

# Package ‘multipol’

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**Description** Various utilities to manipulate multivariate polynomials. The package is almost completely superceded by the 'spray' and 'mvp' packages, which are much more efficient.

**License** GPL

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multipol-package	<i>Multivariate polynomials</i>
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## Description

Various tools to manipulate and combine multivariate polynomials

## Details

Multidimensional arrays are interpreted in a natural way as multivariate polynomials.

Taking a matrix `a` as an example, because this has two dimensions it may be viewed as a bivariate polynomial with `a[i, j]` being the coefficient of  $x^i y^j$ . Note the off-by-one issue; see `?Extract`.

Multivariate polynomials of arbitrary arity are a straightforward generalization using appropriately dimensioned arrays.

Arithmetic operations “+”, “-”, “\*”, “^” operate as though their arguments are multivariate polynomials.

Even quite small multipols are computationally intense; many coefficients have to be calculated and each is the sum of many terms.

The package is almost completely superseded by the **spray** and **mvp** packages, which use a sparse array system for efficiency.

## Author(s)

NA

Maintainer: Robin K. S. Hankin <hankin.robin@gmail.com>

## Examples

```
ones(2)*linear(c(1,-1))           # x^2-y^2
ones(2)*(ones(2,2)-uni(2))       # x^3+y^3
```

```
a <- as.multipol(matrix(1:12,3,4))
a
```

```
a[1,1] <- 11
```

```
f <- as.function(a*a)
```

```
f(c(1,pi))
```

---

as.array                      *Coerce multipols to arrays*

---

**Description**

Coerce multipols to arrays; unclass

**Usage**

```
## S3 method for class 'multipol'  
as.array(x, ...)
```

**Arguments**

x	multipol
...	Further arguments passed to NextMethod()

**Author(s)**

Robin K. S. Hankin

**Examples**

```
a <- as.multipol(matrix(1,2,2))  
as.array(a)
```

---

as.function.multipol    *Coerce a multipol to a function*

---

**Description**

Coerce a multipol to a function using environments

**Usage**

```
## S3 method for class 'multipol'  
as.function(x, ...)
```

**Arguments**

x	A multipol
...	Further arguments, currently ignored

**Author(s)**

Robin K. S. Hankin

**See Also**[as.multipol](#)**Examples**

```

a <- as.multipol(array (1:12, c(2,3,2)))

f1 <- as.function(a)
f2 <- as.function(a*a)

x <- matrix(rnorm(15),ncol=3)

f1(x)^2 - f2(x)  #should be zero [non-trivial!]

```

constant

*Various useful multivariate polynomials***Description**

Various useful multivariate polynomials such as homogeneous polynomials, linear polynomials, etc

**Usage**

```

constant(d)
product(x)
homog(d, n = d, value = 1)
linear(x, power = 1)
lone(d,x)
single(d, e, power = 1)
uni(d)
zero(d)

```

**Arguments**

d	Integer giving the dimensionality (arity) of the result
x	A vector of integers
n, e, power	Integers
value	Value for linear multivariate polynomial

**Details**

In the following, all multipols have their nonzero entries 1 unless otherwise stated.

- Function `constant(d)` returns the constant multivariate polynomial of arity `d`
- Function `product(x)` returns a multipol of arity `length(x)` where `all(dim(product(x))==x)` with all zero entries except the one corresponding to  $\prod_{i=1}^d x_i^{x[i]}$

- Function `homog(d, n)` returns the homogeneous multipol of arity `d` and power `n`. The coefficients are set to `value` (default 1); standard recycling is used
- Function `linear(x)` returns a multipol of arity `length(x)` which is linear in all its arguments and whose coefficients are the elements of `x`. Argument `power` returns an equivalent multipol linear in `x^power`
- Function `lone(d, x)` returns a multipol of arity `d` that is a product of variables `x[i]`
- Function `single(d, e, power)` returns a multipol of arity `d` with a single nonzero entry corresponding to dimension `e` raised to the power `power`
- Function `uni(d)` returns `x1*x2*...*xd` [it is a convenience wrapper for `product(rep(1, d))`]
- Function `zero(d)` returns the zero multipol of arity `d` [it is a convenience wrapper for `0*constant(d)`]
- Function `ones(d)` returns `x1+x2+...+xd` [it is a convenience wrapper for `linear(rep(1, d))`]

### Note

In many ways, the functions documented in this section are an advertisement for the inefficiency of dealing with multipols using arrays: sparse arrays would be the natural solution.

