

Package ‘symbolicQspray’

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Title Multivariate Polynomials with Symbolic Parameters in their Coefficients

Version 1.1.0

Description Introduces the 'symbolicQspray' objects. Such an object represents a multivariate polynomial whose coefficients are fractions of multivariate polynomials with rational coefficients. The package allows arithmetic on such polynomials. It is based on the 'qspray' and 'ratioOfQsprays' packages. Some functions for 'qspray' polynomials have their counterpart for 'symbolicQspray' polynomials. A 'symbolicQspray' polynomial should not be seen as a polynomial on the field of fractions of rational polynomials, but should rather be seen as a polynomial with rational coefficients depending on some parameters, symbolically represented, with a dependence given by fractions of rational polynomials.

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URL <https://github.com/stla/symbolicQspray>

BugReports <https://github.com/stla/symbolicQspray/issues>

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as.symbolicQspray	<i>Coercion to a 'symbolicQspray' object</i>
-------------------	--

Description

Coercion to a 'symbolicQspray' object

Usage

```
## S4 method for signature 'character'
as.symbolicQspray(x)

## S4 method for signature 'qspray'
as.symbolicQspray(x)

## S4 method for signature 'ratioOfQsprays'
as.symbolicQspray(x)

## S4 method for signature 'symbolicQspray'
as.symbolicQspray(x)

## S4 method for signature 'numeric'
as.symbolicQspray(x)

## S4 method for signature 'bigz'
as.symbolicQspray(x)

## S4 method for signature 'bigq'
as.symbolicQspray(x)
```

Arguments

x	a symbolicQspray object or an object for which as.ratioOfQsprays is applicable
---	--

Value

A symbolicQspray object.

Examples

```
as.symbolicQspray(2)
as.symbolicQspray("1/3")
```

changeParameters	<i>Change of parameters in a 'symbolicQspray' polynomial</i>
------------------	--

Description

Replaces the parameters of a symbolicQspray polynomial (which are qspray objects) with some qspray polynomials. E.g. you have a polynomial with two parameters $P_{a,b}(x)$ and you want the polynomial $P_{a+1,b+1}(x)$ (see example).

Usage

```
changeParameters(Qspray, newParameters)
```

Arguments

Qspray	a symbolicQspray polynomial
newParameters	a list containing at least n qspray objects, or objects coercible to qspray objects, where n is the number of parameters in the symbolic polynomial given in the Qspray argument; if this list is named, then its names will be used in the show options of the result

Value

The symbolicQspray polynomial obtained by replacing the parameters of the symbolic polynomial given in the Qspray argument with the polynomials given in the newParameters argument.

See Also

If you want to change the variables of a symbolic qspray, use [changeVariables](#). If you want to assign some values to its parameters, use [substituteParameters](#).

Examples

```
library(symbolicQspray)
( JP <- JacobiPolynomial(2) ) # a univariate polynomial with two parameters
a1 <- qlone(1)
a2 <- qlone(2)
changeParameters(JP, list(a1, a2)) == JP # should be TRUE
changeParameters(JP, list(a1+1, a2+1))
```

changeVariables	<i>Change of variables in a 'symbolicQspray' polynomial</i>
-----------------	---

Description

Replaces the variables of a symbolicQspray polynomial with some symbolicQspray polynomials. E.g. you have a polynomial $P_a(x, y)$ and you want the polynomial $P_a(x + a, y + a)$ (see example).

Usage

```
## S4 method for signature 'symbolicQspray,list'
changeVariables(x, listOfQsprays)
```

Arguments

x	a symbolicQspray polynomial
listOfQsprays	a list containing at least n symbolicQspray objects, or objects coercible to symbolicQspray objects, where n is the number of variables in the polynomial given in the x argument; if this list is named, their names will be used in the show options of the result

Value

The symbolicQspray polynomial obtained by replacing the variables of the polynomial given in the x argument with the polynomials given in the listOfQsprays argument.

See Also

If you want to change the parameters of a symbolic qspray, use [changeParameters](#). If you want to assign some values to its variables, see [substituteVariables](#).

