.nan(x)
```

Arguments

x	An MPCR object.

Value

A bool vector/matrix of the same dimensions as the input.

Examples

```
library(MPCR)

x <- as.MPCR(1:20,precision="double")
is.nan(sqrt(x))
```

15-Miscmath *Miscellaneous mathematical functions*

Description

Miscellaneous mathematical functions.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
abs(x)

## S4 method for signature 'Rcpp_MPCR'
sqrt(x)
```

Arguments

x	An MPCR object.

Value

An MPCR object of the same dimensions as the input.

Examples

```
library(MPCR)

x <- as.MPCR(1:20,precision="double")
sqrt(x)
```

16-NA's *NA's*

Description

is.na() ,na.omit(), and na.exclude() for MPCR objects.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
MPCR.is.na(object,index=-1)
## S4 method for signature 'Rcpp_MPCR'
MPCR.na.exclude(object,value)
## S4 method for signature 'Rcpp_MPCR'
MPCR.na.omit(object)
```

Arguments

object	MPCR object.
index	If a particular index in the MPCR matrix/vector is specified, it will be checked. If no index is provided, all elements will be checked.
value	Value to replace all NAN with.

Value

MPCR.is.na will return matrix/vector/bool according to input of the function.
MPCR.na.exclude & MPCR.na.omit will not return anything.

Examples

```
library(MPCR)
x <- as.MPCR(1:20,precision="single")
x[1] <- NaN
MPCR.is.na(x,index=1) #TRUE
MPCR.na.exclude(x,50)
x[1]  #50
```

17-Replicate *replicate*

Description

Replicates the given input number of times according to count/len , only one should be set at a time, and in case both values are given, only the len value will have effect.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
rep(x,count=0,len=0)
```

Arguments

x	An MPCR object.
count	Value to determine how many times the input value will be replicated.
len	Value to determine the required output size, the input will be replicated until it matches the output len size.

Value

MPCR vector containing the replicated values.

Examples

```
library(MPCR)
x <- as.MPCR(1:16,4,4,"single")
rep_vals_1 <- rep(x,count=2)  #output size will be 16*2
rep_vals_2 <- rep(x,len=2)  #output size will be 2
```

18-Round *Rounding functions*

Description

Rounding functions.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
ceiling(x)

## S4 method for signature 'Rcpp_MPCR'
floor(x)

## S4 method for signature 'Rcpp_MPCR'
trunc(x)

## S4 method for signature 'Rcpp_MPCR'
round(x, digits = 0)
```

Arguments

x	An MPCR object.
digits	The number of digits to use in rounding.

Value

An MPCR object of the same dimensions as the input.

Examples

```
library(MPCR)

input <- runif(20,-1,1)
x <- as.MPCR(input,precision="double")
floor(x)
```

19-Scale *scale*

Description

Center or scale an MPCR object.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
scale(x, center, scale)
```

Arguments

x	An MPCR object.
center, scale	Logical or MPCR objects.

Value

An MPCR matrix.

Examples

```
library(MPCR)
  input <-as.MPCR(1:50,precision="single")
  input$ToMatrix(5, 10)
  temp_center_scale <- as.MPCR(1:10,precision="double")
  z <- scale(x=input, center=FALSE, scale=temp_center_scale)
```

20-Sweep *sweep*

Description

Sweep an MPCR vector through an MPCR matrix.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
sweep(x,stat,margin,FUN)
```

Arguments

x	An MPCR object.
stat	MPCR vector containing the value(s) that should be used in the operation.
margin	1 means row; otherwise means column.
FUN	Sweeping function; must be one of "+", "-", "*", "/", or "^".

Value

An MPCR matrix of the same type as the highest precision input.

Examples

```
library(MPCR)
x <- as.MPCR(1:20,10,2,"single")
y <- as.MPCR(1:5,precision="double")
sweep_out <- sweep(x, stat=y, margin=1, FUN="+")
MPCR.is.double(sweep_out)  #TRUE
```

21-Special Math *Special mathematical functions.*

Description

Special mathematical functions.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
gamma(x)

## S4 method for signature 'Rcpp_MPCR'
lgamma(x)
```

Arguments

x	An MPCR object.

