

# Package ‘madness’

July 14, 2026

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**Version** 0.2.9

**Date** 2026-07-14

**License** LGPL-3

**Title** Automatic Differentiation of Multivariate Operations

**BugReports** <https://github.com/shabbychef/madness/issues>

**Description** An object that supports automatic differentiation of matrix- and multidimensional-valued functions with respect to multidimensional independent variables. Automatic differentiation is via 'forward accumulation'.

**Depends** R (>= 3.2.0)

**Imports** Matrix, matrixcalc, expm, methods

**Suggests** testthat, dplyr, tidyr, lubridate, SharpeR, sandwich, formatR, knitr

**URL** <https://github.com/shabbychef/madness>

**LazyData** true

**VignetteBuilder** knitr

**Collate** 'AllClass.r' 'utils.r' 'Ops.r' 'bind.r' 'blockrep.r' 'coerce.r' 'data.r' 'det.r' 'diag.r' 'eigen.r' 'elwise.r' 'madness\_pkg.r' 'matwise.r' 'max.r' 'norm.r' 'numderiv.r' 'reshape.r' 'solve.r' 'sum.r' 'sums.r' 'theta.r' 'to\_objective.r' 'trace.r' 'twomoments.r' 'vcov.r' 'vec.r'

**RoxygenNote** 7.3.3

**NeedsCompilation** no

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**Repository** CRAN

**Date/Publication** 2026-07-14 21:10:02 UTC

## Contents

|               |           |
|---------------|-----------|
| accessor      | 2         |
| arithops      | 3         |
| as            | 6         |
| as.madness    | 7         |
| bind          | 8         |
| blockrep      | 9         |
| colsums       | 10        |
| det           | 11        |
| eigen         | 12        |
| elwise        | 13        |
| madness-class | 14        |
| madness-NEWS  | 16        |
| marithops     | 18        |
| matrix.trace  | 19        |
| matwise       | 20        |
| max           | 20        |
| norm          | 21        |
| numderiv      | 22        |
| outer         | 23        |
| reshapes      | 24        |
| setter        | 26        |
| show          | 26        |
| solve         | 27        |
| stock_returns | 28        |
| sumprod       | 29        |
| theta         | 29        |
| todiag        | 31        |
| to_objective  | 31        |
| twomoments    | 32        |
| vcov.madness  | 34        |
| vec           | 35        |
| wff3          | 36        |
| [             | 37        |
| <b>Index</b>  | <b>38</b> |

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accessor

*Accessor methods.*

---

## Description

Access slot data from a madness object.

**Usage**

```
val(x)

## S4 method for signature 'madness'
val(x)

## S4 method for signature 'madness'
dim(x)

## S4 method for signature 'madness'
length(x)

dvd(x)

## S4 method for signature 'madness'
dvd(x)

xtag(x)

## S4 method for signature 'madness'
xtag(x)

vtag(x)

## S4 method for signature 'madness'
vtag(x)

var(x)

## S4 method for signature 'madness'
var(x)
```

**Arguments**

x                    a madness object.

**Author(s)**

Steven E. Pav <shabbychef@gmail.com>

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arithops

*Basic Arithmetic Operations.*

---

**Description**

These perform basic arithmetic operations on madness objects: unary plus and minus, addition, subtraction, multiplication, division and power.

**Usage**

```
## S4 method for signature 'madness,missing'
e1 + e2

## S4 method for signature 'madness,missing'
e1 - e2

## S4 method for signature 'madness,madness'
e1 + e2

## S4 method for signature 'madness,numeric'
e1 + e2

## S4 method for signature 'madness,array'
e1 + e2

## S4 method for signature 'numeric,madness'
e1 + e2

## S4 method for signature 'array,madness'
e1 + e2

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

## S4 method for signature 'madness,numeric'
e1 - e2

## S4 method for signature 'madness,array'
e1 - e2

## S4 method for signature 'numeric,madness'
e1 - e2

## S4 method for signature 'array,madness'
e1 - e2

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

## S4 method for signature 'madness,numeric'
e1 * e2

## S4 method for signature 'madness,array'
e1 * e2

## S4 method for signature 'numeric,madness'
e1 * e2
```

```
## S4 method for signature 'array,madness'
e1 * e2

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

## S4 method for signature 'madness,numeric'
e1 / e2

## S4 method for signature 'madness,array'
e1 / e2

## S4 method for signature 'numeric,madness'
e1 / e2

## S4 method for signature 'array,madness'
e1 / e2

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

## S4 method for signature 'madness,numeric'
e1 ^ e2

## S4 method for signature 'madness,array'
e1 ^ e2

## S4 method for signature 'numeric,madness'
e1 ^ e2

## S4 method for signature 'array,madness'
e1 ^ e2
```

## Arguments

e1, e2                      madness or numeric values

## Author(s)

Steven E. Pav <shabbychef@gmail.com>

## Examples

```
set.seed(123)
y <- array(rnorm(3*3),dim=c(3,3))
dy <- matrix(rnorm(length(y)*2),ncol=2)
dx <- crossprod(matrix(rnorm(ncol(dy)*100),nrow=100))
obj0 <- madness(val=y,vtag='y',xtag='x',dvdx=dy,varx=dx)
z <- array(rnorm(3*3),dim=c(3,3))
```

```
anobj <- + obj0
anobj <- - obj0
anobj <- 6 - obj0
anobj <- 1 + obj0
anobj <- obj0 - 3
anobj <- z + obj0
anobj <- obj0 - z

obj1 <- obj0 ^ 2
anobj <- (0.3 * obj0) + (5.1 * obj1)

anobj <- 2 ^ obj0
anobj <- obj1 ^ obj0
anobj <- obj1 / obj0
anobj <- z / obj0
```

---

as

*Coerce madness to something else*

---

## Description

Coerce as something else

## Usage

```
## S4 method for signature 'madness'
as.array(x, ...)

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

## S4 method for signature 'madness'
as.numeric(x, ...)
```

## Arguments

|     |                                                    |
|-----|----------------------------------------------------|
| x   | a madness object                                   |
| ... | further arguments passed to or from other methods. |

## Author(s)

Steven E. Pav <shabbychef@gmail.com>

---

|            |                                    |
|------------|------------------------------------|
| as.madness | <i>Coerce to a madness object.</i> |
|------------|------------------------------------|

---

## Description

Convert model to a madness object.

## Usage

```
as.madness(x, vtag=NULL, xtag=NULL)

## Default S3 method:
as.madness(x, vtag = NULL, xtag = NULL)
```

## Arguments

|      |                                                       |
|------|-------------------------------------------------------|
| x    | an object which can be fed to coef, and possibly vcov |
| vtag | an optional name for the <i>val</i> variable.         |
| xtag | an optional name for the <i>X</i> variable.           |

## Details

Attempts to stuff the coefficients and variance-covariance matrix of a model into a madness object.

## Value

A madness object.