Examples

```
library(symbolicQspray)
f <- function(a, X, Y) {
  a^2 / (a + 1) * X^2*Y + (3*a - 2) / a * Y^2
}
a <- qlone(1)
X <- Qlone(1)
Y <- Qlone(2)
Qspray <- f(a, X, Y)
U <- X + a
V <- Y + a
changeVariables(Qspray, list(U, V)) == f(a, U, V) # should be TRUE
```

compactSymmetricQspray
Compact symmetric qspray

Description

Prints a symmetric symbolicQspray polynomial as a linear combination of the monomial symmetric polynomials.

Usage

```
## S4 method for signature 'symbolicQspray,logical'
compactSymmetricQspray(qspray, check)
```

```
## S4 method for signature 'symbolicQspray,missing'
compactSymmetricQspray(qspray, check)
```

Arguments

qspray	a symbolicQspray object which should correspond to a symmetric polynomial
check	Boolean, whether to check the symmetry

Value

A character string.

See Also

[MSPcombination](#)

derivSymbolicQspray *Partial derivative*

Description

Partial derivative of a symbolicQspray polynomial.

Usage

```
derivSymbolicQspray(Qspray, i, derivative = 1)
```

Arguments

Qspray	object of class symbolicQspray
i	integer, the dimension to differentiate with respect to, e.g. 2 to differentiate w.r.t. y
derivative	positive integer, how many times to differentiate

Value

A symbolicQspray object.

dSymbolicQspray	<i>Partial differentiation</i>
-----------------	--------------------------------

Description

Partial differentiation of a symbolicQspray polynomial.

Usage

dSymbolicQspray(Qspray, orders)

Arguments

Qspray	object of class symbolicQspray
orders	integer vector, the orders of the differentiation; e.g. <code>c(2, 0, 1)</code> means that you differentiate two times with respect to x , you do not differentiate with respect to y , and you differentiate one time with respect to z

Value

A symbolicQspray object.

evalSymbolicQspray	<i>Evaluation of a 'symbolicQspray' polynomial</i>
--------------------	--

Description

Evaluates a symbolicQspray polynomial by substituting some values to the parameters (same as [substituteParameters](#)) or to the variables (same as [substituteVariables](#)) or both.

Usage

evalSymbolicQspray(Qspray, a = NULL, X = NULL)

Arguments

Qspray	a symbolicQspray object
a	vector of values to be substituted to the parameters; these values must be coercible to bigq numbers
X	vector of values to be substituted to the variables; these values must be coercible to bigq numbers

Value

If both `a` and `X` are `NULL`, this returns the input `symbolicQsray` object; otherwise, if `a` is not `NULL`, this returns a `qsray` object, and if `X` is not `NULL`, this returns a `ratioOfQsprays` object.

Examples

```
library(symbolicQsray)
a1 <- qlone(1); a2 <- qlone(2)
X1 <- Qlone(1); X2 <- Qlone(2); X3 <- Qlone(3)
( Qsray <- (a1 + 2)*X1^2*X2 + (a2/(a1^2+a2))*X1*X2*X3 )
a <- c(2, 3)
X <- c(4, 3, 2)
( qsray <- evalSymbolicQsray(Qsray, a = a) )
( r0Q <- evalSymbolicQsray(Qsray, X = X) )
evalSymbolicQsray(Qsray, a = a, X = X)
evalQsray(qsray, X)
evalRatioOfQsprays(r0Q, a)
```

getCoefficient

Get a coefficient in a 'symbolicQsray' polynomial

Description

Get the coefficient of the term with the given monomial.

Usage

```
## S4 method for signature 'symbolicQsray,numeric'
getCoefficient(qsray, exponents)
```

Arguments

<code>qsray</code>	a <code>symbolicQsray</code> object
<code>exponents</code>	a vector of exponents, thereby defining a monomial; trailing zeros are ignored

Value

The coefficient, `ratioOfQsprays` object.

