Package: flint (via r-universe)

March 12, 2025

Version 0.0.4

VersionNote sync configure.ac

Date 2025-03-09

Title Fast Library for Number Theory

Description An R interface to 'FLINT' <https://flintlib.org/>, a C
library for number theory. 'FLINT' extends GNU 'MPFR'
<https://www.mpfr.org/> and GNU 'MP' <https://gmplib.org/> with
support for operations on standard rings (the integers, the
integers modulo n, finite fields, the rational, p-adic, real,
and complex numbers) as well as matrices and polynomials over
rings. 'FLINT' implements midpoint-radius interval arithmetic,
also known as ball arithmetic, in the real and complex numbers,
enabling computation in arbitrary precision with rigorous
propagation of rounding errors; see Johansson (2017)
<doi:10.1109/TC.2017.2690633>. Finally, 'FLINT' provides ball
arithmetic implementations of many special mathematical
functions, with high coverage of reference works such as the
NIST Digital Library of Mathematical Functions
<https://dlmf.nist.gov/>. The R interface defines S4 classes,
generic functions, and methods for representation and basic
operations as well as plain R functions mirroring and
vectorizing entry points in the C library.

License GPL (>= 2)

URL https://github.com/jaganmn/flint

BugReports https://github.com/jaganmn/flint/issues

Depends R (>= 4.3), methods

Imports stats

SystemRequirements flint (>= 3), mpfr (>= 3.1), gmp

SystemRequirementsNote purely informational as we use configure tests

Config/pak/sysreqs libflint-dev libgmp3-dev libmpfr-dev

Repository https://jaganmn.r-universe.dev

RemoteUrl https://github.com/jaganmn/flint

RemoteRef HEAD

RemoteSha 0626db3a6668dab2b66eaa6bba0afacde0d103cb

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flint-package | R *Package* **flint**

Description

An R interface to FLINT, a C library for number theory.

Usage

```
flintABI()
flintIdentical(object, reference)
flintLength(object, exact = TRUE)
flintPrec(prec = NULL)
flintRnd(rnd = NULL)
flintSize(object)
flintTriple(object)
flintVersion()
```

Arguments

object, reference

        objects inheriting from virtual class [flint](). Otherwise, the behaviour is undefined.

exact   a logical indicating if the length should be represented exactly as an object of class [ulong]().

prec   a new default value for the precision of inexact floating-point operations, if non-NULL. The value should be a positive integer indicating a number of bits.

rnd   a new default value for the rounding mode of inexact floating-point operations, if non-NULL. The value should be a character string indicating a rounding mode for signed floating types. Valid characters are '[Uu]' (towards positive infinity), '[Dd]' (towards negative infinity), '[Zz]' (towards zero), '[Aa]' (away from zero), and '[Nn]' (to nearest, with precedence to even significands).

Details

To report a bug or request a feature, use [bug.report](package = "flint").

To render the change log, use [news](package = "flint").

To render the index, use [help](package = "flint")

To render a list of help topics for S4 classes, use [help.search](package = "flint", keyword = "classes")

To render a list of help topics for special mathematical functions, use [help.search](package = "flint", keyword = "math")

Value

flintABI returns the size in bits of C type long int, either 32 or 64. The value is determined when package **flint** is configured. It is checked at configure time and at load time that linked C libraries were configured for the same ABI.

flintIdentical tests whether its arguments inherit from the same nonvirtual subclass of [flint]() and have identical length, elements, and names. If the elements are recursive structures, then they are compared recursively.

flintLength returns a representation of the length of object. If exact = TRUE, then the return value is an object of class [ulong]() representing the length exactly. Otherwise, if the length is less than or equal to .Machine[["integer.max"]], then the return value is a traditional integer vector representing the length exactly. Otherwise, the return value is a traditional double vector representing the length exactly if and only if $n \leq 2^d - 1$ or $2^{d+p} \leq n < 2^{d+p+1}$ and n is divisible by 2^{p+1}, where n is the length, d is .Machine[["double.digits"]], and $p = 0, 1, \ldots$. Lengths not exactly representable in double precision are rounded to the next representable number in the direction of zero. Return values not representing the length exactly have an attribute off preserving the rounding error (an integer in $1, \ldots, 2^p$).

flintPrec returns the previous default precision.

flintRnd returns the previous default rounding mode.

flintSize returns an upper bound for the number of bytes used by object, as an object of class object_size (following function object.size in package **utils**). If no members of the recursive

structure share memory, then the upper bound is exact. Recursion starts at the address stored by the R object, not at the address of the object itself. A corollary is that `flintSize(object)` is zero for `object` of zero length. Another corollary is that the bytes counted by `flintSize` and the bytes counted by [`object.size`](#) are disjoint.

`flintTriple` returns a character vector of length 3 containing the class of `object`, the length of `object`, and the address stored by `object`.

`flintVersion` returns a named list of numeric versions with elements:

package	the R package version.
flint.h	the FLINT header version.
libflint	the FLINT library version.
mpfr.h	the GNU MPFR header version.
libmpfr	the GNU MPFR library version.
gmp.h	the GNU MP header version.
libgmp	the GNU MP library version.

Header versions are determined at compile time. Library versions are determined at compile time (static linking) or at load time (dynamic linking).

Author(s)

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References

FLINT Team (2025). FLINT: Fast Library for Number Theory. <https://flintlib.org/>

Examples

```
flintABI()

oprec <- flintPrec()
nprec <- 100L
stopifnot(identical(flintPrec(nprec), oprec),
          identical(flintPrec(), nprec),
          identical(flintPrec(oprec), nprec),
          identical(flintPrec(), oprec))

ornd <- flintRnd()
nrnd <- "Z"
stopifnot(identical(flintRnd(nrnd), ornd),
          identical(flintRnd(), nrnd),
          identical(flintRnd(ornd), nrnd),
          identical(flintRnd(), ornd))

flintVersion()
```

---

acb-class	*Arbitrary Precision Floating-Point Complex Numbers with Error Bounds*

Description

Class acb extends virtual class `flint`. It represents vectors of complex numbers with error bounds on the real and imaginary parts. Elements are specified by two pairs of mixed format floating-point numbers: an [arb](#) real part and an [arb](#) imaginary part, each specified by an [arf](#) midpoint and a [mag](#) radius.