### Author(s)

Robin K. S. Hankin

### See Also

[outer, product, is.constant](#)

### Examples

```

product(c(1,2,5))      # x * y^2 * z^5
uni(3)                 # xyz
single(3,1)           # x
single(3,2)           # y
single(3,3)           # z
single(3,1,6)         # x^6
single(3,2,6)         # y^6
lone(3,1:2)           # xy
lone(3,c(1,3))        # xz
linear(c(1,2,5))      # x + 2y + 5z
ones(3)               # x+y+z
constant(3)           # 1 + 0x + 0y + 0z
zero(3)               # 0 + 0x + 0y + 0z
homog(3,2)            # x^2 + y^2 + z^2 + xy + xz + yz

# now some multivariate factorization:

ones(2)*linear(c(1,-1))           # x^2-y^2
ones(2)*(linear(c(1,1),2)-uni(2))  # x^3+y^3
linear(c(1,-1))*homog(2,2)         # x^3+y^3 again
ones(2)*(ones(2,4)+uni(2)^2-product(c(1,3))-product(c(3,1))) # x^5+y^5
ones(2)*homog(2,4,c(1,-1,1,-1,1)) # x^5+y^5 again

```

---

deriv	<i>Partial differentiation</i>
-------	--------------------------------

---

### Description

Partial differentiation with respect to any variable

### Usage

```
## S3 method for class 'multipol'  
deriv(expr, i, derivative = 1, ...)
```

### Arguments

expr	A multipol
i	Dimension to differentiate with respect to
derivative	How many times to differentiate
...	Further arguments, currently ignored

### Author(s)

Robin K. S. Hankin

### See Also

[substitute](#)

### Examples

```
a <- as.multipol(matrix(1:12,3,4))  
  
deriv(a,1) # standard usage: derivffferentiate WRT x1  
deriv(a,2) # differentiate WRT x2  
  
deriv(a,1,2) # second derivative  
deriv(a,1,3) # third derivative (zero multipol)
```

---

Extract.multipol	<i>Extract or Replace Parts of a multipol</i>
------------------	---

---

**Description**

Extract or replace subsets of multipols

**Usage**

```

## S3 method for class 'multipol'
x[...]
## S3 replacement method for class 'multipol'
x[...] <- value

```

**Arguments**

x	A multipol
...	Indices to replace. <b>Offset zero! See details section</b>
value	replacement value

**Details**

Extraction and replacement operate with offset zero (using functions taken from the **Oarray** package); see the examples section. This is so that the index matches the power required (there is an off-by-one issue. The *first* element corresponds to the *zeroth* power. One wants index  $i$  to extract/replace the  $i$ -th power and in particular one wants index  $0$  to extract/replace the zeroth power).

Replacement operators return a multipol. Extraction returns an array. This is because it is often not clear exactly what multipol is desired from an extraction operation (it is also consistent with **Oarray**'s behaviour).

**Author(s)**

Original code taken from the Oarray package by Jonty Rougier

**References**

Jonathan Rougier (2007). Oarray: Arrays with arbitrary offsets. R package version 1.4-2.

**Examples**

```

a <- as.multipol(matrix(1,4,6))
a[2,2] <- 100
a
# coefficient of x1^2.x2^2 is 100

a[1:2,1:2]
# a matrix. Note this corresponds to first and second powers
# not zeroth and first (what multipol would you want here?)

```

```
a[2,2]          # 100 to match the "a[2,2] <- 100" assignment above
```

---

```
is.constant      Is a multivariate polynomial constant or zero?
```

---

### Description

Is a multivariate polynomial constant or zero?

### Usage

```
is.constant(a, allow.untrimmed = TRUE)
is.zero(a, allow.untrimmed = TRUE)
```

### Arguments

```
a          A multipol
allow.untrimmed  Boolean with default TRUE meaning to allow a multipol to be zero/constant even
                 if one or more array extents exceed 2
```

### Author(s)

Robin K. S. Hankin

### See Also

[constant](#)

### Examples

```
is.zero(linear(c(1,1i))*linear(c(1,-1i)) - ones(2,2)) # factorize x^2+y^2
```

---

```
multipol      Coerce and test for multipols
```

---

### Description

Coerce and test for multipols

### Usage

```
multipol(x)
as.multipol(x)
is.multipol(x)
```

**Arguments**

x                    Object to be coerced to multipol

**Details**

The usual case is to coerce an array to a multipol. A character string may be given to `as.multipol()`, which will attempt to coerce to a multipol.