Examples

```
a1 <- qlone(1); a2 <- qlone(2)
X <- Qlone(1); Y <- Qlone(2)
p <- 2*(a1/a2)*X^2 + (a1/(a1+a2))*Y + a2^2/a1
getCoefficient(p, 2)      # coefficient of X^2
getCoefficient(p, c(2, 0)) # same as getCoefficient(p, 2)
getCoefficient(p, c(0, 1)) # coefficient of Y (because Y=X^0.Y^1)
getCoefficient(p, 0)      # the constant term
getCoefficient(p, 3)      # coefficient of X^3
```

getConstantTerm	<i>Get the constant term of a 'symbolicQspray' polynomial</i>
-----------------	---

Description

Get the constant term of a symbolicQspray polynomial.

Usage

```
## S4 method for signature 'symbolicQspray'
getConstantTerm(qspray)
```

Arguments

qspray a symbolicQspray object

Value

A ratioOfQsprays object.

hasPolynomialCoefficientsOnly	<i>Whether the coefficients of a 'symbolicQspray' polynomially depend on its parameters</i>
-------------------------------	---

Description

Checks whether the dependence of the coefficients of a symbolicQspray polynomial on their parameters is polynomial.

Usage

```
hasPolynomialCoefficientsOnly(Qspray)
```

Arguments

Qspray a symbolicQspray object

Value

A Boolean value. The coefficients of a symbolicQspray polynomial always are fractions of polynomials. This function checks whether they are polynomials.

Examples

```
JP <- JacobiPolynomial(4)
hasPolynomialCoefficientsOnly(JP)
```

involvedVariables	<i>Variables involved in a 'symbolicQspray' polynomial</i>
-------------------	--

Description

Variables involved in a symbolicQspray object.

Usage

```
## S4 method for signature 'symbolicQspray'
involvedVariables(x)
```

Arguments

x a symbolicQspray object

Value

A vector of integers. Each integer represents the index of a variable involved in x.

See Also

[numberOfVariables](#).

Examples

```
a1 <- qlone(1); a2 <- qlone(2)
X <- Qlone(1); Z <- Qlone(3)
Qspray <- (a1/a2)*X^2 + (a1/(a1+a2))*X*Z + a2^2/a1
involvedVariables(Qspray) # should be c(1L, 3L)
```

isConstant	<i>Whether a 'symbolicQspray' polynomial is constant</i>
------------	--

Description

Checks whether a symbolicQspray object defines a constant polynomial.

Usage

```
## S4 method for signature 'symbolicQspray'
isConstant(x)
```

Arguments

x a symbolicQspray object

Value

A Boolean value.

isQone

Whether a 'symbolicQspray' polynomial is the unit polynomial

Description

Checks whether a symbolicQspray object defines the unit polynomial.

Usage

```
## S4 method for signature 'symbolicQspray'
isQone(qspray)
```

Arguments

qspray a symbolicQspray object

Value

A Boolean value.

isQzero

Whether a 'symbolicQspray' polynomial is null

Description

Checks whether a symbolicQspray object defines the zero polynomial.

Usage

```
## S4 method for signature 'symbolicQspray'
isQzero(qspray)
```

Arguments

qspray a symbolicQspray object

Value

A Boolean value.

isUnivariate	<i>Whether a 'symbolicQspray' polynomial is univariate</i>
--------------	--

Description

Checks whether a symbolicQspray object defines a univariate polynomial.

Usage

```
## S4 method for signature 'symbolicQspray'
isUnivariate(x)
```

Arguments

x a symbolicQspray object

Value

A Boolean value.

Note

It is considered that a constant symbolicQspray is univariate.

JacobiPolynomial	<i>Jacobi polynomial</i>
------------------	--------------------------

Description

Computes the n-th Jacobi polynomial as a symbolicQspray.

Usage

```
JacobiPolynomial(n)
```

Arguments

n index (corresponding to the degree), a positive integer

Details

The Jacobi polynomials are univariate polynomials whose coefficients depend on two parameters.

Value

A symbolicQspray object representing the n-th Jacobi polynomial.

Examples

```
JP1 <- JacobiPolynomial(1)
showSymbolicQsprayOption(JP1, "showRatioOfQsprays") <-
  showRatioOfQspraysXYZ(c("alpha", "beta"))
JP1
```

numberOfParameters	<i>Number of parameters</i>
--------------------	-----------------------------

Description

Number of parameters of a symbolicQspray polynomial, i.e. the number of variables occurring in its coefficients.