Usage

```
## The class generator function:
.acb(...)

## Mode 1: initialize with zeros
## .acb(length = 0L)
##
## Mode 2: initialize with vector
## .acb(length = length(x), x)
##
## Mode 3: initialize by parts
## .acb(length = max0(length(real), length(imag)), real, imag)
##
## where max0 <- function(m, n) if (min(m, n)) max(m, n) else 0L
```

Arguments

`...`	arguments passed to methods for [initialize](#).

Value

The class generator function returns [new](#)("acb", ...).

Slots

`.xData`, `names` inherited from virtual class [flint](#).

Methods

Due to constraints imposed by generic functions, methods typically do *not* provide a formal argument `prec` allowing for a precision to be indicated in the function call. Such methods use the current default precision set by [flintPrec](#).

`! signature(x = "acb")`:
    equivalent to (but faster than) `x == 0`.

`+ signature(e1 = "acb", e2 = "missing")`:
  returns a copy of the argument.

`- signature(e1 = "acb", e2 = "missing")`:
  returns the negation of the argument.

`Complex signature(z = "acb")`:
  mathematical functions of one argument; see `S4groupGeneric`.

`Math signature(x = "acb")`:
  mathematical functions of one argument; see `S4groupGeneric`. Member functions `floor`, `ceiling`, `trunc`, `cummin`, `cummax` are not implemented.

`Math2 signature(x = "acb")`:
  decimal rounding according to a second argument `digits`; see `S4groupGeneric`. There are just two member member functions: `round`, `signif`.

`Ops signature(e1 = "ANY", e2 = "acb")`:
  `signature(e1 = "acb", e2 = "ANY")`:
  binary arithmetic, comparison, and logical operators; see `S4groupGeneric`. The "other" operand must be atomic or inherit from virtual class `flint`. The operands are recycled and promoted as necessary.

`Summary signature(x = "acb")`:
  univariate summary statistics; see `S4groupGeneric`. The return value is a logical vector of length 1 (any, all) or an acb vector of length 1 or 2 (sum, prod). Member functions `min`, `max`, `range` are not implemented.

`anyNA signature(x = "acb")`:
  returns `TRUE` if any element of x has real or imaginary part with midpoint NaN, `FALSE` otherwise.

`as.vector signature(x = "acb")`:
  returns `as.vector(y, mode)`, where y is a complex vector containing the result of converting the midpoints of the real and imaginary parts of x to the range of double, rounding if the value is not exactly representable in double precision. The rounding mode is to the nearest representable number (with precedence to even significands in case of ties), unless a midpoint exceeds `.Machine[["double.xmax"]]` in absolute value, in which case `-Inf` or `Inf` is introduced with a warning. Coercion to types `"character"`, `"symbol"` (synonym `"name"`), `"pairlist"`, `"list"`, and `"expression"`, which are not "number-like", is handled specially.

`coerce signature(from = "ANY", to = "acb")`:
  returns `.acb(x = from)`. An error is signaled if the class or type of `from` is not supported by the method for `initialize`.

`format signature(x = "acb")`:
  returns a character vector suitable for printing, using string format `"(m +/- r)+(m +/- r)i"` and scientific format for each `m` and `r`. Optional arguments control the output; see `format-methods`.

`initialize signature(.Object = "acb", length = "numeric")`:
  returns `.Object` after setting its `.xData` slot. The new slot value is an external pointer to an array of the corresponding C type, which is newly allocated and initialized entirely with zeros (zero midpoint, zero radius in the real and imaginary parts). `.Object` is not copied, so all references are affected.

`initialize signature(.Object = "acb", length = "numeric", x = "atomic|flint")`:
  as above, except that the new slot value points to an array initialized with values from x.

initialize signature(.Object = "acb", length = "numeric", real = "atomic|flint", imag = "atomic|flint"):
   as above, except that the new slot value points to an array whose real and imaginary parts are
   initialized separately with values from real and imag, which are coerced to class [arb](#) and
   recycled as necessary.

is.finite signature(x = "acb"):
   returns a logical vector indicating which elements of x do not have real or imaginary part with
   midpoint NaN, -Inf, or Inf or radius Inf.

is.infinite signature(x = "acb"):
   returns a logical vector indicating which elements of x have real or imaginary part with mid-
   point -Inf or Inf or radius Inf.

is.na, is.nan signature(x = "acb"):
   returns a logical vector indicating which elements of x have real or imaginary part with mid-
   point NaN.

is.unsorted signature(x = "acb"):
   signals an error indicating that <= is not a total order on the range of arb; see xtfrm below.

log signature(x = "acb"):
   returns the logarithm of the argument. The natural logarithm is computed by default (when
   optional argument base is unset).

mean signature(x = "acb"):
   returns the arithmetic mean.

xtfrm signature(x = "acb"):
   signals an error indicating that <= is not a total order on the range of arb: a <= b || b <= a is
   is not TRUE for all finite a and b of class arb. Thus, direct sorting of acb, which is based on
   arb, is not supported. Users wanting to order the *midpoints* of the real and imaginary parts
   should operate on Mid(Real(x)) and Mid(Imag(x)).

References

The FLINT documentation of the underlying C type: https://flintlib.org/doc/acb.html

Johansson, F. (2017). Arb: efficient arbitrary-precision midpoint-radius interval arithmetic. *IEEE Transactions on Computers*, *66*(8), 1281-1292. doi:10.1109/TC.2017.2690633

See Also

Virtual class flint. Generic functions Real and Imag and their replacement forms for getting and
setting real and imaginary parts.

Examples

```
showClass("acb")
showMethods(classes = "acb")
```

---

acf-class   *Arbitrary Precision Floating-Point Complex Numbers*

Description

Class acf extends virtual class [flint](#). It represents vectors of arbitrary precision floating-point complex numbers. Elements have real and imaginary parts, each with arbitrary precision significand and exponent. The underlying C type can represent NaN, -Inf, and Inf real and imaginary parts.

Note that package **stats** exports a function [acf](#), referring to autocovariance and autocorrelation functions of time series. It returns objects of *informal* S3 class acf, for which a small number of *informal* S3 methods are registered. The *formal* S4 class and methods documented here are entirely unrelated.

Usage

```
## The class generator function:
.acf(...)

## Mode 1: initialize with zeros
## .acf(length = 0L)
##
## Mode 2: initialize with vector
## .acf(length = length(x), x)
##
## Mode 3: initialize by parts
## .acf(length = max0(length(real), length(imag)), real, imag)
##
## where max0 <- function(m, n) if (min(m, n)) max(m, n) else 0L
```

Arguments

...   arguments passed to methods for [initialize](#).