Value

An MPCR object of the same dimensions as the input.

Examples

```
library(MPCR)

x <- as.MPCR(1:20,precision="double")
lgamma(x)
```

22-Trig *Trigonometric functions*

Description

Basic trig functions.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
sin(x)

## S4 method for signature 'Rcpp_MPCR'
cos(x)

## S4 method for signature 'Rcpp_MPCR'
tan(x)

## S4 method for signature 'Rcpp_MPCR'
asin(x)

## S4 method for signature 'Rcpp_MPCR'
acos(x)

## S4 method for signature 'Rcpp_MPCR'
atan(x)
```

Arguments

x	An MPCR object.

Value

An MPCR object of the same dimensions as the input.

Examples

```
library(MPCR)

mpcr_matrix <- as.MPCR(1:20,nrow=2,ncol=10,"single")
x <- sin(mpcr_matrix)
```

23-Hyperbolic *Hyperbolic functions*

Description

These functions give the obvious hyperbolic functions. They respectively compute the hyperbolic cosine, sine, tangent, and their inverses, arc-cosine, arc-sine, arc-tangent (or 'area cosine', etc).

Usage

```
## S4 method for signature 'Rcpp_MPCR'
sinh(x)
## S4 method for signature 'Rcpp_MPCR'
cosh(x)
## S4 method for signature 'Rcpp_MPCR'
tanh(x)
## S4 method for signature 'Rcpp_MPCR'
asinh(x)
## S4 method for signature 'Rcpp_MPCR'
acosh(x)
## S4 method for signature 'Rcpp_MPCR'
atanh(x)
```

Arguments

x	An MPCR object.

Value

An MPCR object of the same dimensions as the input.

Examples

```
library(MPCR)

mpcr_matrix <- as.MPCR(1:20,nrow=2,ncol=10,precision="single")
x <- sinh(mpcr_matrix)
```

24-Transpose *transpose*

Description

Transpose an MPCR object.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
t(x)
```

Arguments

x	An MPCR object.

Value

An MPCR object.

Examples

```
library(MPCR)
a <- matrix(1:20, nrow = 2)
a_MPCR <- as.MPCR(a,2,10,"double")
a_MPCR_transpose <- t(a_MPCR)
```

25-Check precision *Metadata functions*

Description

Checks the precision of a given MPCR object.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
MPCR.is.single(x)
## S4 method for signature 'Rcpp_MPCR'
MPCR.is.half(x)
## S4 method for signature 'Rcpp_MPCR'
MPCR.is.double(x)
## S4 method for signature 'Rcpp_MPCR'
MPCR.is.float(x)
```

Arguments

x	An MPCR object.

Value

Boolean indicates the precision of the object according to the used function.

Examples

```
library(MPCR)
x <- as.MPCR(1:20,precision="double")
MPCR.is.double(x) #TRUE
MPCR.is.single(x) #FALSE
```

26-Metadata *Metadata functions*

Description

Metadata functions.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
storage.mode(x)
## S4 method for signature 'Rcpp_MPCR'
typeof(x)
## S4 method for signature 'Rcpp_MPCR'
MPCR.object.size(x)
## S4 method for signature 'Rcpp_MPCR'
MPCR.ChangePrecision(x,precision)
```

Arguments

x	An MPCR object.
precision	String with the required precision.

Value

Prints/change metadata about an MPCR object.

Examples

```
library(MPCR)

x <- as.MPCR(1:20,precision="double")
typeof(x)
MPCR.ChangePrecision(x,"single")
MPCR.is.single(x) #True
```

27-Print *print*

Description

Prints the precision and type of the object, and print will print the meta data of the object without printing the values. Function x$PrintValues() should be used to print the values."

Usage

```
## S4 method for signature 'Rcpp_MPCR'
print(x)

## S4 method for signature 'Rcpp_MPCR'
show(object)
```

Arguments

x, object	An MPCR objects.

Details

Prints metadata about the object and some values.

Value

A string containing the metadata of the MPCR object.

