Package 'dual'

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Type Package

Title Automatic Differentiation with Dual Numbers

Version 0.0.3

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Description Automatic differentiation is achieved by using dual numbers without providing hand-coded gradient functions. The output value of a mathematical function is returned with the values of its exact first derivative (or gradient). For more details see Baydin, Pearlmutter, Radul, and Siskind (2018) <http://jmlr.org/papers/volume18/17-468/17-468.pdf>.

License GPL-3

Depends R (>= 3.2.0), base, stats, methods

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R topics documented:

dual-package *Automatic Differentiation with Dual Numbers*

Description

This package provides mathematical functions that are able to handle computations with dual numbers. Dual numbers are mainly used to implement automatic differentiation. The package is useful to calculate exact derivatives in R without providing hand-coded gradient functions. Kisil (2007) <arXiv:0707.4024>

Details

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Date:	2019-12-14
License:	GPL-3

For a complete list of exported functions, use `library(help = "dual")`.

Author(s)

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References

Baydin, A. G., Pearlmutter, B. A., Radul, A. A., & Siskind, J. M. (2018). Automatic differentiation in machine learning: a survey. *Journal of Marchine Learning Research*, **18**, 1-43.

Cheng, H. H. (1994). Programming with dual numbers and its applications in mechanisms design. *Engineering with Computers*, **10**(4), 212-229.

Examples

```
library(dual)
x <- dual(f = 1.5, grad = c(1, 0, 0))
y <- dual(f = 0.5, grad = c(0, 1, 0))
z <- dual(f = 1.0, grad = c(0, 0, 1))
exp(z - x) * sin(x)^y / x

a <- dual(1.1, grad = c(1.2, 2.3, 3.4, 4.5, 5.6))
0.5 * a^2 - 0.1
```

Arithmetic *Arithmetic Operators*

Description

These unary and binary operators perform arithmetic on dual objects.

Usage

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

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

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

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

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

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

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

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

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

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

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

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

## S4 method for signature 'numeric,dual'
e1 / e2
```

```
## S4 method for signature 'dual,dual'
e1 / e2

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

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

## S4 method for signature 'dual,dual'
e1 ^ e2
```

Arguments

e1	dual object or numeric value.
e2	dual object or numeric value.

Value

The correspondent values of the arithmetic operation on e1 and e2 is returned.

Examples

```
x <- dual(1.5, 1:0)
y <- dual(2.6, 0:1)
+x
-x
x - y
x * y
x / y
x ^ y
x + y
```

---

dual-class *Dual object class An S4 Class for dual numbers*

Description

The method initialize sets the initial values of a new object of the class dual.

The function dual generates an object of class dual for the representation of dual numbers.

The function is.dual returns TRUE if x is of the class dual. It retuns FALSE otherwise.

The method show shows the content of a dual object.

Usage

```
dual(f, grad)

## S4 method for signature 'dual'
initialize(.Object, f = numeric(0), grad = numeric(0))

dual(f, grad)

is.dual(x)

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

Arguments

f	a single numeric value denoting the "Real" component of the dual number.
grad	a numeric vector rappresenting the "Dual" components of the dual number.
.Object	an object of class dual to be initialized
x	an object of class dual.
object	an object of class dual to be shown

Value

an object of the class dual.

a logical value indicating if the object is of the class dual or not.

Slots

f a single numeric value denoting the "Real" component of the dual number

grad a numeric vector rappresenting the "Dual" components of the dual number

Examples

```
x <- dual(3, 0:1)
library(dual)
x <- new("dual", f = 1, grad = 1)
is.dual(3)
is.dual(x)
```

Error *Special Functions of Mathematics*

Description

Special mathematical functions related to the error function.

The function `erfc(x)` is a variant of the cumulative normal (or Gaussian) distribution funciton.

The functions `erfinv(x)` and `erfcinv(x)` respectively implement the inverse functions of `erf(x)` and `erfc(x)`.

Usage

```
erf(x)

## S4 method for signature 'dual'
erf(x)

erfinv(x)

## S4 method for signature 'dual'
erfinv(x)

erfc(x)

## S4 method for signature 'dual'
erfc(x)

erfcinv(x)

## S4 method for signature 'dual'
erfcinv(x)
```

Arguments

`x`	dual object.

Value

A dual object containing the transformed values according to the chosen function.

Examples

```
x <- dual(0.5, 1)
erf(x)
erfc(x)
erfinv(x)
erfcinv(x)
```

Hyperbolic *Hyperbolic Functions*

Description

These functions provide the obvious hyperbolic functions. They respectively compute the hyperbolic cosine, sine, tangent, and their inverses, arc-cosine, arc-sine, arc-tangent.