## Author(s)

Steven E. Pav <shabbychef@gmail.com>

## Examples

```
xy <- data.frame(x=rnorm(100),y=runif(100),z=runif(100))
amod <- lm(z ~ x + y,xy)
amad <- as.madness(amod)
```

---

**bind***Row and Column Bind*

---

**Description**

Row and Column Bind

**Usage**

```
\method{c}{madness}(...)  
  
## S4 method for signature 'madness,missing'  
cbind2(x, y, ...)  
  
## S4 method for signature 'madness,madness'  
cbind2(x, y, ...)  
  
## S4 method for signature 'madness,ANY'  
cbind2(x, y, ...)  
  
## S4 method for signature 'ANY,madness'  
cbind2(x, y, ...)  
  
## S4 method for signature 'madness,missing'  
rbind2(x, y, ...)  
  
## S4 method for signature 'madness,madness'  
rbind2(x, y, ...)  
  
## S4 method for signature 'madness,ANY'  
rbind2(x, y, ...)  
  
## S4 method for signature 'ANY,madness'  
rbind2(x, y, ...)
```

**Arguments**

|      |                                                |
|------|------------------------------------------------|
| ...  | optional arguments for methods (ignored here). |
| x, y | madness or array, numeric, matrix objects.     |

**Author(s)**

Steven E. Pav &lt;shabbychef@gmail.com&gt;

---

|          |                                                    |
|----------|----------------------------------------------------|
| blockrep | <i>Replicate blocks of multidimensional value.</i> |
|----------|----------------------------------------------------|

---

## Description

Replicates a multidimensional object a number of times along given dimensions.

## Usage

```
blockrep(x, nreps)
```

```
repto(x, newdim)
```

```
repto(x, newdim)
```

## Arguments

|        |                                                                                                                                      |
|--------|--------------------------------------------------------------------------------------------------------------------------------------|
| x      | a madness object, representing a k-dimensional object.                                                                               |
| nreps  | an l-vector of positive integers, representing how many times to copy the object.                                                    |
| newdim | an l-vector of positive integers of the new dimension of the output object. These must be integer multiples of the input dimensions. |

## Details

Given a k-dimensional object, and an l-vector of positive integers, for  $l \geq k$ , copy the input object  $l_i$  times in the  $i$ th dimension. Useful for replication and (slow, fake) outer products.

repto replicates to the given dimension, assuming the given dimension are integer multiples of the input dimensions.

## Value

A madness object replicated out.

## Note

An error will be thrown if nreps or newdim are improper.

## Author(s)

Steven E. Pav <shabbychef@gmail.com>

## Examples

```
set.seed(123)
y <- array(rnorm(3*3),dim=c(3,3))
dy <- matrix(rnorm(length(y)*2),ncol=2)
dx <- crossprod(matrix(rnorm(ncol(dy)*100),nrow=100))
obj0 <- madness(val=y,vtag='y',xtag='x',dvdx=dy,varx=dx)

anobj <- blockrep(obj0,c(1,2,1))
anobj <- blockrep(obj0,c(1,1,2))
anobj <- repto(obj0,c(9,12,4))
```

---

colsums

*Form Row and Column Sums and Means*


---

## Description

Form Row and Column Sums and Means for madness objects.

## Usage

```
## S4 method for signature 'madness'
colSums(x, na.rm = FALSE, dims = 1)

## S4 method for signature 'madness'
colMeans(x, na.rm = FALSE, dims = 1)

## S4 method for signature 'madness'
rowSums(x, na.rm = FALSE, dims = 1)

## S4 method for signature 'madness'
rowMeans(x, na.rm = FALSE, dims = 1)
```

## Arguments

|       |                                                                                                                                                                                    |
|-------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x     | madness object.                                                                                                                                                                    |
| na.rm | logical. Should missing values (including NaN) be omitted from the calculations?                                                                                                   |
| dims  | integer number: Which dimensions are regarded as ‘rows’ or ‘columns’ to sum over. For row*, the sum or mean is over dimensions dims+1, ...; for col* it is over dimensions 1:dims. |

## Value

a madness object. Note that the sums are flattened to a column vector.

## Author(s)

Steven E. Pav <shabbychef@gmail.com>

---

det

---

*Matrix Determinant*

---

**Description**

Compute the determinant of a matrix. As for `base::determinant`, a list of the modulus and sign are returned.

**Usage**

```
## S3 method for class 'madness'
determinant(x, logarithm = TRUE, ...)

det(x, ...)

## S4 method for signature 'madness,ANY'
determinant(x, logarithm = TRUE, ...)

## S4 method for signature 'madness,missing'
determinant(x, logarithm = TRUE, ...)

## S4 method for signature 'madness,logical'
determinant(x, logarithm = TRUE, ...)
```

**Arguments**

|                        |                                                                                    |
|------------------------|------------------------------------------------------------------------------------|
| <code>x</code>         | madness object.                                                                    |
| <code>logarithm</code> | logical; if TRUE (default) return the logarithm of the modulus of the determinant. |
| <code>...</code>       | optional arguments, currently unused.                                              |

**Value**

a list with elements `modulus` and `sign`, which are madness objects.

**Note**

throws an error for non-square matrices or non-matrix input.

**Author(s)**

Steven E. Pav <shabbychef@gmail.com>

eigen

*Spectral Decomposition of a Matrix***Description**

Computes eigenvalues and eigenvectors of numeric (double, integer, logical) or complex madness matrices.

**Usage**

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

**Arguments**

|                          |                                                                                                                                                                                                                    |
|--------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>x</code>           | madness object representing a numeric matrix whose spectral decomposition is to be computed.                                                                                                                       |
| <code>symmetric</code>   | if TRUE, the matrix is assumed to be symmetric (or Hermitian if complex) and only its lower triangle (diagonal included) is used. If <code>symmetric</code> is not specified, <code>isSymmetric(x)</code> is used. |
| <code>only.values</code> | if TRUE, only the eigenvalues are computed and returned, otherwise both eigenvalues and eigenvectors are returned.                                                                                                 |
| <code>EISPACK</code>     | logical. Defunct and ignored.                                                                                                                                                                                      |

**Details**

The singular value decomposition of the matrix  $X$  is

$$X = UDV',$$

where  $U$  and  $V$  are orthogonal,  $V'$  is  $V$  transposed, and  $D$  is a diagonal matrix with the singular values on the diagonal.

**Value**

a list with components

**values** a madness object of a vector containing the  $p$  eigenvalues of  $x$ , sorted in *decreasing* order, according to `Mod(value)` in the asymmetric case when they might be complex (even for real matrices). For real asymmetric matrices the vector will be complex only if complex conjugate pairs of eigenvalues are detected.

**vectors** either a  $p \times p$  matrix whose columns contain the eigenvectors of  $x$  or NULL if `only.values` is TRUE. The vectors are normalized to unit length.

Recall that the eigenvectors are only defined up to a constant: even when the length is specified they are still only defined up to a scalar of modulus one (the sign for real matrices). If `r <- eigen(A)`, and `V <- r$vectors`; `lam <- r$values`, then

$$A = VLmbdV^{-1}$$

(up to numerical fuzz), where `Lmbd = diag(lam)`.

**Author(s)**

Steven E. Pav <shabbychef@gmail.com>

**References**

Izenman, Alan Julian. "Reduced-Rank Regression for the Multivariate Linear Model." Journal of Multivariate Analysis 5, pp 248-264 (1975). doi:10.1016/0047259X(75)900421

Kato, Tosio. "Perturbation Theory for Linear Operators." Springer (1995). <https://webhomes.maths.ed.ac.uk/~v1ranick/papers/kato1.pdf>

**See Also**

[eigen](#).

---

elwise

*Element-wise Multivariate Operations*

---

**Description**

Element-wise multivariate operations.