Usage

```
numberOfParameters(Qspray)
```

Arguments

Qspray a symbolicQspray object

Value

An integer, the number of parameters involved in (the coefficients of) Qspray.

Examples

```
JP <- JacobiPolynomial(4) # Jacobi polynomials have two parameters
numberOfParameters(JP)
```

numberOfTerms	<i>Number of terms in a 'symbolicQspray' polynomial</i>
---------------	---

Description

Number of terms in the polynomial defined by a symbolicQspray object.

Usage

```
## S4 method for signature 'symbolicQspray'
numberOfTerms(qspray)
```

Arguments

qspray a symbolicQspray object

Value

An integer.

numberOfVariables	<i>Number of variables of a 'symbolicQspray' polynomial</i>
-------------------	---

Description

Number of variables involved in a symbolicQspray object.

Usage

```
## S4 method for signature 'symbolicQspray'
numberOfVariables(x)
```

Arguments

x a symbolicQspray object

Value

An integer.

Note

The number of variables in the symbolicQspray object Qlone(d) is d, not 1.

See Also

[involvedVariables](#).

permuteVariables	<i>Permute variables</i>
------------------	--------------------------

Description

Permute the variables of a symbolicQspray polynomial.

Usage

```
## S4 method for signature 'symbolicQspray,numeric'
permuteVariables(x, permutation)
```

Arguments

x a symbolicQspray object
permutation a permutation

Value

A symbolicQspray object.

Examples

```
f <- function(a1, a2, X, Y, Z) {
  (a1^2 + 5*a2) / (a1 + 1) * X^2*Y + (3*a1 - a2) / a2 * Y^3
}
a1 <- qlone(1)
a2 <- qlone(2)
X <- Qlone(1)
Y <- Qlone(2)
Z <- Qlone(3)
Qspray <- f(a1, a2, X, Y, Z)
perm <- c(3, 1, 2)
permuteVariables(Qspray, perm) == f(a1, a2, Z, X, Y) # should be TRUE
```

Qlone

Polynomial variable

Description

Creates a polynomial variable for a symbolicQspray.

Usage

Qlone(n)

Arguments

n positive integer, the index of the variable

Value

A symbolicQspray object.

Examples

```
X <- Qlone(1)
Y <- Qlone(2)
(X + Y)^2
Qlone(0) == 1
```

Qone	<i>The unit 'symbolicQspray' polynomial</i>
------	---

Description

Returns the symbolicQspray polynomial identically equal to 1.

Usage

Qone()

Value

A symbolicQspray object.

Qzero	<i>The null 'symbolicQspray' polynomial</i>
-------	---

Description

Returns the symbolicQspray polynomial identically equal to 0.

Usage

Qzero()

Value

A symbolicQspray object.

rSymbolicQspray	<i>Random 'symbolicQspray'</i>
-----------------	--------------------------------

Description

Generates a random symbolicQspray object.

Usage

rSymbolicQspray()

Value

A symbolicQspray object.

showSymbolicQspray *Print a 'symbolicQspray' object*

Description

Prints a symbolicQspray object given a function to print a ratioOfQsprays object.

Usage

```
showSymbolicQspray(
  showRatioOfQsprays,
  showMonomial,
  lbrace = "{ ",
  rbrace = " }",
  addition = " + ",
  multiplication = " * "
)
```

Arguments

showRatioOfQsprays	a function which prints a ratioOfQsprays object
showMonomial	a function which prints a monomial, such as showMonomialXYZ() (and not showMonomialXYZ!)
lbrace, rbrace	used to enclose the coefficients
addition	used to separate the terms
multiplication	used to separate the coefficient and the monomial within a term

Value

A function which prints a symbolicQspray object.

Note

The function returned by this function is appropriate for usage in [showSymbolicQsprayOption<-](#) as the option "showSymbolicQspray" but in general we would rather use [showSymbolicQsprayX1X2X3](#) or [showSymbolicQsprayXYZ](#), or rather set the options "a", "X" and "quotientBar".

See Also

[showSymbolicQsprayX1X2X3](#), [showSymbolicQsprayXYZ](#).