Value

The class generator function returns [new](#)("acf", ...).

Slots

.xData, names inherited from virtual class [flint](#).

Methods

Due to constraints imposed by generic functions, methods typically do *not* provide a formal argument prec allowing for a precision to be indicated in the function call. Such methods use the current default precision set by [flintPrec](#).

! signature(x = ″acf″):
  equivalent to (but faster than) x == 0.

+ signature(e1 = ″acf″, e2 = ″missing″):
  returns a copy of the argument.

- signature(e1 = ″acf″, e2 = ″missing″):
  returns the negation of the argument.

Complex signature(z = ″acf″):
  mathematical functions of one argument; see S4groupGeneric.

Math signature(x = ″acf″):
  mathematical functions of one argument; see S4groupGeneric. Member functions floor,
  ceiling, trunc, cummin, cummax are not implemented.

Math2 signature(x = ″acf″):
  decimal rounding according to a second argument digits; see S4groupGeneric. There are
  just two member member functions: round, signif.

Ops signature(e1 = ″ANY″, e2 = ″acf″):
  signature(e1 = ″acf″, e2 = ″ANY″):
  binary arithmetic, comparison, and logical operators; see S4groupGeneric. The "other"
  operand must be atomic or inherit from virtual class flint. The operands are recycled and
  promoted as necessary.

Summary signature(x = ″acf″):
  univariate summary statistics; see S4groupGeneric. The return value is a logical vector of
  length 1 (any, all) or an acf vector of length 1 or 2 (sum, prod). Member functions min, max,
  range are not implemented.

anyNA signature(x = ″acf″):
  returns TRUE if any element of x has real or imaginary part NaN, FALSE otherwise.

as.vector signature(x = ″acf″):
  returns as.vector(y, mode), where y is a complex vector containing the result of con-
  verting the real and imaginary parts of x to the range of double, rounding if the value is
  not exactly representable in double precision. The rounding mode is to the nearest repre-
  sentable number (with precedence to even significands in case of ties), unless parts exceed
  .Machine[[″double.xmax″]] in absolute value, in which case -Inf or Inf is introduced
  with a warning. Coercion to types ″character″, ″symbol″ (synonym ″name″), ″pairlist″,
  ″list″, and ″expression″, which are not "number-like", is handled specially.

coerce signature(from = ″ANY″, to = ″acf″):
  returns .acf(x = from). An error is signaled if the class or type of from is not supported by
  the method for initialize.

format signature(x = ″acf″):
  returns a character vector suitable for printing, using string format ″a+bi″ and scientific for-
  mat for each a and b. Optional arguments control the output; see format-methods.

initialize signature(.Object = ″acf″, length = ″numeric″):
  returns .Object after setting its .xData slot. The new slot value is an external pointer to an
  array of the corresponding C type, which is newly allocated and initialized entirely with zeros.
  .Object is not copied, so all references are affected.

initialize signature(.Object = ″acf″, length = ″numeric″, x = ″atomic|flint″):
  as above, except that the new slot value points to an array initialized with values from x.

initialize signature(.Object = "acf", length = "*numeric*", real = "*atomic|flint*", imag = "*atomic|flint*"):
    as above, except that the new slot value points to an array whose real and imaginary parts are
    initialized separately with values from real and imag, which are coerced to class arf and
    recycled as necessary.

is.finite signature(x = "acf"):
    returns a logical vector indicating which elements of x do not have real or imaginary part NaN,
    -Inf, or Inf.

is.infinite signature(x = "acf"):
    returns a logical vector indicating which elements of x have real or imaginary part -Inf or
    Inf.

is.na, is.nan signature(x = "acf"):
    returns a logical vector indicating which elements of x have real or imaginary part NaN.

is.unsorted signature(x = "acf"):
    returns a logical indicating if x is not sorted in nondecreasing order (increasing order if op-
    tional argument strictly is set to TRUE) by real part then by imaginary part.

mean signature(x = "acf"):
    returns the arithmetic mean.

xtfrm signature(x = "acf"):
    returns a numeric vector that sorts in the same order as x. The permutation order(xtfrm(x),
    ...) orders x first by its real part then by its imaginary part, with the caveat that all a+NaNi
    and NaN+bi have equal precedence (for compatibility with **base**).

See Also

Virtual class flint. Generic functions Real and Imag and their replacement forms for getting and
setting real and imaginary parts.

Examples

```
showClass("acf")
showMethods(classes = "acf")
```

---

arb-class   *Arbitrary Precision Floating-Point Real Numbers with Error Bounds*

Description

Class arb extends virtual class flint. It represents vectors of arbitrary precision floating-point
real numbers with error bounds. Elements are specified by a pair of mixed format floating-point
numbers: an arf midpoint and a mag radius.

Arithmetic on arb vectors is midpoint-radius interval arithmetic, also known as ball arithmetic,
enabling computation with rigorous propagation of errors. Logic and comparison involving arb
vectors are defined as follows: unary op(x) is true if and only if op is true for all elements of the
interval x, and binary op(x, y) is true if and only if op is true for all elements of the Cartesian
product of the intervals x and y. A corollary is that the operator <= does not define a *total order* on
the range of arb (that is, the set of intervals $[m - r, m + r]$), and a consequence is that methods for
generic functions that necessitate a total order tend to signal an error.

Usage

```
## The class generator function:
.arb(...)

## Mode 1: initialize with zeros
## .arb(length = 0L)
##
## Mode 2: initialize with vector
## .arb(length = length(x), x)
##
## Mode 3: initialize by parts
## .arb(length = max0(length(mid), length(rad)), mid, rad)
##
## where max0 <- function(m, n) if (min(m, n)) max(m, n) else 0L
```

Arguments

`...`	arguments passed to methods for [`initialize`]().

Value

The class generator function returns [`new`]("arb", ...).

Slots

`.xData`, `names` inherited from virtual class [`flint`]().

Methods

Due to constraints imposed by generic functions, methods typically do *not* provide a formal argument `prec` allowing for a precision to be indicated in the function call. Such methods use the current default precision set by [`flintPrec`]().

`! signature(x = "arb")`:
   equivalent to (but faster than) x == 0.

`+ signature(e1 = "arb", e2 = "missing")`:
   returns a copy of the argument.

`- signature(e1 = "arb", e2 = "missing")`:
   returns the negation of the argument.