**Note**

Subsets of a multipol are accessed and set using **Oarray**-style extraction with an offset of zero.

**Author(s)**

Robin K. S. Hankin

**See Also**

[extract.multipol](#)

**Examples**

```
a <- as.multipol(array(1:12,c(2,3,2)))
```

---

oom

*One over one minus a multipol*

---

**Description**

Uses Taylor's theorem to give one over one minus a multipol

**Usage**

```
oom(n, a, maxorder=NULL)
```

**Arguments**

n                    The order of the approximation; see details  
a                    A multipol  
maxorder            A vector of integers giving the maximum order as per `taylor()`

**Details**

The motivation for this function is the *formal* power series  $(1 - x)^{-1} = 1 + x + x^2 + \dots$ . The way to think about it is to observe that  $(1 + x + x^2 + \dots + x^n)(1 - x) = 1 - x^{n+1}$ , even if  $x$  is a multivariate polynomial (one needs only power associativity and a distributivity law, so this works for polynomials). The right hand side is 1 if we neglect powers of  $x$  greater than the  $n$ -th, so the two terms on the left hand side are multiplicative inverses of one another.

Argument  $n$  specifies how many terms of the series to take.

The function uses an efficient array method when  $x$  has only a single non-zero entry. In other cases, a variant of Horner's method is used.

**Author(s)**

Robin K. S. Hankin

**References**

I. J. Good 1976. "On the application of symmetric Dirichlet distributions and their mixtures to contingency tables". *The Annals of Statistics*, volume 4, number 6, pp1159-1189; equation 5.6, p1166

**See Also**

[taylor](#)

**Examples**

```
oom(4, homog(3, 1))

# How many 2x2 contingency tables of nonnegative integers with rowsums =
# c(2,2) and colsums = c(2,2) are there? Good gives:

(
  oom(2, lone(4, c(1, 3))) *
  oom(2, lone(4, c(1, 4))) *
  oom(2, lone(4, c(2, 3))) *
  oom(2, lone(4, c(2, 4)))
)[2, 2, 2, 2]

# easier to use the aylmer package:

## Not run:
library(aylmer)
no.of.boards(matrix(1, 2, 2))

## End(Not run)
```

Ops.multipol

*Arithmetic ops group methods for multipols***Description**

Allows arithmetic operators to be used for multivariate polynomials such as addition, multiplication, and integer powers.

**Usage**

```
## S3 method for class 'multipol'
Ops(e1, e2 = NULL)
mprod(..., trim = TRUE, maxorder=NULL)
mplus(..., trim = TRUE, maxorder=NULL)
mneg(a, trim = TRUE, maxorder=NULL)
mps(a, b, trim = TRUE, maxorder=NULL)
mpow(a, n, trim = TRUE, maxorder=NULL)
```

**Arguments**

e1, e2, a	Multipols; scalars coerced
b	Scalar
n	Integer power
...	Multipols
trim	Boolean, with default TRUE meaning to return a trim()-ed multipol and FALSE meaning not to trim
maxorder	Numeric vector indicating maximum orders of the output [that is, the highest power retained in the multivariate Taylor expansion about $\text{rep}(0, d)$ ]. Length-one input is recycled to length d; default value of NULL means to return the full result. More details given under <code>taylor()</code>

**Details**

The function `Ops.multipol()` passes unary and binary arithmetic operators (“+”, “-”, “\*”, and “^”) to the appropriate specialist function.

In `multipol.R`, these specialist functions all have formal names such as `.multipol.prod.scalar()` which follow a rigorous pattern; they are not intended for the end user. They are not exported from the namespace as they begin with a dot.

Five conveniently-named functions are provided in the package for the end-user; these offer greater control than the arithmetic command-line operations in that arguments `trim` or `maxorder` may be set. They are:

- `mprod()` for products,
- `mplus()` for addition,
- `mneg()` for the negative,

- `mps()` for adding a scalar,
- `mpow()` for powers.

Addition and multiplication of multivariate polynomials is commutative and associative, to machine precision.