**Usage**

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

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

```
## S4 method for signature 'madness'  
log(x)
```

```
## S4 method for signature 'madness'  
log10(x)
```

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

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

```
## S4 method for signature 'madness'  
cos(x)
```

```
## S4 method for signature 'madness'  
tan(x)
```

**Arguments**

`x`                      madness object.

**Details**

These operations are scalar-to-scalar operations applied to each element of a multidimensional array.

**Note**

The `exp`, `log`, and `sqrt` functions are not to be confused with the matrix-wise operations, `expm`, `logm` and `sqrtm`

**Author(s)**

Steven E. Pav <shabbychef@gmail.com>

**See Also**

[matwise](#)

---

madness-class

*Madness Class.*


---

**Description**

An S4 class to enable forward differentiation of multivariate computations. Think of ‘madness’ as ‘multivariate automatic differentiation -ness.’ There is also a constructor method for madness objects, and a wrapper method.

**Usage**

```
## S4 method for signature 'madness'
initialize(
  .Object,
  val,
  dvdx,
  xtag = NA_character_,
  vtag = NA_character_,
  varx = matrix(nrow = 0, ncol = 0)
)

madness(val, dvdx = NULL, vtag = NULL, xtag = NULL, varx = NULL)
```

**Arguments**

|                      |                                                                                                                 |
|----------------------|-----------------------------------------------------------------------------------------------------------------|
| <code>.Object</code> | a madness object, or proto-object.                                                                              |
| <code>val</code>     | an array of some numeric value, of arbitrary dimension.                                                         |
| <code>dvdX</code>    | a matrix of the derivative of (the vector of) <code>val</code> with respect to some independent variable, $X$ . |
| <code>xtag</code>    | an optional name for the $X$ variable.                                                                          |
| <code>vtag</code>    | an optional name for the <i>val</i> variable.                                                                   |
| <code>varX</code>    | an optional variance-covariance matrix of the independent variable, $X$ .                                       |

**Details**

A madness object contains a (multidimensional) value, and the derivative of that with respect to some independent variable. The purpose is to simplify computation of multivariate derivatives, especially for use in the Delta method. Towards this usage, one may store the covariance of the independent variable in the object as well, from which the approximate variance-covariance matrix can easily be computed. See [vcov](#).

Note that derivatives are all implicitly 'flattened'. That is, when we talk of the derivative of  $i \times j$  matrix  $Y$  with respect to  $m \times n$  matrix  $X$ , we mean the derivative of the  $ij$  vector  $\text{vec}(Y)$  with respect to the  $mn$  vector  $\text{vec}(X)$ . Moreover, derivatives follow the 'numerator layout' convention: this derivative is a  $ij \times mn$  matrix whose first column is the derivative of  $\text{vec}(Y)$  with respect to  $X_{1,1}$ . Numerator layout feels unnatural because it makes a gradient vector of a scalar-valued function into a row vector. Despite this deficiency, it makes the product rule feel more natural. (2FIX: is this so?)

**Value**

An object of class `madness`.

**Slots**

|                   |                                                                                                                                                                                                                                                                                                                                                                                                               |
|-------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>val</code>  | an array of some numeric value. (Note that array includes matrix as a subclass.) The numeric value can have arbitrary dimension.                                                                                                                                                                                                                                                                              |
| <code>dvdX</code> | a matrix of the derivative of (the vector of) <code>val</code> with respect to some independent variable, $X$ . A Derivative is indeed a 2-dimensional matrix. Derivatives have all been 'flattened'. See the details. If not given, defaults to the identity matrix, in which case $\text{val} = X$ , which is useful to initialization. Note that the derivative is with respect to an 'unrestricted' $X$ . |
| <code>xtag</code> | an optional name for the $X$ variable. Operations between two objects of the class with distinct <code>xtag</code> data will result in an error, since they are considered to have different independent variables.                                                                                                                                                                                           |
| <code>vtag</code> | an optional name for the <i>val</i> variable. This will be propagated forward.                                                                                                                                                                                                                                                                                                                                |
| <code>varX</code> | an optional variance-covariance matrix of the independent variable, $X$ .                                                                                                                                                                                                                                                                                                                                     |

**Author(s)**

Steven E. Pav <shabbychef@gmail.com>

## References

Petersen, Kaare Brandt and Pedersen, Michael Syskind. "The Matrix Cookbook." Technical University of Denmark (2012). <http://www2.imm.dtu.dk/pubdb/pubs/3274-full.html>

Magnus, Jan R. and Neudecker, H. "Matrix Differential Calculus with Applications in Statistics and Econometrics." 3rd Edition. Wiley Series in Probability and Statistics: Texts and References Section (2007).

## Examples

```
obj <- new("madness", val=matrix(rnorm(10*10),nrow=10), dwdx=diag(100), xtag="foo", vtag="foo")
obj2 <- madness(val=matrix(rnorm(10*10),nrow=10), xtag="foo", vtag="foo^2")
```

---

madness-NEWS

*News for package ‘madness’:*


---

## Description

News for package ‘madness’.

### **madness** Version 0.2.9 (2026-07-14)

- Fix vignette references.

### **madness** Version 0.2.8 (2023-08-20)

- emergency CRAN release to fix package documentation.

### **madness** Version 0.2.7 (2020-02-07)

- emergency CRAN release to deal with ellipsis in documentation.

### **madness** Version 0.2.6 (2019-04-19)

- emergency CRAN release to deal with change in generic signature for colSums, colMeans, rowSums, rowMeans.

### **madness** Version 0.2.5 (2018-08-27)

- emergency CRAN release to deal with failing vignette on alternative BLAS.

### **madness** Version 0.2.4 (2018-08-26)

- adding to unit tests.
- fix scalar to array promotion.
- fix broken vtag in aperm.
- add FF3 and stock returns data to build vignette.

**madness** Version 0.2.3 (2018-02-14)

- emergency CRAN release to deal with failing tests under alternative BLAS/LAPACK libraries.

**madness** Version 0.2.2 (2017-04-26)

- emergency CRAN release for upstream changes to diag. thanks to Martin Maechler for the patch.

**madness** Version 0.2.1 (2017-04-13)

- emergency CRAN release for failed build.
- no new functionality.

**madness** Version 0.2.0 (2016-01-19)

- add static vignette.
- modify twomoments.
- release to CRAN.

**madness** Version 0.1.0.400 (2016-01-12)

- adding max and min.

**madness** Version 0.1.0.300 (2016-01-10)

- adding eigen.

**madness** Version 0.1.0.200 (2016-01-07)

- exporting diag.

**madness** Version 0.1.0 (2015-12-15)

- first CRAN release.

**madness** Initial Version 0.0.0.5000 (2015-12-01)

- first github release.

---

marithops

*Basic Matrix Arithmetic Operations.*


---

## Description

These perform basic matrix arithmetic on madness objects: matrix multiplication, cross product, Kronecker product.

