

# Package ‘MMPR’

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**Type** Package

**Title** Multi- and Mixed- Precision Support in R

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**Description** The MMPR package provides a new data-structure support for multi- and mixed-precision for R users. The package supports 16-bit, 32-bit, and 64-bit operations with the ability to perform mixed-precision operations through a newly defined tile-based data structure.

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**Imports** methods, Rcpp (>= 1.0.9)

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01-MMPR

*MMPR S4 Class***Description**

MMPR 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)).

**Constructor**

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

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

`precision` String to indicate the precision of MMPR 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 MMPR 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 MMPR:

**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 MMPR matrix to vector, no memory overhead.

## Examples

```
## Not run:
# Example usage of the class and its methods
mmpr_object <- new(MMPR, 50, "single")

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

mmpr_object$PrintValues()
mmpr_object$ToVector()

mmpr_object

## End (Not run)
```

## Description

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

## Constructor

`new` creates a new instance of Tile-Matrix MMPRTile class.  
`new(MMPRTile, 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 MMPRTile:

### 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 MMPRTile Matrix.

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

### Examples

```
## Not run:
# 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(MMPRTile, 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

## End (Not run)
```

### MMPR Converter

Convert R object to MMPR object.

#### MMPR converters:

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

**data** R matrix/vector.

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

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

**precision** String indicates the precision of the new MMPR object (half, single, or double).

## R Converter

Convert an MMPR object to R object.

### R vector converter:

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

x MMPR object.

### R matrix converter:

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

x MMPR object.

## Examples

```
## Not run:

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

## End(Not run)
```

---

04-Arithmetic

*Binary arithmetic numeric/MMPR objects.*

---

## Description

Binary arithmetic for numeric/MMPR objects.

## Usage

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

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

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

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

## S4 method for signature 'Rcpp_MMPR,Rcpp_MMPR'
```

```

e1 ^ e2

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

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

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

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

## S4 method for signature 'Rcpp_MMPR,BaseLinAlg'
e1 ^ e2

```

### Arguments

`e1, e2`                Numeric/MMPR objects.

### Value

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

### Examples

```

## Not run:
library(MMPR)
s1 <- as.MMPR(1:20,nrow=2,ncol=10,"single")
s2 <- as.MMPR(21:40,nrow=2,ncol=10,"double")

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

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

## End(Not run)

```

### Description

Binary comparison operators for numeric/MMPR objects.

**Usage**

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

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

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

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

## S4 method for signature 'Rcpp_MMPR,Rcpp_MMPR'
e1 > e2

## S4 method for signature 'Rcpp_MMPR,Rcpp_MMPR'
e1 >= e2

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

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

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

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

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

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

**Arguments**

e1, e2                      Numeric/MMPR objects.

**Value**

A vector/matrix of logicals.



**Examples**

```
## Not run:
library(MMPR)
s1 <- as.MMPR(1:20,nrow=2,ncol=10,"single")
s2 <- as.MMPR(21:40,nrow=2,ncol=10,"double")

x <- s1 > s2

## End(Not run)
```

---

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

---

**Description**

Extract or replace elements from an MMPR 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 MMPR 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**

```
## S3 method for class 'Rcpp_MMPR'
x[i, j, drop = TRUE]
## S3 method for class 'Rcpp_MMPR'
x [<- i, j, ..., value
## S3 method for class 'Rcpp_MMPR'
x[[i, drop = TRUE]]
## S3 method for class 'Rcpp_MMPR'
x [[<- i, ..., value
```

**Arguments**

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

**Examples**

```
## Not run:
library(MMPR)
x <- as.MMPR(1:50,"single")
ext <- x[5]
x[5] <- 0
```

```
x$ToMatrix(5,10)
x[2,5]
x[3,5] <- 100

## End(Not run)
```

---

07-Dimensions	<i>dimensions</i>
---------------	-------------------

---

### Description

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

### Usage

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

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

### Arguments

**x**                      An MMPR object.

### Value

The number of rows/cols in an MMPR object.

### Examples

```
## Not run:
library(MMPR)
x <- as.MMPR(1:16,4,4,"single")
y <- as.MMPR(1:20,4,5,"double")
rows_x <- nrow(x)
cols_y <- ncol(y)

## End(Not run)
```

**MMPR deep copy**

Create a copy of an MMPR 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:**

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

x MMPR object.

**MMPRTile deep copy**

Create a duplicate of an MMPRTile 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:**

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

x MMPRTile matrix.

**Examples**