`Complex signature(z = "arb")`:
   mathematical functions of one argument; see [`S4groupGeneric`]().

`Math signature(x = "arb")`:
   mathematical functions of one argument; see [`S4groupGeneric`]().

`Math2 signature(x = "arb")`:
   decimal rounding according to a second argument `digits`; see [`S4groupGeneric`](). There are just two member member functions: [`round`](), [`signif`]().

Ops signature(e1 = "ANY", e2 = "arb"):
  signature(e1 = "arb", e2 = "ANY"):
    binary arithmetic, comparison, and logical operators; see S4groupGeneric. The "other"
    operand must be atomic or inherit from virtual class flint. The operands are recycled and
    promoted as necessary.

Summary signature(x = "arb"):
    univariate summary statistics; see S4groupGeneric. The return value is a logical vector of
    length 1 (any, all) or an arb vector of length 1 or 2 (sum, prod, min, max, range).

anyNA signature(x = "arb"):
    returns TRUE if any element of x has midpoint NaN, FALSE otherwise.

as.vector signature(x = "arb"):
    returns as.vector(y, mode), where y is a double vector containing the result of converting
    the midpoints of x to the range of double, rounding if the value is not exactly representable in
    double precision. The rounding mode is to the nearest representable number (with precedence
    to even significands in case of ties), unless a midpoint exceeds .Machine[["double.xmax"]]
    in absolute value, in which case -Inf or Inf is introduced with a warning. Coercion to
    types "character", "symbol" (synonym "name"), "pairlist", "list", and "expression",
    which are not "number-like", is handled specially.

coerce signature(from = "ANY", to = "arb"):
    returns .arb(x = from). An error is signaled if the class or type of from is not supported by
    the method for initialize.

format signature(x = "arb"):
    returns a character vector suitable for printing, using string format "(m +/- r)" and scientific
    format for m and r. Optional arguments control the output; see format-methods.

initialize signature(.Object = "arb", length = "*numeric*"):
    returns .Object after setting its .xData slot. The new slot value is an external pointer to an
    array of the corresponding C type, which is newly allocated and initialized entirely with zeros
    (zero midpoint, zero radius). .Object is not copied, so all references are affected.

initialize signature(.Object = "arb", length = "*numeric*", x = "*atomic|flint*"):
    as above, except that the new slot value points to an array initialized by the elements of x.

initialize signature(.Object = "arb", length = "*numeric*", mid = "*atomic|flint*", rad = "*atomic|flint*"):
    as above, except that the new slot value points to an array whose midpoints and radii are ini-
    tialized separately with values from mid and rad, which are coerced to classes arf and mag
    and recycled as necessary.

is.finite signature(x = "arb"):
    returns a logical vector indicating which elements of x do not have midpoint NaN, -Inf, or Inf
    or radius Inf.

is.infinite signature(x = "arb"):
    returns a logical vector indicating which elements of x have midpoint -Inf or Inf or radius
    Inf.

is.na, is.nan signature(x = "arb"):
    returns a logical vector indicating which elements of x have midpoint NaN.

is.unsorted signature(x = "arb"):
    signals an error indicating that <= is not a total order on the range of arb; see xtfrm below.

log signature(x = "arb"):
:   returns the logarithm of the argument. The natural logarithm is computed by default (when optional argument base is unset).

mean signature(x = "arb"):
:   returns the arithmetic mean.

xtfrm signature(x = "arb"):
:   signals an error indicating that <= is not a total order on the range of arb: a <= b || b <= a is is not TRUE for all finite a and b of class arb. Thus, direct sorting of arb is not supported. Users wanting to order the *midpoints* should operate on Mid(x).

References

The FLINT documentation of the underlying C type: https://flintlib.org/doc/arb.html

Johansson, F. (2017). Arb: efficient arbitrary-precision midpoint-radius interval arithmetic. *IEEE Transactions on Computers*, *66*(8), 1281-1292. doi:10.1109/TC.2017.2690633

See Also

Virtual class flint. Generic functions Mid and Rad and their replacement forms for getting and setting midpoints and radii.

Examples

```
showClass("arb")
showMethods(classes = "arb")
```

---

arb_dirichlet_zeta   *Zeta and Related Functions*

Description

Compute the Riemann zeta function, the Hurwitz zeta function, or Lerch's transcendent. Lerch's transcendent $\Phi(z, s, a)$ is defined by

$$\sum_{k=0}^{\infty} \frac{z^k}{(k+a)^s}$$

for $|z| < 1$ and by analytic continuation elsewhere in the z-plane. The Riemann and Hurwitz zeta functions are the special cases $\zeta(s) = \Phi(1, s, 1)$ and $\zeta(s, a) = \Phi(1, s, a)$, respectively. See the references for restrictions on s and a.

Usage

```
arb_dirichlet_zeta(s, prec = flintPrec())
acb_dirichlet_zeta(s, prec = flintPrec())

arb_dirichlet_hurwitz(s, a = 1, prec = flintPrec())
acb_dirichlet_hurwitz(s, a = 1, prec = flintPrec())
```

```
## arb_dirichlet_lerch_phi(z = 1, s, a = 1, prec = flintPrec())
   acb_dirichlet_lerch_phi(z = 1, s, a = 1, prec = flintPrec())
```

Arguments

z, s, a   numeric, complex, arb, or acb vectors.

prec   a numeric or slong vector indicating the desired precision as a number of bits.

Value

An arb or acb vector storing function values with error bounds. Its length is the maximum of the
lengths of the arguments or zero (zero if any argument has length zero). The arguments are recycled
as necessary.

References

The FLINT documentation of the underlying C functions: https://flintlib.org/doc/acb_dirichlet.
html

NIST Digital Library of Mathematical Functions: https://dlmf.nist.gov/25

See Also

Classes arb and acb.