## Usage

```
## S4 method for signature 'madness,madness'
x %*% y
```

```
## S4 method for signature 'madness,array'
x %*% y
```

```
## S4 method for signature 'array,madness'
x %*% y
```

```
## S4 method for signature 'madness,madness'
crossprod(x, y)
```

```
## S4 method for signature 'madness,ANY'
crossprod(x, y)
```

```
## S4 method for signature 'madness,missing'
crossprod(x, y)
```

```
## S4 method for signature 'ANY,madness'
crossprod(x, y)
```

```
## S4 method for signature 'madness,madness'
tcrossprod(x, y)
```

```
## S4 method for signature 'madness,ANY'
tcrossprod(x, y)
```

```
## S4 method for signature 'madness,missing'
tcrossprod(x, y)
```

```
## S4 method for signature 'ANY,madness'
tcrossprod(x, y)
```

## Arguments

x, y                      madness or numeric matrix values.

**Author(s)**

Steven E. Pav <shabbychef@gmail.com>

**Examples**

```
set.seed(123)
y <- array(rnorm(3*3),dim=c(3,3))
dy <- matrix(rnorm(length(y)*2),ncol=2)
dx <- crossprod(matrix(rnorm(ncol(dy)*100),nrow=100))
obj0 <- madness(val=y,vtag='y',xtag='x',dvdxdy=dy,varx=dx)
z <- array(rnorm(3*3),dim=c(3,3))

anobj <- obj0 %**% obj0
anobj <- z %**% obj0
anobj <- crossprod(obj0)
anobj <- crossprod(obj0,z)
anobj <- tcrossprod(obj0,obj0)
# NYI:
# anobj <- obj0 %x% obj0
```

---

matrix.trace

---

*Matrix Trace*


---

**Description**

Matrix Trace

**Usage**

```
matrix.trace(x)

## S4 method for signature 'ANY'
matrix.trace(x)

## S4 method for signature 'madness'
matrix.trace(x)
```

**Arguments**

x                      madness object.

**Author(s)**

Steven E. Pav <shabbychef@gmail.com>

matwise

*Matrix-wise Multivariate Operations***Description**

Element-wise multivariate operations.

**Usage**

```
## S4 method for signature 'madness'
sqrtm(x)

## S3 method for class 'madness'
chol(x, ...)
```

**Arguments**

x                      madness object.  
 ...                    further arguments passed to or from other methods.

**Details**

These operations are operations on matrices: compute the symmetric square root or the Cholesky factor. In the future, the matrix exponent and logarithm may be implemented?

**Author(s)**

Steven E. Pav <shabbychef@gmail.com>

max

*Maxima and Minima***Description**

Return the maxima and minima of the input values.

**Usage**

```
## S4 method for signature 'madness'
max(x, ..., na.rm = FALSE)

## S4 method for signature 'madness'
min(x, ..., na.rm = FALSE)
```

**Arguments**

|       |                                                                                |
|-------|--------------------------------------------------------------------------------|
| x     | madness object arguments.                                                      |
| ...   | madness object arguments.                                                      |
| na.rm | a logical (TRUE or FALSE) indicating whether missing values should be removed. |

**Details**

max and min return the maximum or minimum of *all* the values present in their arguments.

If na.rm is FALSE and NA value in any of the arguments will cause a value of NA to be returned, otherwise NA values are ignored.

The minimum and maximum of a numeric empty set are +Inf and -Inf (in this order!) which ensures *transitivity*, e.g.,  $\min(x1, \min(x2)) == \min(x1, x2)$ . For numeric x  $\max(x) == -\text{Inf}$  and  $\min(x) == +\text{Inf}$  whenever  $\text{length}(x) == 0$  (after removing missing values if requested).

**Author(s)**

Steven E. Pav <shabbychef@gmail.com>

---

norm

---

*Matrix and vector norms.*


---

**Description**

Compute the norm of a vector or matrix, as determined by the type.

**Usage**

```
maxeig(x)

## S4 method for signature 'madness'
maxeig(x)

## S4 method for signature 'madness,missing'
norm(x)

## S4 method for signature 'madness,ANY'
norm(x, type = "One")
```

**Arguments**

|      |                                                                                                                                                                                                                                                                                            |
|------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x    | madness object.                                                                                                                                                                                                                                                                            |
| type | character string, specifying the <i>type</i> of matrix norm to be computed. A character indicating the type of norm desired.<br>"O", "o" or "1" specifies the <b>one</b> norm, (maximum absolute column sum);<br>"I" or "i" specifies the <b>infinity</b> norm (maximum absolute row sum); |

"F", "f", "E" or "e" specifies the **F**robenius norm (the **E**uclidean norm of  $x$  treated as if it were a vector);

"M" or "m" specifies the **m**aximum modulus of all the elements in  $x$ ; and

"2" specifies the "spectral" or 2-norm, which is the largest singular value ([svd](#)) of  $x$ .

The default is "0". Only the first character of `type[1]` is used.

### Value

the matrix norm, a non-negative number.

### Note

This should probably be fixed to return a scalar, not a 1 by 1 matrix?

### Author(s)

Steven E. Pav <shabbychef@gmail.com>

---

numderiv

*Numerical (approximate) Differentiation.*

---

### Description

Approximates the derivative of a function at the input by numerical methods.

### Usage

```
numderiv(f, x, eps=1e-8, type=c('forward','central','backward'),...)
```

```
## S4 method for signature 'ANY,array'
```

```
numderiv(f, x, eps = 1e-08, type = c("forward", "central", "backward"), ...)
```

```
## S4 method for signature 'ANY,madness'
```

```
numderiv(f, x, eps = 1e-08, type = c("forward", "central", "backward"), ...)
```

### Arguments

|                   |                                                                                             |
|-------------------|---------------------------------------------------------------------------------------------|
| <code>f</code>    | a function, to be evaluated at and near $x$ .                                               |
| <code>x</code>    | array, matrix, or madness object.                                                           |
| <code>eps</code>  | the 'epsilon', a small value added or subtracted from $x$ to compute the first differences. |
| <code>type</code> | the type of first difference, case-insensitive, substrings ok.                              |
| <code>...</code>  | arguments passed on to <code>f</code> .                                                     |

**Details**

For a multivariate-valued function of multivariate data, approximates the derivative at a point via the forward, central, or backward first differences, returning a madness object.

**Value**

A matrix if x is numeric; a madness object if x is a madness object.

**Author(s)**

Steven E. Pav <shabbychef@gmail.com>

**Examples**

```
f <- function(x,h) {
  cos(x + h)
}
x <- array(rnorm(100),dim=c(10,10))
madx <- numderiv(f,x,1e-8,h=pi)
```

---

outer

*Outer product.*


---

**Description**

Computes the outer product (or sum, quotient, etc) of the Cartesian product of two inputs.

**Usage**

```
## S4 method for signature 'ANY,ANY'
outer(X, Y, FUN = "*", ...)

## S4 method for signature 'madness,madness'
outer(X, Y, FUN = "*", ...)

## S4 method for signature 'madness,array'
outer(X, Y, FUN = "*", ...)

## S4 method for signature 'array,madness'
outer(X, Y, FUN = "*", ...)

X %o% Y

## S4 method for signature 'madness,madness'
kronecker(X, Y)

## S4 method for signature 'madness,array'
```

```
kronecker(X, Y)

## S4 method for signature 'array,madness'
kronecker(X, Y)
```

### Arguments

|      |                                                                                                                                       |
|------|---------------------------------------------------------------------------------------------------------------------------------------|
| X, Y | madness or numeric matrix values.                                                                                                     |
| FUN  | a function to use on the outer products, found <i>via</i> <a href="#">match.fun</a> (except for the special case " <code>*</code> "). |
| ...  | optional arguments to be passed to FUN.                                                                                               |

### Value

a madness object.