```
## Not run:
# Example usage of the class and its methods
a <- matrix(1:36, 6, 6)
mmpr_matrix <- as.MMPR(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_mmpr_matrix = mmpr_matrix
temp_mmpr_matrix[2,2] <- 500
mmpr_matrix[2,2]          #500

mmpr_matrix_copy <- MMPR.copy(mmpr_matrix)
mmpr_matrix[2,2] <-100
mmpr_matrix_copy[2,2] <- 200

mmpr_matrix[2,2]          #100
mmpr_matrix_copy[2,2]     #200

## End(Not run)
```

---

09-Concatenate	<i>concatenate</i>
----------------	--------------------

---

**Description**

`c()` function for MMPR objects.

**Usage**

```
## S3 method for class 'List of MMPR objects'
MMPR.Concatenate(x)
```

**Arguments**

`x`                      List of MMPR objects.

**Value**

MMPR object containing values from all objects in the list.

**Examples**

```
## Not run:
library(MMPR)
x <- as.MMPR(1:20,precision="single")
y <- as.MMPR(1:20,precision="single")
list <- c(x,y)
new_obj <- MMPR.Concatenate(list)

## End(Not run)
```

---

10-Bind	<i>rbind</i>
---------	--------------

---

**Description**

`rbind()` and `cbind()` for MMPR objects.

**Usage**

```
## S3 method for class 'Rcpp_MMPR'
MMPR.rbind(x,y)

## S3 method for class 'Rcpp_MMPR'
MMPR.cbind(x,y)
```

**Arguments**

`x`                    An MMPR object.  
`y`                    An MMPR object.

**Value**

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

**Examples**

```
## Not run:
library(MMPR)
# create 2 MMPR matrix a,b
x <- rbind(a,b)
y <- cbind(a,b)

## End(Not run)
```

---

11-Diagonal	<i>diag</i>
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---

**Description**

Returns the diagonal of an MMPR matrix.

**Usage**

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

**Arguments**

`x`                    An MMPR matrix.

**Value**

An MMPR vector contains the main diagonal of the matrix.

**Examples**

```
## Not run:
library(MMPR)
x <- as.MMPR(1:16,4,4,"single")
diag_vals <- diag(x)

## End(Not run)
```

**Description**

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

**Usage**

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

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

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

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

**Arguments**

`x`                      An MMPR object.

**Value**

Min/max value/index.

**Examples**

```
## Not run:
library(MMPR)

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

## End(Not run)
```

**Description**

exp/log functions.

**Usage**

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

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

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

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

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

**Arguments**

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

**Value**

An MMPR object of the same dimensions as the input.

**Examples**

```
## Not run:
library(MMPR)

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

## End (Not run)
```

**Description**

Finite, infinite, and NaNs.

**Usage**

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

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

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

**Arguments**

`x`                      An MMPR object.

**Value**

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

**Examples**

```
## Not run:
library(MMPR)

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

## End(Not run)
```

**Description**

Miscellaneous mathematical functions.



**Usage**

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

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

**Arguments**

`x`                      An MMPR object.

**Value**

An MMPR object of the same dimensions as the input.

**Examples**

```
## Not run:
library(MMPR)

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

## End(Not run)
```

---

16-NA's

NA's

---

**Description**

`is.na()`, `na.omit()`, and `na.exclude()` for MMPR objects.

**Usage**

```
## S3 method for class 'Rcpp_MMPR'
MMPR.is.na(object,index=-1)
## S3 method for class 'Rcpp_MMPR'
MMPR.na.exclude(object,value)
## S3 method for class 'Rcpp_MMPR'
MMPR.na.omit(object)
```

**Arguments**

`object`                  MMPR object.

`index`                    If a particular index in the MMPR 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**

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

**Examples**

```
## Not run:
library(MMPR)
x <- as.MMPR(1:20,precision="single")
x[1] <- NAN
MMPR.is.na(x,index=1) #TRUE
MMPR.na.exclude(x,50)
x[1] #50

## End(Not run)
```

---

17-Replicate	<i>replicate</i>
--------------	------------------

---

**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_MMPR'
rep(x,count=0,len=0)
```

**Arguments**

x	An MMPR 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**

MMPR vector containing the replicated values.

**Examples**

```
## Not run:
library(MMPR)
x <- as.MMPR(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
```

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

---

18-Round

*Rounding functions*


---

### Description

Rounding functions.