Examples

```
library(MPCR)
x <- as.MPCR(1:16,4,4,"single")
y <- as.MPCR(1:20,4,5,"double")
x
print(y)
```

28-Cholesky decomposition *cholesky decomposition*

Description

Performs the Cholesky factorization of a positive definite MPCR matrix x.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
chol(x,upper_triangle=TRUE)
```

Arguments

x	An MPCR matrix.
upper_triangle	Boolean to check on which triangle the cholesky decomposition should be applied.

Value

An MPCR matrix.

Examples

```
library(MPCR)
x <- as.MPCR(c(1.21, 0.18, 0.13, 0.41, 0.06, 0.23,
               0.18, 0.64, 0.10, -0.16, 0.23, 0.07,
               0.13, 0.10, 0.36, -0.10, 0.03, 0.18,
               0.41, -0.16, -0.10, 1.05, -0.29, -0.08,
               0.06, 0.23, 0.03, -0.29, 1.71, -0.10,
               0.23, 0.07, 0.18, -0.08, -0.10, 0.36),6,6,precision="double")
chol_out <- chol(x)
```

29-Cholesky inverse *cholesky inverse*

Description

Performs the inverse of the original matrix using the Cholesky factorization of an MPCR matrix x.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
chol2inv(x, size = NCOL(x))
```

Arguments

x	An MPCR object.
size	The number of columns to use.

Value

An MPCR object.

Examples

```
library(MPCR)
x <- as.MPCR(c(1.21, 0.18, 0.13, 0.41, 0.06, 0.23,
               0.18, 0.64, 0.10, -0.16, 0.23, 0.07,
               0.13, 0.10, 0.36, -0.10, 0.03, 0.18,
               0.41, -0.16, -0.10, 1.05, -0.29, -0.08,
               0.06, 0.23, 0.03, -0.29, 1.71, -0.10,
               0.23, 0.07, 0.18, -0.08, -0.10, 0.36),6,6,precision="single")
chol_out <- chol(x)
chol <- chol2inv(chol_out)
```

30-Crossprod *crossprod*

Description

Calculates the cross product of two MPCR matrices. It uses BLAS routine `gemm()` for **A** X **B** operations and `syrk()` for **A** X **A^T** operations.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
crossprod(x, y = NULL)

## S4 method for signature 'Rcpp_MPCR'
tcrossprod(x, y = NULL)
```

Arguments

x	An MPCR object.
y	Either `NULL`, or an MPCR matrix.

Details

Calculates cross product of two MPCR matrices performs:
x %*% y , t(x) %*% x
This function uses blas routine `gemm()` for **A** X **B** operations & `syrk()` for **A** X **A^T** operations.

Value

An MPCR matrix.

Examples

```
library(MPCR)
x <- as.MPCR(1:16,4,4,"single")
y <- as.MPCR(1:20,4,5,"double")

z <- crossprod(x)     # t(x) x
z <- tcrossprod(x)    # x t(x)
z <- crossprod(x,y)   # x y
z <- x %*% y          # x y
```

31-Eigen decomposition

eigen decomposition

Description

Solves a system of equations or invert an MPCR matrix, using lapack routine `syevr()`

Usage

```
## S4 method for signature 'Rcpp_MPCR'
eigen(x, only.values = FALSE)
```

Arguments

`x`	An MPCR object.
`only.values`	(TRUE/FALSE)?

Value

A list contains MPCR objects describing the values and optionally vectors.

32-Symmetric *isSymmetric*

Description

Check if a given MPCR matrix is symmetric.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
isSymmetric(object, ...)
```

Arguments

object	An MPCR matrix.
...	Ignored.

Value

A logical value.

Examples

```
library(MPCR)

x <- as.MPCR(1:50,25,2,"Single")
isSymmetric(x)                      #false
```

33-Norm *norm*

Description

Compute norm.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
norm(x, type = "O")
```

Arguments

x	An MPCR object.
type	"O"-ne, "I"-nfinity, "F"-robenius, "M"-ax modulus, and "1" norms.

Value

An MPCR object.

Examples

```
library(MPCR)

x <- as.MPCR(1:20,precision="double")
norm(x, type="O")
```

34-QR decomposition *QR decomposition*

Description

QR factorization and related functions.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
qr(x, tol = 1e-07)

## S4 method for signature 'ANY'
qr.Q(qr, complete = FALSE, Dvec)

## S4 method for signature 'ANY'
qr.R(qr, complete = FALSE)
```

Arguments

x	An MPCR matrix.
qr	QR decomposition MPCR object.
tol	The tolerance for determining numerical column rank.
complete	Should the complete or truncated factor be returned?
Dvec	Vector of diagonals to use when re-constructing Q (**default is 1's**).