### Author(s)

Steven E. Pav <shabbychef@gmail.com>

### Examples

```
set.seed(123)
y <- array(rnorm(3*3),dim=c(3,3))
dy <- matrix(rnorm(length(y)*2),ncol=2)
dx <- crossprod(matrix(rnorm(ncol(dy)*100),nrow=100))
obj0 <- madness(val=y,vtag='y',xtag='x',dvdxdy=dy,varx=dx)

y1 <- array(rnorm(3*3),dim=c(3,3))
dy1 <- matrix(rnorm(length(y1)*2),ncol=2)
dx1 <- crossprod(matrix(rnorm(ncol(dy1)*100),nrow=100))
obj1 <- madness(val=y1,vtag='y1',xtag='x',dvdxdy1=dy1,varx=dx1)

anobj <- outer(obj0,obj0,'*')
anobj <- outer(obj0,obj0,'+')
anobj <- outer(obj0,obj1,'-')
anobj <- outer(obj0,obj1,'/')
```

---

reshapes

*Basic Reshape Operations*

---

### Description

Basic Reshape Operations

**Usage**

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

## S4 method for signature 'madness'
tril(x, k = 0)

## S4 method for signature 'madness'
triu(x, k = 0)

## S4 replacement method for signature 'madness'
dim(x) <- value

## S3 method for class 'madness'
aperm(a, perm = NULL, resize = TRUE, ...)
```

**Arguments**

|        |                                                                                                                                                                                                                                                                                                                             |
|--------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x      | madness object.                                                                                                                                                                                                                                                                                                             |
| k      | the index of the diagonal number from which to extract.madness object.                                                                                                                                                                                                                                                      |
| value  | an array of the new dimensions of the object value.                                                                                                                                                                                                                                                                         |
| a      | the array to be transposed.                                                                                                                                                                                                                                                                                                 |
| perm   | the subscript permutation vector, usually a permutation of the integers 1:n, where n is the number of dimensions of a. When a has named dimnames, it can be a character vector of length n giving a permutation of those names. The default (used whenever perm has zero length) is to reverse the order of the dimensions. |
| resize | a flag indicating whether the vector should be resized as well as having its elements reordered (default TRUE).                                                                                                                                                                                                             |
| ...    | optional arguments passed to methods, currently unused by package <b>Matrix</b> .                                                                                                                                                                                                                                           |

**Author(s)**

Steven E. Pav <shabbychef@gmail.com>

**See Also**

[vec](#), [todiag](#)

---

|        |                        |
|--------|------------------------|
| setter | <i>Setter methods.</i> |
|--------|------------------------|

---

**Description**

Modify slot data of a madness object. Note that the value and the derivative cannot easily be changed, as allowing this form of access would likely result in badly computed derivatives.

**Usage**

```
xtag(x) <- value

## S4 replacement method for signature 'madness'
xtag(x) <- value

vtag(x) <- value

## S4 replacement method for signature 'madness'
vtag(x) <- value

varx(x) <- value

## S4 replacement method for signature 'madness'
varx(x) <- value
```

**Arguments**

|       |                                         |
|-------|-----------------------------------------|
| x     | a madness object.                       |
| value | the new value of the tag or derivative. |

**Author(s)**

Steven E. Pav <shabbychef@gmail.com>

---

|      |                               |
|------|-------------------------------|
| show | <i>Show a madness object.</i> |
|------|-------------------------------|

---

**Description**

Displays the madness object.

**Usage**

```
show(object)

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

**Arguments**

object                    a madness object.

**Author(s)**

Steven E. Pav <shabbychef@gmail.com>

**Examples**

```
obj <- madness(val=matrix(rnorm(10*10),nrow=10), xtag="foo", vtag="foo^2")
obj
```

---

solve

*Basic Matrix Inversion*

---

**Description**

Basic Matrix Inversion

**Usage**

```
## S4 method for signature 'ANY,missing'
solve(a, b)

## S4 method for signature 'madness,missing'
solve(a, b)

## S4 method for signature 'madness,madness'
solve(a, b)

## S4 method for signature 'madness,array'
solve(a, b)

## S4 method for signature 'madness,ANY'
solve(a, b)

## S4 method for signature 'array,madness'
solve(a, b)

## S4 method for signature 'ANY,madness'
solve(a, b)
```

**Arguments**

a, b                    madness object or matrix value.

**Author(s)**

Steven E. Pav <shabbychef@gmail.com>

---

`stock_returns`*Stock Returns Data*

---

**Description**

Historical weekly relative returns of common shares of IBM and AAPL, downloaded from Quandl.

**Usage**

```
data(stock_returns)
```

**Format**

A `data.frame` object with 1930 observations and 3 columns The columns are defined as follows:

**Date** The closing date at which the return was observed, as a `Date` object. These are Friday dates, ranging from January 1981 through December 2017.

**AAPL** The simple returns of AAPL common shares, based on weekly (adjusted) close prices. A value of `0.01` corresponds to a one percent return. Close prices are adjusted for splits and dividends by Quandl.

**IBM** The simple returns of IBM common shares, based on weekly (adjusted) close prices. A value of `0.01` corresponds to a one percent return. Close prices are adjusted for splits and dividends by Quandl.

**Author(s)**

Steven E. Pav <shabbychef@gmail.com>

**Source**

Data were collated from Quandl on August 25, 2018. This data is no longer freely available from Quandl, but may be available directly from Nasdaq, see for example <https://www.nasdaq.com/market-activity/stocks/aapl/historical> and <https://www.nasdaq.com/market-activity/stocks/ibm/historical>

**Examples**

```
data(stock_returns)
str(stock_returns)
```

---

sumprod

*Sum and Product.*


---

### Description

Compute sum or product of madness objects.

### Usage

```
## S4 method for signature 'madness'
sum(x, ..., na.rm = FALSE)

## S4 method for signature 'madness'
prod(x, ..., na.rm = FALSE)
```

### Arguments

|       |                                                              |
|-------|--------------------------------------------------------------|
| x     | a numeric or madness object.                                 |
| ...   | ignored here.                                                |
| na.rm | logical. Should missing values (including 'NaN') be removed? |

### Value

a madness object representing a scalar value.

### Author(s)

Steven E. Pav <shabbychef@gmail.com>

### Examples

```
xv <- matrix(rnorm(5*5),ncol=5)
xmad <- madness(xv)
prod(xv)
sum(xv)
```

---

theta

*Estimate the symmetric second moment array of values.*


---

### Description

Given rows of observations of some vector (or multidimensional data), estimates the second moment by taking a simple mean, returning a madness object.

**Usage**

```
theta(X, vcov.func=vcov, xtag=NULL)
```

**Arguments**

|                        |                                                                                                                                                                                |
|------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>X</code>         | a multidimensional array (or a data frame) of observed values.                                                                                                                 |
| <code>vcov.func</code> | a function which takes an object of class <code>lm</code> , and computes a variance-covariance matrix. If equal to the string "normal", we assume multivariate normal returns. |
| <code>xtag</code>      | an optional string tag giving the name of the input data. defaults to figuring it out from the input expression.                                                               |

**Details**

Given a  $n \times k_1 \times k_2 \times \dots \times k_l$  array whose 'rows' are independent observations of  $X$ , computes the  $k_1 \times k_2 \times \dots \times k_l \times k_1 \times k_2 \dots k_l$  array of the mean of `outer(X, X)` based on  $n$  observations, returned as a [madness](#) object. The variance-covariance is also estimated, and stored in the object.