### Usage

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

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

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

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

### Arguments

<code>x</code>	An MMPR object.
<code>digits</code>	The number of digits to use in rounding.

### Value

An MMPR object of the same dimensions as the input.

### Examples

```
## Not run:
library(MMPR)

x <- as.MMPR(1:20,precision="double")
floor(x)

## End(Not run)
```

19-Scale

*scale***Description**

Center or scale an MMPR object.

**Usage**

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

**Arguments**

*x*                      An MMPR object.  
*center, scale*                      Logical or MMPR objects.

**Value**

An MMPR matrix.

**Examples**

```
## Not run:
library(MMPR)
x <- as.MMPR(1:50, "single")
x$ToMatrix(5, 10)
temp_center_scale <- new(1:10, precision="double")
z <- scale(x=temp_scale, center=FALSE, scale=temp_center_scale)

## End(Not run)
```

20-Sweep

*sweep***Description**

Sweep an MMPR vector through an MMPR matrix.

**Usage**

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

**Arguments**

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

**Value**

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

**Examples**

```
## Not run:
library(MMPR)
x <- as.MMPR(1:20,10,2,"single")
y <- as.MMPR(1:5,precision="double")
sweep_out <- sweep(x, stat=y, margin=1, FUN="+")
MMPR.is.double(sweep_out) #TRUE

## End(Not run)
```

---

21-Special Math      *Special mathematical functions.*

---

**Description**

Special mathematical functions.

**Usage**

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

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

**Arguments**

<code>x</code>	An MMPR object.
----------------	-----------------

**Value**

An MMPR object of the same dimensions as the input.

**Examples**

```
## Not run:
library(MMPR)

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

## End(Not run)
```

---

22-Trig*Trigonometric functions*

---

**Description**

Basic trig functions.

**Usage**

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

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

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

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

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

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

**Arguments**

x                      An MMPR object.

**Value**

An MMPR object of the same dimensions as the input.

**Examples**

```
## Not run:
library(MMPR)

mppr_matrix <- as.MMPR(1:20,nrow=2,ncol=10,"single")
x <- sin(mppr_matrix)

## End(Not run)
```

---

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_MMPR'
sinh(x)

## S4 method for signature 'Rcpp_MMPR'
cosh(x)

## S4 method for signature 'Rcpp_MMPR'
tanh(x)

## S4 method for signature 'Rcpp_MMPR'
asinh(x)

## S4 method for signature 'Rcpp_MMPR'
acosh(x)

## S4 method for signature 'Rcpp_MMPR'
atanh(x)
```

**Arguments**

x                      An MMPR object.

**Value**

An MMPR object of the same dimensions as the input.

**Examples**

```
## Not run:
library(MMPR)

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

## End(Not run)
```

---

24-Transpose

*transpose*

---

**Description**

Transpose an MMPR object.

**Usage**

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

**Arguments**

**x**                      An MMPR object.

**Value**

An MMPR object.

**Examples**

```
## Not run:
library(MMPR)
a <- matrix(1:20, nrow = 2)
a_mmp_r <- as.MMPR(a,2,10,"double")
a_mmp_r_transpose <- t(a_mmp_r)

## End(Not run)
```



---

## 25-Check precision *Metadata functions*

---

### Description

Checks the precision of a given MMPR object.

### Usage

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

### Arguments

`x`                      An MMPR object.

### Value

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

### Examples

```
## Not run:
library(MMPR)

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

## End(Not run)
```

---

## 26-Metadata *Metadata functions*

---

### Description

Metadata functions.

**Usage**

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

**Arguments**

`x`                      An MMPR object.

`precision`            String with the required precision.

**Value**

Prints/change metadata about an MMPR object.

**Examples**

```
## Not run:
library(MMPR)

x <- as.MMPR(1:20,precision="double")
typeof(x)
MMPR.ChangePrecision(x,"single")

## End(Not run)
```

---

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_MMPR'
print(x)

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

**Arguments**

`x, object`      An MMRP objects.

**Details**

Prints metadata about the object and some values.

**Examples**

```
## Not run:
library(MMRP)
x <- as.MMRP(1:16,4,4,"single")
y <- as.MMRP(1:20,4,5,"double")
x
print(y)