Usage

```
## S4 method for signature 'dual'
cosh(x)

## S4 method for signature 'dual'
sinh(x)

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

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

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

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

Arguments

x	a dual object

Value

A dual object containing the transformed values according to the chosen function.

Examples

```
x <- dual(0.5, 1)
cosh(x)
sinh(x)
tanh(x)
acosh(1 + x)
asinh(x)
atanh(x)
```

log *Logarithms and Exponentials*

Description

Logarithms and Exponentials

Usage

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

## S4 method for signature 'dual,numeric'
logb(x, base = exp(1))

## S4 method for signature 'numeric,dual'
logb(x, base = exp(1))

## S4 method for signature 'dual,dual'
logb(x, base = exp(1))

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

## S4 method for signature 'dual'
log2(x)

## S4 method for signature 'dual'
log1p(x)

## S4 method for signature 'dual'
exp(x)

## S4 method for signature 'dual'
expm1(x)
```

Arguments

x	a dual object or numeric value.
base	a dual object or a positive number. Defaults to e=exp(1).

Value

A dual object containing the transformed values according to the chosen function.

Examples

```
x <- dual(sqrt(pi), 1:0)
y <- dual(pi * .75, 0:1)
log(x)
logb(x, base = 1.1)
logb(3.1, base = x)

logb(x, y)
log10(x)
log2(x)

log1p(x)

exp(2*x)
expm1(2*x)
```

MathFun *Miscellaneous Mathematical Functions*

Description

The function `abs(x)` computes the absolute value of `x`, while `sqrt(x)` computes the square root of `x`.

Usage

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

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

Arguments

`x`	a dual object or numeric value.

Value

A dual object containing the transformed values according to the chosen function.

Examples

```
x <- dual(4.3, 1:0)
y <- dual(7.6, 0:1)
abs(-2.2 * x + 0.321 * y)
sqrt(y - x)
```

Special *Special Functions of Mathematics*

Description

Special mathematical functions related to the beta and gamma.

Usage

```
## S4 method for signature 'dual,dual'
beta(a, b)

## S4 method for signature 'dual,numeric'
beta(a, b)

## S4 method for signature 'numeric,dual'
beta(a, b)

## S4 method for signature 'dual,dual'
lbeta(a, b)

## S4 method for signature 'dual,numeric'
lbeta(a, b)

## S4 method for signature 'numeric,dual'
lbeta(a, b)

## S4 method for signature 'dual'
gamma(x)

## S4 method for signature 'dual'
lgamma(x)

## S4 method for signature 'dual'
psigamma(x, deriv = 0L)

## S4 method for signature 'dual'
digamma(x)

## S4 method for signature 'dual'
trigamma(x)

## S4 method for signature 'dual,dual'
choose(n, k)

## S4 method for signature 'numeric,dual'
choose(n, k)
```

```
## S4 method for signature 'dual,numeric'
choose(n, k)

## S4 method for signature 'dual,dual'
lchoose(n, k)

## S4 method for signature 'numeric,dual'
lchoose(n, k)

## S4 method for signature 'dual,numeric'
lchoose(n, k)

## S4 method for signature 'dual'
factorial(x)

## S4 method for signature 'dual'
lfactorial(x)
```

Arguments

a	non-negative numeric value or dual object with non-negative real part.
b	non-negative numeric value or dual object with non-negative real part.
x	dual object or numeric value.
deriv	integer value.
n	dual object or numeric value.
k	dual object or numeric value.

Value

A dual object containing the transformed values according to the chosen function.

Examples

```
x <- dual(0.5, 1)
a <- dual(1.2, 1:0)
b <- dual(2.1, 0:1)

beta(a, b)
beta(1, b)
beta(a, 1)
lbeta(a, b)
lbeta(1, b)
lbeta(a, 1)

gamma(x)
lgamma(x)
psigamma(x, deriv = 0)
digamma(x)
```

```
trigamma(x)
psigamma(x, 2)
psigamma(x, 3)


n <- 7.8 + a
k <- 5.6 + b
choose(n, k)
choose(5, k)
choose(n, 2)

lchoose(n, k)
lchoose(5, k)
lchoose(n, 2)

factorial(x)
lfactorial(x)
```

Trig *Trigonometric Functions*

Description

These functions give the obvious trigonometric functions. They respectively compute the cosine, sine, tangent, arc-cosine, arc-sine, arc-tangent, and the two-argument arc-tangent.

`cospi(x)`, `sinpi(x)`, and `tanpi(x)`, compute `cos(pi*x)`, `sin(pi*x)`, and `tan(pi*x)`.

Usage

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

## S4 method for signature 'dual'
sin(x)

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

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

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

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

```
## S4 method for signature 'dual,numeric'
atan2(y, x)

## S4 method for signature 'numeric,dual'
atan2(y, x)

## S4 method for signature 'dual,dual'
atan2(y, x)

## S4 method for signature 'dual'
cospi(x)

## S4 method for signature 'dual'
sinpi(x)

## S4 method for signature 'dual'
tanpi(x)
```

Arguments

x	dual object or numeric value.
y	dual object or numeric value.

Value

A dual object containing the transformed values according to the chosen function.

Examples

```
x <- dual(1, 1:0)
y <- dual(1, 0:1)

cos(x)
sin(x)
tan(x)
acos(x - 0.5)
asin(x - 0.5)
atan(x - 0.5)
atan2(x, y)
atan2(2.4, y)
atan2(x, 1.2)
cospi(1.2 * x)
sinpi(3.4 * x)
tanpi(5.6 * x)
```

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