One may use the default method for computing covariance, via the [vcov](#) function, or via a 'fancy' estimator, like `sandwich:vcovHAC`, `sandwich:vcovHC`, *etc.*

**Value**

A `madness` object representing the mean of the outer product of the tail dimensions of  $X$ .

**Author(s)**

Steven E. Pav <shabbychef@gmail.com>

**See Also**

[twomoments](#)

**Examples**

```
set.seed(123)
X <- matrix(rnorm(1000*3), ncol=3)
th <- theta(X)

## Not run:
if (require(sandwich)) {
  th2 <- theta(X,vcov.func=vcovHC)
}

## End(Not run)
# works on data frames too:
set.seed(456)
X <- data.frame(a=runif(100),b=rnorm(100),c=1)
th <- theta(X)
```

---

|        |                            |
|--------|----------------------------|
| todiag | <i>Diagonal Operations</i> |
|--------|----------------------------|

---

**Description**

Diagonal Operations

**Usage**

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

todiag(x)

## S4 method for signature 'madness'
todiag(x)
```

**Arguments**

x                      madness object.

**Note**

the (somewhat odd) use of `stats::diag` for two different functions is *not* repeated here, at least for now.

**Author(s)**

Steven E. Pav <shabbychef@gmail.com>

**See Also**

[reshapes](#)

---

|              |                                                                       |
|--------------|-----------------------------------------------------------------------|
| to_objective | <i>Convert a madness object into an objective value with gradient</i> |
|--------------|-----------------------------------------------------------------------|

---

**Description**

Given a madness object representing a scalar value, strip out that value and attach an attribute of its derivative as a gradient. This is a convenience method that simplifies construction of objective functions for optimization routines.

**Usage**

```
to_objective(X)
```

**Arguments**

`X` a madness object representing a scalar.

**Value**

A scalar numeric with a gradient attribute of the derivative.

**Note**

An error will be thrown if the value is not a scalar.

**Author(s)**

Steven E. Pav <shabbychef@gmail.com>

**Examples**

```
# an objective function for matrix factorization with penalty:
fitfun <- function(R,L,Y,nu=-0.1) {
  dim(R) <- c(length(R),1)
  Rmad <- madness(R)
  dim(Rmad) <- c(ncol(L),ncol(Y))
  Err <- Y - L %*% Rmad
  penalty <- sum(exp(nu * Rmad))
  fit <- norm(Err,'f') + penalty
  to_objective(fit)
}
set.seed(1234)
L <- array(runif(30*5),dim=c(30,5))
Y <- array(runif(nrow(L)*20),dim=c(nrow(L),20))
R0 <- array(runif(ncol(L)*ncol(Y)),dim=c(ncol(L),ncol(Y)))
obj0 <- fitfun(R0,L,Y)
fooz <- nlm(fitfun, R0, L, Y, iterlim=3)
```

---

twomoments

---

*Estimate the mean and covariance of values.*


---

**Description**

Given rows of observations of some vector (or multidimensional data), estimates the mean and covariance of the values, returning two madness objects. These have a common covariance and 'xtag', so can be combined together.

**Usage**

```
twomoments(X, diag.only=FALSE, vcov.func=vcov, xtag=NULL, df=NULL)
```

## Arguments

|                        |                                                                                                                                                                                                                                          |
|------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>X</code>         | a multidimensional array (or a data frame) of observed values.                                                                                                                                                                           |
| <code>diag.only</code> | logical flag, defaulting to FALSE. When TRUE, only the diagonal of the covariance is computed, and returned instead of the entire covariance. This should be used for reasons of efficiency when only the marginal variances are needed. |
| <code>vcov.func</code> | a function which takes an object of class <code>lm</code> , and computes a variance-covariance matrix. If equal to the string "normal", we assume multivariate normal returns.                                                           |
| <code>xtag</code>      | an optional string tag giving the name of the input data. defaults to figuring it out from the input expression.                                                                                                                         |
| <code>df</code>        | the number of degrees of freedom to subtract from the sample size in the denominator of the covariance matrix estimate. The default value is the number of elements in the mean, the so-called Bessel's correction.                      |

## Details

Given a  $n \times k_1 \times k_2 \times \dots \times k_l$  array whose 'rows' are independent observations of  $X$ , computes the  $k_1 \times k_2 \times \dots \times k_l$  array of the mean of  $X$  and the  $k_1 \times k_2 \times \dots \times k_l \times k_1 \times k_2 \dots k_l$  array of the covariance, based on  $n$  observations, returned as two [madness](#) objects. The variance-covariance of each is estimated. The two objects have the same 'xtag', and so may be combined together. When the `diag.only=TRUE`, only the diagonal of the covariance is computed and returned.

One may use the default method for computing covariance, via the [vcov](#) function, or via a 'fancy' estimator, like `sandwich:vcovHAC`, `sandwich:vcovHC`, *etc.*

## Value

A two element list. When `diag.only=FALSE`, the first element of the list is `mu`, representing the mean, a [madness](#) object, the second is `Sigma`, representing the covariance, also a [madness](#) object. When `diag.only=TRUE`, the first element is `mu`, but the second is `sigmasq`, a [madness](#) object representing the diagonal of the covariance matrix.

## Author(s)

Steven E. Pav <[shabbychef@gmail.com](mailto:shabbychef@gmail.com)>

## See Also

[theta](#)

## Examples

```
set.seed(123)
X <- matrix(rnorm(1000*8),ncol=8)
alst <- twomoments(X)
markowitz <- solve(alst$Sigma,alst$mu)
vcov(markowitz)

# now compute the Sharpe ratios:
alst <- twomoments(X,diag.only=TRUE,df=1)
```

```
srs <- alst$mu / sqrt(alst$sigma2)
```

---

|              |                                                          |
|--------------|----------------------------------------------------------|
| vcov.madness | <i>Calculate Variance-Covariance Matrix for a model.</i> |
|--------------|----------------------------------------------------------|

---

## Description

Returns the variance-covariance matrix of the parameters computed by a madness object.

## Usage

```
## S3 method for class 'madness'
vcov(object, ...)
```

## Arguments

|        |                                                                                                      |
|--------|------------------------------------------------------------------------------------------------------|
| object | a madness object. A varx matrix must have been set on the object, otherwise an error will be thrown. |
| ...    | additional arguments for method functions. Ignored here.                                             |

## Details

Let  $X$  represent some quantity which is estimated from data. Let  $\Sigma$  be the (known or estimated) variance-covariance matrix of  $X$ . If  $Y$  is some computed function of  $X$ , then, by the Delta method (which is a first order Taylor approximation), the variance-covariance matrix of  $Y$  is approximately

$$\frac{dY}{dX} \Sigma \left( \frac{dY}{dX} \right)^{\top},$$

where the derivatives are defined over the 'unrolled' (or vectorized)  $Y$  and  $X$ .

Note that  $Y$  can represent a multidimensional quantity. Its variance covariance matrix, however, is two dimensional, as it too is defined over the 'unrolled'  $Y$ .

## Value

A matrix of the estimated covariances between the values being estimated by the madness object. While  $Y$  may be multidimensional, the return value is a square matrix whose side length is the number of elements of  $Y$

## Author(s)

Steven E. Pav <shabbychef@gmail.com>

## See Also

[vcov.](#)

## Examples