Examples

```
dzet <- acb_dirichlet_zeta
dhur <- acb_dirichlet_hurwitz
dler <- acb_dirichlet_lerch_phi

## Somewhat famous particular values :
debugging <- tolower(Sys.getenv("R_FLINT_CHECK_EXTRA")) == "true"
    s <- .acb(x = c(   -1,    0,       2,        4))
zeta.s <- .acb(x = c(-1/12, -1/2, pi^2/6, pi^4/90))
stopifnot(all.equal(dzet(  s   ), zeta.s),
          all.equal(dhur(  s, 1), zeta.s),
          !debugging ||
          {
          print(cbind(as.complex(dler(1, s, 1)), as.complex(zeta.s)))
          all.equal(dler(1, s, 1), zeta.s) # FLINT bug, report this
          })

set.seed(0xabcdL)
r <- 10L
eps <- 0x1p-4
a    <- flint:::complex.runif(r, modulus = c(    0, 1/eps))
z.l1 <- flint:::complex.runif(r, modulus = c(    0, 1-eps))
z.g1 <- flint:::complex.runif(r, modulus = c(1+eps, 1/eps))
z <- .acb(x = c(z.l1, z.g1))
```

```
## A relation with the hypergeometric function from
##   http://dlmf.nist.gov/25.14.E3_3 :
h2f1 <- acb_hypgeom_2f1
stopifnot(all.equal(dler(z.l1, 1, a), h2f1(a, 1, a + 1, z.l1)/a))

## TODO: test values also for z[Mod(z) > 1] ...
```

---

arb_hypgeom_2f1 *Hypergeometric Functions*

Description

Computes the principal branch of the hypergeometric function $_2F_1(a, b, c, z)$, defined by

$$\sum_{k=0}^{\infty} \frac{(a)_k (b)_k}{(c)_k} \frac{z^k}{k!}$$

for $|z| < 1$ and by analytic continuation elsewhere in the z-plane, or the principal branch of the *regularized* hypergeometric function $_2F_1(a, b, c, z)/\Gamma(c)$.

Usage

```
arb_hypgeom_2f1(a, b, c, x, flags = 0L, prec = flintPrec())
acb_hypgeom_2f1(a, b, c, z, flags = 0L, prec = flintPrec())
```

Arguments

a, b, c, x, z	numeric, complex, [arb], or [acb] vectors.
flags	an integer vector. The lowest bit of the integer element(s) indicates whether to regularize. Later bits indicate special cases for which an alternate algorithm may be used. Non-experts should use flags = 0L or 1L, leaving the later bits unset.
prec	a numeric or [slong] vector indicating the desired precision as a number of bits.

Value

An [arb] or [acb] vector storing function values with error bounds. Its length is the maximum of the lengths of the arguments or zero (zero if any argument has length zero). The arguments are recycled as necessary.

References

The FLINT documentation of the underlying C functions: https://flintlib.org/doc/arb_hypgeom.html, https://flintlib.org/doc/acb_hypgeom.html

NIST Digital Library of Mathematical Functions: https://dlmf.nist.gov/15

See Also

Classes [arb] and [acb].

Examples

```
h2f1 <- acb_hypgeom_2f1

set.seed(0xbcdeL)
r <- 10L
eps <- 0x1p-4
z.l1 <- flint:::complex.runif(r, modulus = c(    0, 1-eps))
z.g1 <- flint:::complex.runif(r, modulus = c(1+eps, 1/eps))
z <- .acb(x = c(z.l1, z.g1))

## Elementary special cases from http://dlmf.nist.gov/15.4 :
stopifnot(all.equal(h2f1(1.0, 1.0, 2.0,  z  ),
                    -log(1 - z)/z),
          all.equal(h2f1(0.5, 1.0, 1.5,  z^2),
                    0.5 * (log(1 + z) - log(1 - z))/z),
          all.equal(h2f1(0.5, 1.0, 1.5, -z^2),
                    atan(z)/z))
## [ see more in ../tests/hypgeom.R ]
```

---

arb_hypgeom_gamma   *Gamma and Related Functions*

Description

Compute the gamma function, the reciprocal gamma function, the logarithm of the absolute value of the gamma function, the polygamma function, or the beta function. The gamma function $\Gamma(z)$ is defined by

$$\int_0^\infty t^{z-1} e^{-t} \mathrm{d}t$$

for $\Re(z) > 0$ and by analytic continuation elsewhere in the z-plane, excluding poles at $z = 0, -1, \ldots$. The beta function $B(a, b)$ is defined by

$$\int_0^1 t^{a-1}(1 - t)^{b-1} \mathrm{d}t$$

for $\Re(a), \Re(b) > 0$ and by analytic continuation to all other (a, b).

Usage

```
arb_hypgeom_gamma(x, prec = flintPrec())
acb_hypgeom_gamma(z, prec = flintPrec())

arb_hypgeom_rgamma(x, prec = flintPrec())
acb_hypgeom_rgamma(z, prec = flintPrec())

arb_hypgeom_lgamma(x, prec = flintPrec())
acb_hypgeom_lgamma(z, prec = flintPrec())
```

```
## arb_hypgeom_polygamma(s = 0, z, prec = flintPrec())
   acb_hypgeom_polygamma(s = 0, z, prec = flintPrec())

arb_hypgeom_beta(a, b, prec = flintPrec())
acb_hypgeom_beta(a, b, prec = flintPrec())
```

Arguments

x, z, s, a, b   numeric, complex, arb, or acb vectors.

prec   a numeric or slong vector indicating the desired precision as a number of bits.

Details

acb_hypgeom_polygamma(s, z) evaluates the polygamma function of order s at z. The order s can be any complex number. For nonnegative integers m, s = m corresponds to the derivative of order m of the digamma function $\psi(z) = \Gamma'(z)/\Gamma(z)$. Use acb_hypgeom_polygamma(0, z) to evaluate the digamma function at z.

Value

An arb or acb vector storing function values with error bounds. Its length is the maximum of the lengths of the arguments or zero (zero if any argument has length zero). The arguments are recycled as necessary.

References

The FLINT documentation of the underlying C functions: https://flintlib.org/doc/arb_hypgeom.html, https://flintlib.org/doc/acb_hypgeom.html

NIST Digital Library of Mathematical Functions: https://dlmf.nist.gov/5

See Also

Classes arb and acb; arb_hypgeom_gamma_lower and arb_hypgeom_beta_lower for the "incomplete" gamma and beta functions.