## End(Not run)
```

---

28-Cholesky decomposition  
*cholesky decomposition*

---

**Description**

Performs the Cholesky factorization of a positive definite MMRP matrix `x`.

**Usage**

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

**Arguments**

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

**Value**

An MMRP matrix.

**Examples**

```
## Not run:
library(MMRP)
# x <- as.MMRP(vals,nrow,ncol,precision)
chol_out <- chol(x)

## End(Not run)
```

---

29-Cholesky inverse  
*cholesky inverse*

---

### Description

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

### Usage

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

### Arguments

$x$	An MMPR object.
size	The number of columns to use.

### Value

An MMPR object.

### Examples

```
## Not run:
library(MMPR)
# x <- as.MMPR(vals,nrow,ncol,precision)
chol_out <- chol(x)
chol <- chol2inv(chol_out)

## End(Not run)
```

---

30-Crossprod      *crossprod*

---

### Description

Calculates the cross product of two MMPR matrices. It uses BLAS routine `gemm()` for  $\mathbf{A} \times \mathbf{B}$  operations and `syrk()` for  $\mathbf{A} \times \mathbf{A}^T$  operations.

### Usage

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

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

**Arguments**

`x`                      An MMPR object.

`y`                      Either NULL, or an MMPR matrix.

**Details**

Calculates cross product of two MMPR matrices performs:

`x %*% y`, `t(x) %*% x`

This function uses blas routine `gemm()` for **A X B** operations & `syrrk()` for **A X A<sup>T</sup>** operations.

**Value**

An MMPR matrix.

**Examples**

```
## Not run:
library(MMPR)
x <- as.MMPR(1:16,4,4,"single")
y <- as.MMPR(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

## End(Not run)
```

---

3l-Eigen decomposition  
*eigen decomposition*

---

**Description**

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

**Usage**

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

**Arguments**

`x`                      An MMPR object.

`only.values`        (TRUE/FALSE)?

**Value**

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

**Examples**

```
## Not run:
library(MMPR)
x <- as.MMPR("your_data", nrow, ncol, precision)
y <- eigen(x)

## End(Not run)
```

---

32-Symmetric	<i>isSymmetric</i>
--------------	--------------------

---

**Description**

Check if a given MMPR matrix is symmetric.

**Usage**

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

**Arguments**

object	An MMPR matrix.
...	Ignored.

**Value**

A logical value.

**Examples**

```
## Not run:
library(MMPR)

x <- as.MPPR(1:200, 100, 2, "Single")
isSymmetric(x) #false

crossprod_output <- crossprod(x)
isSymmetric(crossprod_output) #true

## End(Not run)
```

---

33-Norm	<i>norm</i>
---------	-------------

---

**Description**

Compute norm.

**Usage**

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

**Arguments**

<code>x</code>	An MMPR object.
<code>type</code>	"O"-ne, "I"-nfinity, "F"-robenius, "M"-ax modulus, and "l" norms.

**Value**

An MMPR object.

**Examples**

```
## Not run:
library(MMPR)

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

## End(Not run)
```

---

34-QR decomposition	<i>QR decomposition</i>
---------------------	-------------------------

---

**Description**

QR factorization and related functions.

**Usage**

```
## S4 method for signature 'Rcpp_MMPR'
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**

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

**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**

```
## Not run:

library(MMPR)

qr_input <- as.MMPR( c(1, 2, 3, 2, 4, 6, 3, 3, 3), 3, 3, "single")
qr_out <- qr(qr_input)
qr_out
qr_out[["qr"]]$PrintValues()
qr_out[["qraux"]]$PrintValues()
qr_out[["pivot"]]$PrintValues()
qr_out[["rank"]]$PrintValues()

qr_q <- qr.Q(qr_out)
qr_q

## End(Not run)
```



---

35-Reciprocal condition  
*reciprocal condition*

---

**Description**

Compute matrix norm.

**Usage**

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

**Arguments**

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

**Value**

An MMPR Object.

**Examples**

```
## Not run:
library(MMPR)

x <- as.MMPR(1:20,precision="double")
rcond(x)

## End(Not run)
```

---

36-Solve *solve*

---

**Description**

Solve a system of equations or invert an MMPR matrix.

**Usage**

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

**Arguments**

`a, b`                    An MMPR objects.  
`...`                    Ignored.

**Value**

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

**Examples**

```
## Not run:
library(MMPR)

x <- as.MMPR(1:20,4,5,"double")
y <- crossprod(x)
solve(y)

## End(Not run)
```

---

37-Singular value decomposition  
*SVD*

---

**Description**

SVD factorization.