```
y <- array(rnorm(2*3),dim=c(2,3))
dy <- matrix(rnorm(length(y)*2),ncol=2)
dx <- crossprod(matrix(rnorm(ncol(dy)*100),nrow=100))
obj <- madness(val=y,dvdx=dy,varx=dx)
print(vcov(obj))
```

---

vec

*vectorize a multidimensional array.*


---

## Description

Turn a multidimensional array into a (column) vector. Turn a (typically symmetric) matrix into a (column) vector of the lower triangular part. Or reverse these operations.

## Usage

```
vec(x)

## S4 method for signature 'madness'
vec(x)

## S4 method for signature 'array'
vec(x)

vech(x, k = 0)

## S4 method for signature 'array'
vech(x, k = 0)

## S4 method for signature 'madness'
vech(x, k = 0)

ivech(x, k = 0, symmetric = FALSE)

## S4 method for signature 'ANY'
ivech(x, k = 0, symmetric = FALSE)

## S4 method for signature 'madness'
ivech(x, k = 0, symmetric = FALSE)
```

## Arguments

|           |                                                                                                |
|-----------|------------------------------------------------------------------------------------------------|
| x         | a madness object or multidimensional array or matrix.                                          |
| k         | the diagonal from which to subselect.                                                          |
| symmetric | logical whether to put the array on the antidiagonal as well. Will throw an error if $k > 0$ . |

**Value**

a madness object or an array, of the vectorized array or the subselected part. For the inverse operations, promotes to a madness of a matrix, or a matrix.

**Author(s)**

Steven E. Pav <shabbychef@gmail.com>

**See Also**

[reshapes](#), in particular `tril`.

**Examples**

```
y <- matrix(rnorm(16),ncol=4)
sy <- y + t(y)
vy <- vec(sy)
vmy <- vec(madness(sy))
vhy <- vech(sy)
vmhy <- vech(madness(sy))

ivech(c(1,2,3))
ivech(c(1,2,3),-1)
ivech(c(1,2,3),-1,symmetric=TRUE)
ivech(c(1,2,3,4,5,6,7,8),1)
```

---

wff3

*Weekly Fama French 3 Factor Returns*


---

**Description**

The weekly returns of the 3 Fama French Factors: Market, the cap factor SMB, and the growth factor HML.

**Usage**

```
wff3
```

**Format**

A data.frame object with 4800 observations and 5 columns. The data run from July, 1926 through June, 2018. As in the upstream source, the data are given in *percents*, meaning a value of 1.00 corresponds to a 1% movement. Note also that returns presumably are ‘simple’ returns, not log returns, though this is not clarified by the upstream source. The columns are defined as follows:

**Date** The closing data, as a Date object. These are typically Saturdays.

**Mkt** The Market weekly return. Note that the risk free rate has been added back to the excess returns published by the upstream source.

SMB The cap factor weekly return.

HML The growth factor weekly return.

RF The risk-free rate, presumably as an weekly rate, though note that no corrections have been made for weekend effects when adding the risk-free rate back to the market rate.

### Author(s)

Steven E. Pav <shabbychef@gmail.com>

### Source

Kenneth French data library, via Quandl. See [http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data\\_library.html](http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html), data description at [http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/Data\\_Library/f-f\\_factors.html](http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/Data_Library/f-f_factors.html).

### Examples

```
data(wff3)
str(wff3)
```

---

[ *Extract parts of a madness value.*

---

### Description

Extract parts of a madness value.

### Usage

```
## S4 method for signature 'madness,ANY,ANY,ANY'
x[i, j, ..., drop = TRUE]