Examples

```
## TODO
```

---

arb_hypgeom_gamma_lower

Incomplete Gamma and Related Functions

Description

Compute the principal branch of the (optionally, regularized) incomplete gamma and beta functions. The lower incomplete gamma function $\gamma(s, z)$ is defined by

$$\int_0^z t^{s-1} e^{-t} \mathrm{d}t$$

for $\Re(s) > 0$ and by analytic continuation elsewhere in the s-plane, excluding poles at $s = 0, -1, \ldots$. The upper incomplete gamma function $\Gamma(s, z)$ is defined by

$$\int_z^\infty t^{s-1} e^{-t} \mathrm{d}t$$

for $\Re(s) > 0$ and by analytic continuation elsewhere in the s-plane except at $z = 0$. The incomplete beta function $B(a, b, z)$ is defined by

$$\int_0^z t^{a-1} (1-t)^{b-1} \mathrm{d}t$$

for $\Re(a), \Re(b) > 0$ and by analytic continuation to all other (a, b). It coincides with the beta function at $z = 1$. The regularized functions are $\gamma(s, z)/\Gamma(s)$, $\Gamma(s, z)/\Gamma(s)$, and $B(a, b, z)/B(a, b)$.

Usage

```
arb_hypgeom_gamma_lower(s, x, flags = 0L, prec = flintPrec())
acb_hypgeom_gamma_lower(s, z, flags = 0L, prec = flintPrec())

arb_hypgeom_gamma_upper(s, x, flags = 0L, prec = flintPrec())
acb_hypgeom_gamma_upper(s, z, flags = 0L, prec = flintPrec())

arb_hypgeom_beta_lower(a, b, x, flags = 0L, prec = flintPrec())
acb_hypgeom_beta_lower(a, b, z, flags = 0L, prec = flintPrec())
```

Arguments

x, z, s, a, b	numeric, complex, arb, or acb vectors.
flags	an integer vector with elements 0, 1, or 2 indicating unregularized, regularized, or "alternately" regularized; see the FLINT documentation.
prec	a numeric or slong vector indicating the desired precision as a number of bits.

Value

An arb or acb vector storing function values with error bounds. Its length is the maximum of the lengths of the arguments or zero (zero if any argument has length zero). The arguments are recycled as necessary.

References

The FLINT documentation of the underlying C functions: https://flintlib.org/doc/arb_hypgeom.html, https://flintlib.org/doc/acb_hypgeom.html

NIST Digital Library of Mathematical Functions: https://dlmf.nist.gov/8

See Also

Classes arb and acb; arb_hypgeom_gamma and arb_hypgeom_beta for the "complete" gamma and beta functions.

Examples

```
hg  <- acb_hypgeom_gamma
hgl <- acb_hypgeom_gamma_lower
hgu <- acb_hypgeom_gamma_upper

hb  <- acb_hypgeom_beta
hbl <- acb_hypgeom_beta_lower

set.seed(0xcdefL)
r <- 10L
eps <- 0x1p-4
a <- flint:::complex.runif(r, modulus = c(  0, 1/eps))
b <- flint:::complex.runif(r, modulus = c(  0, 1/eps))
z <- flint:::complex.runif(r, modulus = c(eps, 1/eps))

## Some trivial identities
stopifnot(# http://dlmf.nist.gov/8.2.E3
          all.equal(hgl(a, z) + hgu(a, z), hg(a), tolerance = 1e-5),
          # https://dlmf.nist.gov/8.4.E5
          all.equal(hgu(1, z), exp(-z), check.class = FALSE))

## Regularization
stopifnot(all.equal(hgl(a,    z, flags = 1L), hgl(a,    z)/hg(a  )),
          all.equal(hgu(a,    z, flags = 1L), hgu(a,    z)/hg(a  )),
          all.equal(hbl(a, b, z, flags = 1L), hbl(a, b, z)/hb(a, b)))

## A relation with the hypergeometric function from
##   https://dlmf.nist.gov/8.17.E7 :
h2f1 <- acb_hypgeom_2f1
stopifnot(all.equal(hbl(a, b, z), z^a * h2f1(a, 1 - b, a + 1, z)/a))
```

---

arb_lambertw   *Lambert W function*

Description

Computes any branch W_k of the multiple-valued Lambert W function. $W(z)$ is the set of solutions w of the equation $we^w = z$.

Usage

```
arb_lambertw(x,         flags = 0L, prec = flintPrec())
acb_lambertw(z, k = 0L, flags = 0L, prec = flintPrec())
```

Arguments

x, z	numeric, complex, [arb], or [acb] vectors.
k	an integer or [fmpz] vector listing indices of branches of the function. 0 indicates the principal branch.
flags	for arb_lambertw: an integer vector indicating which of the index 0 and index -1 branches is computed (0 means index 0, 1 means index -1). for acb_lambertw: an integer vector indicating how branch cuts are defined. Nonzero values are nonstandard; see the first reference.
prec	a numeric or [slong] vector indicating the desired precision as a number of bits.

Value

An [arb] or [acb] vector storing function values with error bounds. Its length is the maximum of the lengths of the arguments or zero (zero if any argument has length zero). The arguments are recycled as necessary.

References

The FLINT documentation of the underlying C functions: <https://flintlib.org/doc/arb.html>, <https://flintlib.org/doc/acb.html>

NIST Digital Library of Mathematical Functions: <https://dlmf.nist.gov/4.13>

See Also

Classes [arb] and [acb].

Examples

```
## TODO
```

---

arf-class	*Arbitrary Precision Floating-Point Real Numbers*

Description

Class arf extends virtual class [flint]. It represents vectors of arbitrary precision floating-point real numbers. Elements have arbitrary precision significand and exponent. The underlying C type can represent NaN, -Inf, and Inf.

Usage

```
## The class generator function:
.arf(...)

## Mode 1: initialize with zeros
## .arf(length = 0L)
##
## Mode 2: initialize with vector
## .arf(length = length(x), x)
```

Arguments

... arguments passed to methods for `initialize`.

Value

The class generator function returns `new("arf", ...)`.

Slots

`.xData`, `names` inherited from virtual class `flint`.

Methods

Due to constraints imposed by generic functions, methods typically do *not* provide a formal argument `prec` allowing for a precision to be indicated in the function call. Such methods use the current default precision set by `flintPrec`.

`! signature(x = "arf")`:
    equivalent to (but faster than) `x == 0`.

`+ signature(e1 = "arf", e2 = "missing")`:
    returns a copy of the argument.

`- signature(e1 = "arf", e2 = "missing")`:
    returns the negation of the argument.

`Complex signature(z = "arf")`:
    mathematical functions of one argument; see `S4groupGeneric`.

`Math signature(x = "arf")`:
    mathematical functions of one argument; see `S4groupGeneric`. Notably, the logarithmic, exponential, (inverse) trigonometric, (inverse) hyperbolic, and gamma-related member functions are not yet implemented. Users wanting those can (for now) operate on `as(x, "arb")`.