Examples

```
set.seed(421)
( Qspray <- rSymbolicQspray() )
showRatioOfQsprays <-
  showRatioOfQspraysXYZ(c("a", "b", "c"), quotientBar = " / ")
showMonomial <- showMonomialX1X2X3("X")
f <- showSymbolicQspray(showRatioOfQsprays, showMonomial, "{{{", "}}}")
f(Qspray)
# setting a show option:
showSymbolicQsprayOption(Qspray, "showSymbolicQspray") <- f
Qspray
# the show options are preserved by certain operations, e.g.:
2*Qspray
```

```
showSymbolicQsprayABCXYZ
```

Print a 'symbolicQspray' object

Description

Prints a symbolicQspray object.

Usage

```
showSymbolicQsprayABCXYZ(
  params,
  vars = c("X", "Y", "Z"),
  quotientBar = " %/% ",
  ...
)
```

Arguments

params	vector of strings, usually some letters, to denote the parameters of the polynomial
vars	a vector of strings, usually some letters, to denote the variables of the polynomial
quotientBar	a string for the quotient bar between the numerator and the denominator of a ratioOfQsprays object, including surrounding spaces, e.g. " / "
...	arguments other than showRatioOfQsprays and showMonomial passed to showSymbolicQspray

Value

A function which prints symbolicQspray objects.

Note

This function is built by applying [showSymbolicQspray](#) to [showRatioOfQspraysXYZ](#)(params) and [showMonomialXYZ](#)(vars).

Examples

```
set.seed(421)
( Qspray <- rSymbolicQspray() )
showSymbolicQsprayABXYZ(c("a", "b", "c"), c("U", "V"))(Qspray)
```

```
showSymbolicQsprayOption<-
```

Set a show option to a 'symbolicQspray' object

Description

Set show option to a symbolicQspray object

Usage

```
showSymbolicQsprayOption(x, which) <- value
```

Arguments

x	a symbolicQspray object
which	which option to set; this can be "a", "X", "quotientBar", "showMonomial", "showRatioOfQsprays" or "showSymbolicQspray"
value	the value for the option

Value

This returns the updated symbolicQspray.

Examples

```
set.seed(421)
Qspray <- rSymbolicQspray()
showSymbolicQsprayOption(Qspray, "a") <- "x"
showSymbolicQsprayOption(Qspray, "X") <- "A"
showSymbolicQsprayOption(Qspray, "quotientBar") <- " / "
Qspray
showSymbolicQsprayOption(Qspray, "showRatioOfQsprays") <-
  showRatioOfQspraysXYZ()
Qspray
```

```
showSymbolicQsprayX1X2X3
```

Print a 'symbolicQspray' object

Description

Prints a symbolicQspray object.

Usage

```
showSymbolicQsprayX1X2X3(a = "a", X = "X", quotientBar = " %/% ", ...)
```

Arguments

a	a string, usually a letter, to denote the non-indexed variables of the ratioOfQsprays coefficients
X	a string, usually a letter, to denote the non-indexed variables
quotientBar	a string for the quotient bar between the numerator and the denominator of a ratioOfQsprays object, including surrounding spaces, e.g. " / "
...	arguments other than showRatioOfQsprays and showMonomial passed to showSymbolicQspray

Value

A function which prints symbolicQspray objects.

Note

This function is built by applying [showSymbolicQspray](#) to [showRatioOfQspraysX1X2X3\(a\)](#) and [showMonomialX1X2X3\(X\)](#).

Examples

```
set.seed(421)
Qspray <- rSymbolicQspray()
showSymbolicQsprayX1X2X3(quotientBar = " / ")(Qspray)
```

showSymbolicQsprayXYZ *Print a 'symbolicQspray' object*

Description

Prints a symbolicQspray object.

Usage

```
showSymbolicQsprayXYZ(
  a = "a",
  letters = c("X", "Y", "Z"),
  quotientBar = " %/% ",
  ...
)
```

Arguments

a	a string, usually a letter, to denote the non-indexed variables of the ratioOfQsprays coefficients
letters	a vector of strings, usually some letters, to denote the variables of the polynomial
quotientBar	a string for the quotient bar between the numerator and the denominator of a ratioOfQsprays object, including surrounding spaces, e.g. " / "
...	arguments other than showRatioOfQsprays and showMonomial passed to showSymbolicQspray

Value

A function which prints symbolicQspray objects.