## S4 method for signature 'madness,ANY,missing,ANY'
x[i, j, ..., drop = TRUE]
```

### Arguments

|        |                                                                                                                                                                                                                                      |
|--------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| x      | a madness object.                                                                                                                                                                                                                    |
| i      | indices specifying elements to extract or replace.                                                                                                                                                                                   |
| j, ... | further indices specifying elements to extract or replace.                                                                                                                                                                           |
| drop   | relevant for matrices and arrays. If TRUE the result is coerced to the lowest possible dimension (see the examples). This only works for extracting elements, not for the replacement. See <a href="#">drop</a> for further details. |

### Author(s)

Steven E. Pav <shabbychef@gmail.com>

# Index

- \* **data**
  - stock\_returns, [28](#)
  - wff3, [36](#)
- \* **differentiation**
  - madness-class, [14](#)
- \* **multivariate**
  - madness-class, [14](#)
- \*, array, madness-class (arithops), [3](#)
- \*, array, madness-method (arithops), [3](#)
- \*, madness, array-class (arithops), [3](#)
- \*, madness, array-method (arithops), [3](#)
- \*, madness, madness-class (arithops), [3](#)
- \*, madness, madness-method (arithops), [3](#)
- \*, madness, numeric-class (arithops), [3](#)
- \*, madness, numeric-method (arithops), [3](#)
- \*, numeric, madness-class (arithops), [3](#)
- \*, numeric, madness-method (arithops), [3](#)
- +, array, madness-class (arithops), [3](#)
- +, array, madness-method (arithops), [3](#)
- +, madness, array-class (arithops), [3](#)
- +, madness, array-method (arithops), [3](#)
- +, madness, madness-class (arithops), [3](#)
- +, madness, madness-method (arithops), [3](#)
- +, madness, missing-method (arithops), [3](#)
- +, madness, numeric-class (arithops), [3](#)
- +, madness, numeric-method (arithops), [3](#)
- +, madness-class (arithops), [3](#)
- +, numeric, madness-class (arithops), [3](#)
- +, numeric, madness-method (arithops), [3](#)
- , array, madness-class (arithops), [3](#)
- , array, madness-method (arithops), [3](#)
- , madness, array-class (arithops), [3](#)
- , madness, array-method (arithops), [3](#)
- , madness, madness-class (arithops), [3](#)
- , madness, madness-method (arithops), [3](#)
- , madness, missing-method (arithops), [3](#)
- , madness, numeric-class (arithops), [3](#)
- , madness, numeric-method (arithops), [3](#)
- , madness-class (arithops), [3](#)
- , numeric, madness-class (arithops), [3](#)
- , numeric, madness-method (arithops), [3](#)
- /, array, madness-class (arithops), [3](#)
- /, array, madness-method (arithops), [3](#)
- /, madness, array-class (arithops), [3](#)
- /, madness, array-method (arithops), [3](#)
- /, madness, madness-class (arithops), [3](#)
- /, madness, madness-method (arithops), [3](#)
- /, madness, numeric-class (arithops), [3](#)
- /, madness, numeric-method (arithops), [3](#)
- /, numeric, madness-class (arithops), [3](#)
- /, numeric, madness-method (arithops), [3](#)
- [, [37](#)
- [, madness, ANY, ANY, ANY-method ([), [37](#)
- [, madness, ANY, missing, ANY-method ([), [37](#)
- %%, array, madness-class (arithops), [18](#)
- %%, array, madness-method (arithops), [18](#)
- %%, madness, array-class (arithops), [18](#)
- %%, madness, array-method (arithops), [18](#)
- %%, madness, madness-method (arithops), [18](#)
- %o% (outer), [23](#)
- ^, array, madness-class (arithops), [3](#)
- ^, array, madness-method (arithops), [3](#)
- ^, madness, array-class (arithops), [3](#)
- ^, madness, array-method (arithops), [3](#)
- ^, madness, madness-class (arithops), [3](#)
- ^, madness, madness-method (arithops), [3](#)
- ^, madness, numeric-class (arithops), [3](#)
- ^, madness, numeric-method (arithops), [3](#)
- ^, numeric, madness-class (arithops), [3](#)
- ^, numeric, madness-method (arithops), [3](#)
- '%%', madness, madness-class (arithops), [18](#)
- abs, madness-method (elwise), [13](#)
- accessor, [2](#)
- ANY, array-method (numderiv), [22](#)
- ANY, madness-method (numderiv), [22](#)
- aperm (reshapes), [24](#)

- arithops, [3](#)
- as, [6](#)
- as.madness, [7](#)
- bind, [8](#)
- blockrep, [9](#)
- c.madness (bind), [8](#)
- cbind2, ANY, madness-method (bind), [8](#)
- cbind2, madness, ANY-method (bind), [8](#)
- cbind2, madness, madness-method (bind), [8](#)
- cbind2, madness, missing-method (bind), [8](#)
- chol (matwise), [20](#)
- colMeans (colsums), [10](#)
- colMeans, madness-method (colsums), [10](#)
- colSums (colsums), [10](#)
- colsums, [10](#)
- colSums, madness-method (colsums), [10](#)
- cos, madness-method (elwise), [13](#)
- crossprod (marithops), [18](#)
- crossprod, ANY, madness-method (marithops), [18](#)
- crossprod, madness, ANY-method (marithops), [18](#)
- crossprod, madness, madness-method (marithops), [18](#)
- crossprod, madness, missing-method (marithops), [18](#)
- det, [11](#)
- determinant (det), [11](#)
- determinant, madness, ANY-method (det), [11](#)
- determinant, madness, logical-method (det), [11](#)
- determinant, madness, missing-method (det), [11](#)
- determinant.madness (det), [11](#)
- diag (toddiag), [31](#)
- diag, madness-method (toddiag), [31](#)
- dim, madness-method (accessor), [2](#)
- dim<-, madness, ANY-method (reshapes), [24](#)
- dim<-, madness-method (reshapes), [24](#)
- drop, [37](#)
- dvdv (accessor), [2](#)
- dvdv, madness-method (accessor), [2](#)
- eigen, [12](#), [13](#)
- eigen, madness-method (eigen), [12](#)
- elwise, [13](#)
- exp, madness-method (elwise), [13](#)
- initialize, madness-class (madness-class), [14](#)
- initialize, madness-method (madness-class), [14](#)
- isSymmetric, [12](#)
- ivech (vec), [35](#)
- ivech, ANY-method (vec), [35](#)
- ivech, madness-method (vec), [35](#)
- kronecker, array, madness-class (outer), [23](#)
- kronecker, array, madness-method (outer), [23](#)
- kronecker, madness, array-class (outer), [23](#)
- kronecker, madness, array-method (outer), [23](#)
- kronecker, madness, madness-class (outer), [23](#)
- kronecker, madness, madness-method (outer), [23](#)
- length, madness-method (accessor), [2](#)
- log, madness-method (elwise), [13](#)
- log10, madness-method (elwise), [13](#)
- madness, [30](#), [33](#)
- madness (madness-class), [14](#)
- madness-class, [14](#)
- madness-NEWS, [16](#)
- marithops, [18](#)
- match.fun, [24](#)
- matrix.trace, [19](#)
- matrix.trace, ANY-method (matrix.trace), [19](#)
- matrix.trace, madness-method (matrix.trace), [19](#)
- matwise, [14](#), [20](#)
- max, [20](#)
- max, madness-class (max), [20](#)
- max, madness-method (max), [20](#)
- maxeig (norm), [21](#)
- maxeig, madness-method (norm), [21](#)
- min (max), [20](#)
- min, madness-class (max), [20](#)
- min, madness-method (max), [20](#)
- norm, [21](#)

- norm, madness, ANY-method (norm), 21
- norm, madness, missing-method (norm), 21
- norm, madness-method (norm), 21
- numderiv, 22
- numderiv, ANY, array-method (numderiv), 22
- numderiv, ANY, madness-method (numderiv), 22
- outer, 23
- outer, ANY, ANY-method (outer), 23
- outer, array, madness-method (outer), 23
- outer, madness, array-method (outer), 23
- outer, madness, madness-method (outer), 23
- prod (sumprod), 29
- prod, madness-class (sumprod), 29
- prod, madness-method (sumprod), 29
- rbind2, ANY, madness-method (bind), 8
- rbind2, madness, ANY-method (bind), 8
- rbind2, madness, madness-method (bind), 8
- rbind2, madness, missing-method (bind), 8
- repto (blockrep), 9
- reshapes, 24, 31, 36
- rowMeans (colsums), 10
- rowMeans, madness-method (colsums), 10
- rowSums (colsums), 10
- rowSums, madness-method (colsums), 10
- setter, 26
- show, 26
- show, madness-method (show), 26
- sin, madness-method (elwise), 13
- solve, 27
- solve, ANY, madness-method (solve), 27
- solve, ANY, missing-method (solve), 27
- solve, array, madness-method (solve), 27
- solve, madness, ANY-method (solve), 27
- solve, madness, array-method (solve), 27
- solve, madness, madness-method (solve), 27
- solve, madness, missing-method (solve), 27
- sqrt, madness-method (elwise), 13
- sqrtm (matwise), 20
- sqrtm, madness-method (matwise), 20
- stock\_returns, 28
- sum (sumprod), 29
- sum, madness-class (sumprod), 29
- sum, madness-method (sumprod), 29
- sumprod, 29
- svd, 22
- t (reshapes), 24
- t, madness-method (reshapes), 24
- tan, madness-method (elwise), 13
- tcrossprod (marithops), 18
- tcrossprod, ANY, madness-method (marithops), 18
- tcrossprod, madness, ANY-method (marithops), 18
- tcrossprod, madness, madness-method (marithops), 18
- tcrossprod, madness, missing-method (marithops), 18
- theta, 29, 33
- to\_objective, 31
- todiag, 25, 31
- todiag, madness-method (todiag), 31
- tril (reshapes), 24
- tril, madness-method (reshapes), 24
- triu (reshapes), 24
- triu, madness-method (reshapes), 24
- twomoments, 30, 32
- val (accessor), 2
- val, madness-method (accessor), 2
- varx (accessor), 2
- varx, madness-method (accessor), 2
- varx<- (setter), 26
- varx<-, madness-method (setter), 26
- vcov, 15, 30, 33, 34
- vcov.madness, 34
- vec, 25, 35
- vec, array-method (vec), 35
- vec, madness-method (vec), 35
- vech (vec), 35
- vech, array-method (vec), 35
- vech, madness-method (vec), 35
- vtag (accessor), 2
- vtag, madness-method (accessor), 2
- vtag<- (setter), 26
- vtag<-, madness-method (setter), 26
- wff3, 36
- xtag (accessor), 2
- xtag, madness-method (accessor), 2
- xtag<- (setter), 26
- xtag<-, madness-method (setter), 26