`Math2 signature(x = "arf")`:
    decimal rounding according to a second argument `digits`; see `S4groupGeneric`. There are just two member member functions: `round`, `signif`.

`Ops signature(e1 = "ANY", e2 = "arf")`:
    `signature(e1 = "arf", e2 = "ANY")`:
    binary arithmetic, comparison, and logical operators; see `S4groupGeneric`. The "other" operand must be atomic or inherit from virtual class `flint`. The operands are recycled and promoted as necessary.

Summary signature(x = "arf"):
:   univariate summary statistics; see S4groupGeneric. The return value is a logical vector of length 1 (any, all) or an arf vector of length 1 or 2 (sum, prod, min, max, range).

anyNA signature(x = "arf"):
:   returns TRUE if any element of x is NaN, FALSE otherwise.

as.vector signature(x = "arf"):
:   returns as.vector(y, mode), where y is a double vector containing the result of converting each element of x to the range of double, rounding if the value is not exactly representable in double precision. The rounding mode is to the nearest representable number (with precedence to even significands in case of ties), unless the element exceeds .Machine[["double.xmax"]] in absolute value, in which case -Inf or Inf is introduced with a warning. Coercion to types "character", "symbol" (synonym "name"), "pairlist", "list", and "expression", which are not "number-like", is handled specially.

coerce signature(from = "ANY", to = "arf"):
:   returns .arf(x = from). An error is signaled if the class or type of from is not supported by the method for initialize.

format signature(x = "arf"):
:   returns a character vector suitable for printing, using scientific format. Optional arguments control the output; see format-methods.

initialize signature(.Object = "arf", length = "numeric"):
:   returns .Object after setting its .xData slot. The new slot value is an external pointer to an array of the corresponding C type, which is newly allocated and initialized entirely with zeros. .Object is not copied, so all references are affected.

initialize signature(.Object = "arf", length = "numeric", x = "atomic|flint"):
:   as above, except that the new slot value points to an array initialized with values from x.

is.finite signature(x = "arf"):
:   returns a logical vector indicating which elements of x are not NaN, -Inf, or Inf.

is.infinite signature(x = "arf"):
:   returns a logical vector indicating which elements of x are -Inf or Inf.

is.na, is.nan signature(x = "arf"):
:   returns a logical vector indicating which elements of x are NaN.

is.unsorted signature(x = "arf"):
:   returns a logical indicating if x is not sorted in nondecreasing order (increasing order if optional argument strictly is set to TRUE).

mean signature(x = "arf"):
:   returns the arithmetic mean.

References

The FLINT documentation of the underlying C type: https://flintlib.org/doc/arf.html

Johansson, F. (2017). Arb: efficient arbitrary-precision midpoint-radius interval arithmetic. *IEEE Transactions on Computers*, *66*(8), 1281-1292. doi:10.1109/TC.2017.2690633

See Also

Virtual class flint.

Examples

```
showClass("arf")
showMethods(classes = "arf")
```

---

c.flint   *Concatenate Vectors*

Description

Primitive function c is internally generic but dispatches only on its first argument. A corollary is that c(x, ...) does *not* dispatch the S4 method with signature x="flint" if x is not a flint vector, even if a flint vector appears later in the call as an element of .... An S3 method c.flint is registered *and exported* to support concatenation with c.flint(x, ...) as an alternative to c(as(x, "flint"), ...).

Usage

```
## S3 method for class 'flint'
c(..., recursive = FALSE, use.names = TRUE)
```

Arguments

...	objects inheriting from virtual class flint, atomic (except character) vectors, and NULL.
recursive	a logical indicating if pairlists, lists, and expressions should be handled recursively. If TRUE, then the function behaves as if such arguments were replaced by their terminal nodes.
use.names	a logical indicating if names should be preserved.

Value

If none of the arguments is a flint vector, then the internal default method for c is dispatched.

If at least one argument is a flint vector, then the return value is a flint vector, unless recursive = FALSE and at least one argument is a symbol, pairlist, list, or expression, in which case the return value is a list or expression. The length is the sum of the lengths of the arguments.

If the return value is a flint vector, then its class is the most specific subclass of flint whose range contains the ranges of the classes of the arguments.

See Also

Virtual class flint.

Examples

```
x <- .slong(x = 2:5)
c(x, 6L)
c(1L, x) # bad
c.flint(x, 6L)
c.flint(1L, x)
```

Constants   *Mathematical Constants Represented to Arbitrary Precision*

Description

Compute standard mathematical constants to arbitrary precision.

Usage

```
arb_const_pi(prec = flintPrec())
arb_const_log2(prec = flintPrec())
arb_const_log10(prec = flintPrec())
arb_const_e(prec = flintPrec())
```

Arguments

prec   a numeric or slong vector indicating the desired precision as a number of bits.

Value

An arb vector storing function values with error bounds. Its length is the length of prec, typically 1.

References

The FLINT documentation of the underlying C functions: https://flintlib.org/doc/arb.html

See Also

Class arb.

Examples

```
prec <- cumprod(rep(c(1, 2), c(1L, 15L)))
arb_const_pi(prec)
```

---

flint-class   *Class of FLINT-Type Vectors*

Description

Class `flint` is a virtual class representing vectors of any FLINT C type. The C type is determined by the class attribute and interfaced exactly using R's external pointer type.

Slots

`.xData` an external pointer. The protected field is an integer vector of length 1 or 2 storing the object length whose size is 32 or 64 bits depending on the ABI; see `flintABI`. The pointer field contains the address of a block of allocated memory of size greater than or equal to the object length times the size of the FLINT C type. It is a null pointer if and only if the object length is zero.

Methods for `initialize` set a finalizer on `.xData` (see `reg.finalizer`) to ensure that allocated memory is freed before `.xData` is itself freed by the garbage collector.

`names` a character vector of length 0, indicating that the object is unnamed, or of length equal to the object length. A corollary is that objects whose length exceeds the maximum length of a character vector cannot have names.