Details

The factorization is performed by the LAPACK routine `geqp3()`. This should be similar to calling `qr()` on an ordinary R matrix with the argument `LAPACK=TRUE`.

Value

qr	Output of `qr()`.

Examples

```
library(MPCR)


qr_input <-as.MPCR( c(1, 2, 3, 2, 4, 6, 3, 3, 3),3,3,"single")
qr_out <- qr(qr_input)
qr_out
```

35-Reciprocal condition

reciprocal condition

Description

Compute matrix norm.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
rcond(x, norm = "O", useInv = FALSE)
```

Arguments

x	An MPCR object.
norm	"O"-ne or "I"-nfinity norm.
useInv	TRUE to use the lower triangle only.

Value

An MPCR Object.

Examples

```
library(MPCR)

x <- as.MPCR(1:25,precision="double")
x$ToMatrix(5,5)

rcond(x)
```

36-Solve *solve*

Description

Solve a system of equations or invert an MPCR matrix.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
solve(a, b = NULL, ...)
```

Arguments

a, b	An MPCR objects.
...	Ignored.

Value

Solves the equation AX=B .and if B=NULL t(A) will be used.

Examples

```
library(MPCR)

x <- as.MPCR(1:20,4,5,"double")
solve(x)
```

37-Singular value decomposition *SVD*

Description

SVD factorization.

Usage

```
## S4 method for signature 'Rcpp_MPCR'
La.svd(x, nu = min(n, p), nv = min(n, p))

## S4 method for signature 'Rcpp_MPCR'
svd(x, nu = min(n, p), nv = min(n, p))
```

Arguments

x	An MPCR matrix.
nu, nv	The number of left/right singular vectors to return.

Details

The factorization is performed by the LAPACK routine gesdd().

Value

The SVD decomposition of the MPCR matrix.

Examples

```
library(MPCR)
svd_vals <- c(1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 0,
              0, 0, 0, 0, 0, 0, 1, 1, 1, 0, 0, 0, 0, 0, 0,
              0, 0, 0, 1, 1, 1)

x <- as.MPCR(svd_vals,9,4,"single")
y <- svd(x)
```

38-Back/Forward solve *Back/Forward solve*

Description

Solves a system of linear equations where the coefficient matrix is upper or lower triangular. The function solves the equation A X = B, where A is the coefficient matrix, X is the solution vector, and B is the right-hand side vector.

Usage

```
 ## S4 method for signature 'Rcpp_MPCR,Rcpp_MPCR'
backsolve(r, x, k = ncol(r), upper.tri = TRUE, transpose = FALSE)

 ## S4 method for signature 'Rcpp_MPCR,Rcpp_MPCR'
forwardsolve(l, x, k = ncol(l), upper.tri = FALSE, transpose = FALSE)
```

Arguments

l	An MPCR object.
r	An MPCR object.
x	An MPCR object whose columns give the right-hand sides for the equations.
k	The number of columns of r and rows of x to use.

upper.tri	logical; if TRUE, the upper triangular part of r is used. Otherwise, the lower one.
transpose	logical; if TRUE, solve for t(l , r) %*% output == x.

Value

An MPCR object represents the solution to the system of linear equations.