Note

This function is built by applying [showSymbolicQspray](#) to [showRatioOfQspraysX1X2X3\(a\)](#) and [showMonomialXYZ\(letters\)](#).

Examples

```
set.seed(421)
Qspray <- rSymbolicQspray()
showSymbolicQsprayX1X2X3(quotientBar = " / ")(Qspray)
```

substituteParameters *Assign values to the parameters of a 'symbolicQsray'*

Description

Substitutes some values to the parameters of a symbolicQsray polynomial.

Usage

```
substituteParameters(Qsray, values)
```

Arguments

Qsray	a symbolicQsray object
values	vector of values to be substituted to the parameters; these values must be coercible to bigq numbers

Value

A qsray object.

See Also

Use [changeParameters](#) to apply a transformation of the parameters. Use [substituteVariables](#) to substitute some values to the variables.

Examples

```
library(symbolicQsray)
f <- function(a1, a2, X, Y) {
  (a1 + 2)*X^2*Y + (a2/(a1^2+a2))*X*Y
}
Qsray <- f(qlone(1), qlone(2), qlone(1), qlone(2))
a <- c(2, "2/3")
( qsray <- substituteParameters(Qsray, values = a) )
a <- gmp::as.bigq(a)
qsray == f(a[1], a[2], qlone(1), qlone(2)) ## should be TRUE
```

substituteVariables *Assign values to the variables of a 'symbolicQspray'*

Description

Substitutes some values to the variables of a symbolicQspray polynomial.

Usage

```
substituteVariables(Qspray, values)
```

Arguments

Qspray	a symbolicQspray object
values	vector of values to be substituted to the variables; these values must be coercible to bigq numbers

Value

A ratioOfQsprays object.

See Also

Use [changeVariables](#) to apply a transformation of the variables. Use [substituteParameters](#) to substitute some values to the parameters.

Examples

```
library(symbolicQspray)
f <- function(a1, a2, X, Y) {
  (a1 + 2)*X^2*Y + (a2/(a1^2+a2))*X*Y
}
a1 <- qlone(1); a2 <- qlone(2)
Qspray <- f(a1, a2, Qlone(1), Qlone(2))
values <- c(3, "2/3")
(r0Q <- substituteVariables(Qspray, values) )
values <- gmp::as.bigq(values)
r0Q == f(a1, a2, values[1], values[2]) ## should be TRUE
```

swapVariables

Swap variables

Description

Swap two variables of a symbolicQspray.

Usage

```
## S4 method for signature 'symbolicQspray,numeric,numeric'
swapVariables(x, i, j)
```

Arguments

x a symbolicQspray object
i, j indices of the variables to be swapped

Value

A symbolicQspray object.

Examples

```
library(symbolicQspray)
f <- function(a1, a2, X, Y, Z) {
  (a1^2 + 5*a2) / (a1 + 1) * X^2*Y + (3*a1 - a2) / a2 * Y^3
}
a1 <- qlone(1)
a2 <- qlone(2)
X <- Qlone(1)
Y <- Qlone(2)
Z <- Qlone(3)
Qspray <- f(a1, a2, X, Y, Z)
swapVariables(Qspray, 2, 3) == f(a1, a2, X, Z, Y) # should be TRUE
```

symbolicQspray-unary

Unary operators for 'symbolicQspray' objects

Description

Unary operators for symbolicQspray objects.

Usage

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

## S4 method for signature 'symbolicQspray,missing'
e1 - e2
```

Arguments

e1	object of class symbolicQspray
e2	nothing

Value

A symbolicQspray object.

symbolicQspray_from_list

(internal) Make a 'symbolicQspray' object from a list

Description

This function is for internal usage. It is exported because it is also used for internal usage in others packages.

Usage

```
symbolicQspray_from_list(x)
```

Arguments

x	list returned by the Rcpp function returnSymbolicQspray
---	---

Value

A symbolicQspray object.

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