### Author(s)

Robin K. S. Hankin

### See Also

[outer](#), [trim](#), [taylor](#)

### Examples

```
a <- as.multipol(matrix(1,4,5))
100+a

f <- as.function(a+1i)
f(5:6)

b <- as.multipol(array(rnorm(12),c(2,3,2)))

f1 <- as.function(b)
f2 <- as.function(b*b)
f3 <- as.function(b^3) # could have said b*b*b

x <- c(1,pi,exp(1))

f1(x)^2 - f2(x) #should be zero
f1(x)^3 - f3(x) #should be zero

x1 <- as.multipol(matrix(1:10,ncol=2))
x2 <- as.multipol(matrix(1:10,nrow=2))
x1+x2
```

---

polyprod

*Multivariate polynomial product*

---

### Description

Gives an generalized outer product of two multipols

### Usage

```
polyprod(m1, m2, overlap = 0)
```

**Arguments**

m1, m2            multipols to be combined  
 overlap           Integer indicating how many variables are common to m1 and m2; default of zero corresponds to no variables in common

**Author(s)**

Robin K. S. Hankin

**See Also**

[Ops.multipol](#)

**Examples**

```
a <- as.multipol(matrix(1,2,2))    # 1+x+y+xy

polyprod(a,a)            # (1+x+y+xy)*(1+z+t+zt)    --- offset=0
polyprod(a,a,1)         # (1+x+y+xy)*(1+y+z+yz)
polyprod(a,a,2)         # (1+x+y+xy)^2
```

---

print.multipol            *Print method for multipols*

---

**Description**

Print methods for multipols

**Usage**

```
## S3 method for class 'multipol'
print(x, ...)
do_dimnames(a, include.square.brackets = getOption("isb"), varname =
getOption("varname"), xyz = getOption("xyz"))
## S3 method for class 'multipol'
as.character(x, ..., xyz = getOption("xyz"), varname =
getOption("varname"))
```

**Arguments**

a, x                Multipol or array  
 include.square.brackets    Boolean with TRUE meaning to, er, include square brackets in the dimnames (eg [x3]^5) and default FALSE meaning to omit them (eg x3^5)  
 varname            String to describe root variable name (eg varname="y" gives y3^5 or [y3]^5)

xyz Boolean with default TRUE meaning to represent multipols of dimension  $d \leq 3$  using x, y, and z for the variable names and FALSE meaning to use x1, x2, x3. This option is ignored if  $d > 3$ ; see examples section

... Further arguments (currently ignored)

### Details

Function `do_dimnames()` is a helper function that takes an array and gives it dimnames appropriate for expression as a multipol. Default behaviour is governed by options `isb`, `varname`, and `xyz`. The function might be useful but it is really intended to be called by `print.multipol()`.

The default behaviour of `do_dimnames()` and `as.character()`, and hence the `print` method for multipols, may be modified by using the `options()` function. See examples section below.

### Author(s)

Robin K. S. Hankin

### Examples

```
ones(2,5)

options("showchars" = TRUE)
ones(2,5)

options("xyz" = FALSE)
ones(2,5)

options("varname" = "fig")
ones(2,5)

options("showchars" = FALSE)
ones(2,5)

do_dimnames(matrix(0,2,3),varname="fig",include=TRUE)
```

---

put

*Substitute a value for a variable*

---

### Description

Substitute a value for a variable and return a multipol of arity d-1

### Usage

```
put(a, i, value, keep = TRUE)
```

**Arguments**

a	multipol
i	Dimension to substitute
value	value to substitute for x[i]
keep	Boolean with default TRUE meaning to retain singleton dimensions and FALSE meaning to drop them

**Author(s)**

Robin K. S. Hankin

**See Also**

[deriv.multipol](#)

**Examples**

```
a <- as.multipol(matrix(1:12,3,4))
put(a,1,pi)
put(a,2,pi)

b <- as.multipol(array(1:12,c(3,2,3)))

put(b,2,pi,TRUE)
put(b,2,pi,FALSE)
```

---

trim

*Remove redundant entries from a multipol*

---

**Description**

Remove redundant entries from a multivariate polynomial: function `trim()` trims the array of non-significant zeroes as far as possible without altering its value as a multipol; function `taylor()` returns the multivariate Taylor expansion to a specified order.

**Usage**

```
trim(a)
taylor(a,maxorder=NULL)
```

**Arguments**

a	A multipol
maxorder	The multivariate order of the expansion returned; default of NULL means to return a unaltered

**Value**

Returns a multipol

**Note**

If `a` is a zero multipol (that is, a multivariate polynomial with all entries zero) of any size, then `trim(a)` is a zero multipol of the same arity as `a` but with extent 1 in each direction.

**Author(s)**

Robin K. S. Hankin

**See Also**

[Ops.multipol](#)

**Examples**

```
a <- matrix(0,7,7)
a[1:3,1:4] <- 1:12
a <- as.multipol(a)
a
trim(a)
taylor(a,2)
```

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