Examples

```
library(MPCR)
a <- matrix(c(2, 0, 0, 3), nrow = 2)
b <- matrix(c(1, 2), nrow = 2)
a_MPCR <- as.MPCR(a,2,2,"single")
b_MPCR <- as.MPCR(b,2,1,"double")
x <- backsolve(a_MPCR, b_MPCR)
```

39-MPCR GEMM *MPCR GEMM (Matrix-Matrix Multiplication)*

Description

Performs matrix-matrix multiplication of two given MPCR matrices to performs:
C = alpha A * B + beta C
C = alpha A A^T + beta C

Usage

```
## S4 method for signature 'Rcpp_MPCR'
MPCR.gemm(a,b = NULL,c,transpose_a= FALSE,transpose_b=FALSE,alpha=1,beta=0)
```

Arguments

a	An MPCR matrix A.
b	An MPCR matrix B, if NULL, the function will perform syrk operation from blas.
c	Input/Output MPCR matrix C.
transpose_a	A flag to indicate whether transpose matrix A should be used, if B is NULL and transpose_a =TRUE The function will perform the following operation: **C=alphaA^TXA+betaC**.
transpose_b	A flag to indicate whether transpose matrix B should be used.
alpha	Specifies the scalar alpha.
beta	Specifies the scalar beta.

Value

An MPCR matrix.

40-MPCR TRSM *MPCR TRSM (Triangular Solve)*

Description

Solves a triangular matrix equation.
performs:
op(A)*X=alpha*B
X*op(A)=alpha*B

Usage

```
## S4 method for signature 'Rcpp_MPCR'
MPCR.trsm(a,b,upper_triangle,transpose,side = 'L',alpha =1)
```

Arguments

a	MPCR Matrix A.
b	MPCR Matrix B.
upper_triangle	If the value is TRUE, the referenced part of matrix A corresponds to the upper triangle, with the opposite triangle assumed to contain zeros.
transpose	If TRUE, the transpose of A is used.
side	'R for Right side, 'L' for Left side.
alpha	Factor used for A, If alpha is zero, A is not accessed.

Value

An MPCR Matrix.

41-MPCRTile GEMM *MPCRTile GEMM (Matrix-Matrix Multiplication)*

Description

Tile-based matrix-matrix multiplication of two given MPCR tiled matrices to **perform:**
C = **alpha*A** X **B** + **beta*C**

Usage

```
## S4 method for signature 'Rcpp_MPCRTile'
MPCRTile.gemm(a,b,c,transpose_a= FALSE,transpose_b=FALSE,alpha=1,beta=0,num_threads=1)
```

Arguments

a	An MPCR tile matrix A.
b	An MPCR tile matrix B.
c	Input/Output MPCR tile matrix C.
transpose_a	A flag to indicate whether transpose matrix A should be used.
transpose_b	A flag to indicate whether transpose matrix B should be used.
alpha	Specifies the scalar alpha.
beta	Specifies the scalar beta.
num_threads	An integer to determine number if thread to run using openmp, default = 1 (serial with no parallelization).

Value

An MPCR tile matrix C.

42-MPCRTile POTRF *MPCRTile Chol (Cholesky decomposition)*

Description

Tile-based Cholesky decomposition of a positive definite tile-based symmetric matrix.

Usage

```
## S4 method for signature 'Rcpp_MPCRTile'
chol(x, overwrite_input = TRUE, num_threads = 1)
```

Arguments

x	An MPCR tile matrix.
overwrite_input	A flag to determine whether to overwrite the input (TRUE), or return a new MPCR tile matrix.
num_threads	An integer to determine number if thread to run using openmp, default = 1 (serial with no parallelization).

Value

An MPCR tile matrix.

43-MPCRTile TRSM *MPCRTile TRSM (Triangular Solve)*

Description

Tile-based algorithm to solve a triangular matrix equation for MPCR tiled matrices.
performs:
op(A)*X=alpha*B
X*op(A)=alpha*B

Usage

```
## S4 method for signature 'Rcpp_MPCRTile'
MPCRTile.trsm(a,b,side,upper_triangle,transpose,alpha)
```

Arguments

a	An MPCR tile matrix A.
b	An MPCR tile matrix B, X after returning.
side	'R' for right side, 'L' for left side.
upper_triangle	What part of the matrix A is referenced (if TRUE upper triangle is referenced), the opposite triangle being assumed to be zero.
transpose	If TRUE, the transpose of A is used.
alpha	Factor used for A, If alpha is zero, A is not accessed.

Value

An MPCR Tile Matrix B ->(X).

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