**Usage**

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

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

**Arguments**

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

**Details**

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

**Examples**

```
## Not run:
library(MMPR)
x <- as.MMPR("your_data",nrow,ncol,precision)
y <- svd(x)

## End(Not run)
```

---

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_MMPR,Rcpp_MMPR'
backsolve(r, x, k = ncol(r), upper.tri = TRUE, transpose = FALSE)

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

**Arguments**

<code>l</code>	An MMPR object.
<code>r</code>	An MMPR object.
<code>x</code>	An MMPR object whose columns give the right-hand sides for the equations.
<code>k</code>	The number of columns of <code>r</code> and rows of <code>x</code> to use.
<code>upper.tri</code>	logical; if TRUE, the upper triangular part of <code>r</code> is used. Otherwise, the lower one.
<code>transpose</code>	logical; if TRUE, solve for $t(l, r)$ %*% output == <code>x</code> .

**Value**

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

**Examples**

```
## Not run:
library(MMPR)
a <- matrix(c(2, 0, 0, 3), nrow = 2)
b <- matrix(c(1, 2), nrow = 2)
a_mmpr <- as.MMPR(a, 2, 2, "single")
b_mmpr <- as.MMPR(b, 2, 1, "double")
x <- forwardsolve(a_mmpr, b_mmpr)
x

## End(Not run)
```

39-MMPR GEMM

*MMPR GEMM (Matrix-Matrix Multiplication)***Description**

Performs matrix-matrix multiplication of two given MMPR matrices to performs:

$C = \alpha A * B + \beta C$

$C = \alpha A A^T + \beta C$

**Usage**

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

**Arguments**

a	An MMPR matrix A.
b	An MMPR matrix B, if NULL, the function will perform syrk operation from blas.
c	Input/Output MMPR 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: <b><math>C = \alpha A^T A + \beta C</math></b> .
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 MMPR matrix.

**Examples**

```

## Not run:
library(MMPR)
# create 3 MMPR matrices a,b,c
print(c)
MMPR.gemm(a,b,c,transpose_a=false,transpose_b=TRUE,alpha=1,beta=1)
print(c)

## End(Not run)

```

40-MMPR TRSM

*MMPR 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_MMPR'
MMPR.trsm(a,b,upper_triangle,transpose,side = 'L',alpha =1)

```

**Arguments**

a	MMPR Matrix A.
b	MMPR 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 MMPR Matrix.

**Examples**

```
## Not run:
library(MMPR)
# create 2 MMPR matrices a,b
c <- MMPR.trsm(a,b,upper_triangle=TRUE,transpose=FALSE,side='L',alpha=1)
print(c)

## End(Not run)
```

---

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

---

**Description**

Tile-based matrix-matrix multiplication of two given MMPR tiled matrices to **perform:**  
 $C = \alpha * A \times B + \beta * C$

**Usage**

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

**Arguments**

a	An MMPR tile matrix A.
b	An MMPR tile matrix B.
c	Input/Output MMPR 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 of thread to run using openmp, default = 1 (serial with no parallelization).

**Value**

An MMPR tile matrix C.

**Examples**

```
## Not run:
library(MMPR)
# create 3 MMPR Tile matrices a,b,c
print(c)
MMPRTile.gemm(a,b,c,transpose_a=false,transpose_b=TRUE,alpha=1,beta=1,num_threads = 8)
print(c)

## End(Not run)
```

---

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

---

**Description**

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

**Usage**

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

**Arguments**

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

**Value**

An MMPR tile matrix.

**Examples**

```
## Not run:
x <- chol(y, overwrite_input=FALSE, num_threads=8)
x <- chol(x)

## End(Not run)
```

---

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


---

**Description**

Tile-based algorithm to solve a triangular matrix equation for MMPR tiled matrices.  
performs:  
 $\text{op}(A)*X=\alpha*B$   
 $X*\text{op}(A)=\alpha*B$

**Usage**

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

**Arguments**

a	An MMPR tile matrix A.
b	An MMPR 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 MMPR Tile Matrix B  $\rightarrow$  (X).

**Examples**

```
## Not run:
library(MMPR)
# create 2 MMPR Tile matrices a,b
print(b)
MMPRTile.trsm(a,b,side='L',upper_triangle=TRUE,transpose=FALSE,alpha=1)
print(b)

## End(Not run)
```