Methods

`[` signature(x = "ANY", i = "flint", j = "missing", drop = "missing"):
   signature(x = "flint", i = "ANY", j = "missing", drop = "missing"):
   signature(x = "flint", i = "flint", j = "missing", drop = "missing"):
   return a traditional vector or a `flint` vector containing the elements of x indexed by i (the "subscript"). The subscript can be missing, NULL, logical, integer, double, character, `ulong`, `slong`, `fmpz`, or `fmpq`. Methods for signatures with x = "flint" signal an error for NA and out of bounds subscripts, as the C types interfaced by `flint` vectors have no representation for missing values. Note that `[` does not perform S4 dispatch if its first positional argument is not an S4 object. If it is known that i is a `flint` vector and not known whether x is a `flint` vector, then consider programming defensively by calling `[` as `` `[` ``(i = i, x = x) rather than as x[i].

`[<-` signature(x = "ANY", i = "ANY", j = "missing", value = "flint"):
   signature(x = "ANY", i = "flint", j = "missing", value = "ANY"):
   signature(x = "ANY", i = "flint", j = "missing", value = "flint"):
   signature(x = "flint", i = "ANY", j = "missing", value = "ANY"):
   signature(x = "flint", i = "ANY", j = "missing", value = "flint"):
   signature(x = "flint", i = "flint", j = "missing", value = "ANY"):
   signature(x = "flint", i = "flint", j = "missing", value = "flint"):
   return the traditional vector or `flint` vector obtained by replacing the elements of x indexed by i (the "subscript") with elements of value, which are recycled as necessary. The subscript can be missing, NULL, logical, integer, double, character, `ulong`, `slong`, `fmpz`, or `fmpq`. The class of the return value is determined following strict rules from the classes of x and value,

which are promoted to the value class as necessary. If the value class is a subclass of flint, then an error is signaled for NA and out of bounds subscripts, as the C types interfaced by flint vectors have no representation for missing values. Note that [<- does not perform S4 dispatch if its first positional argument is not an S4 object. If it is known that i is a flint vector and not known whether x is a flint vector, then consider calling [<- as `[`(i = i, x = x) <- value rather than as x[i] <- value. If it known that value is a flint vector and not known whether x or i is a flint vector, then consider doing something like x <- `[<-`(value = value, x = x, i = i).

[[signature(x = "ANY", i = "flint", j = "missing"):
    signature(x = "flint", i = "ANY", j = "missing"):
    signature(x = "flint", i = "flint", j = "missing"):
    similar to [, with differences as documented in Extract.

[[<- signature(x = "ANY", i = "ANY", j = "missing", value = "flint"):
    signature(x = "ANY", i = "flint", j = "missing", value = "ANY"):
    signature(x = "ANY", i = "flint", j = "missing", value = "flint"):
    signature(x = "flint", i = "ANY", j = "missing", value = "ANY"):
    signature(x = "flint", i = "ANY", j = "missing", value = "flint"):
    signature(x = "flint", i = "flint", j = "missing", value = "ANY"):
    signature(x = "flint", i = "flint", j = "missing", value = "flint"):
    similar to [<-, with differences as documented in Extract.

all.equal signature(x = "ANY", y = "flint"):
    signature(x = "flint", y = "ANY"):
    signature(x = "flint", y = "flint"):
    returns either TRUE, indicating that there is no meaningful difference between x and y, or a character vector describing differences. The implementation (including optional arguments) is adapted from all.equal.numeric, hence see *its* documentation. Notably, comparison of objects inheriting from different subclasses of virtual class flint and comparison with objects (typically atomic vectors) coercible to virtual class flint are supported with check.class = FALSE. See flintIdentical for much more strict comparison objects inheriting from flint.

anyDuplicated signature(x = "flint"):
    returns anyDuplicated(mtfrm(x), ...).

as.raw, as.logical, as.integer, as.numeric, as.complex signature(x = "flint"):
    returns the value of as.vector(x, mode = *). Methods for as.vector must be defined for subclasses of flint. Note that as.double dispatches internally the method for as.numeric, so there is no method for as.double; see also as.numeric, section 'S4 Methods'.

as.matrix, as.array, as.Date, as.POSIXct, as.POSIXlt signature(x = "flint"):
    coerces the argument with as.vector and dispatches.

as.data.frame signature(x = "flint"):
    this method is a copy of as.data.frame.vector. It enables the construction of data frames containing flint vectors using as.data.frame and functions that call it such as data.frame and cbind.data.frame.

c signature(x = "flint"):
    returns c.flint(x, ...), the concatenation of the arguments. Function c.flint is exported to work around the fact that c(x, ...) dispatches only on x.

coerce signature(from = "ANY", to = "flint"):
    coerces atomic (except character) vectors from to the most specific subclass of flint whose range contains the range of typeof(from).

cut signature(x = "flint"):

  returns findInterval(x=x, vec=breaks, left.open=right, rightmost.closed=include.lowest),
  hence see below. The behaviour is consistent with the default method for cut with argument
  labels set to FALSE, provided that breaks is sorted and no element of x is out of bounds.

duplicated signature(x = "flint"):

  returns duplicated(mtfrm(x), ...).

findInterval returns a ulong vector of length equal to the length of x, following the documented
  behaviour of the **base** function, hence see findInterval. A caveat is that an error is signaled
  if x contains NaN, because ulong has no representation for R's missing value NA_integer_.

is.na<- signature(x = "flint"):

  returns the value of x after x[value] <- *na*, where *na* is an NA of integer, double, or complex
  type, depending on the class of x.

length signature(x = "flint"):

  returns flintLength(x, exact = FALSE).

length<- signature(x = "flint"):

  returns a flint vector of length given by the second argument value. The first min(length(x),
  value) elements are copied from x and the remaining elements are initialized to zero.

match signature(x = "ANY", table = "flint"):

  signature(x = "flint", table = "ANY"):

  signature(x = "flint", table = "flint"):

  returns an integer vector matching x to table after coercing to a common class then "match
  transforming" with mtfrm. The behaviour is parallel to that of the default method, hence see
  match.

mtfrm signature(x = "flint"):

  returns format(x, base = 62L, digits = 0L), a character vector representing the elements
  of x exactly in base 62 (chosen over smaller bases to reduce the number of characters in the
  output); see also format-methods.

names signature(x = "flint"):

  returns the value of the names slot or NULL, NULL if the names slot has zero length.

names<- signature(x = "flint", value = "NULL"):

  returns x with names slot set to a character vector of length zero.

names<- signature(x = "flint", value = "character"):

  returns x with names slot set to value. Attributes of value are stripped. NA_character_ are
  appended to value if its length is less than the length of x. An error is signaled if its length is
  greater.

print signature(x = "flint"):

  prints format(x) without quotes and returns x invisibly. The output has a header listing the
  class and length of x and the address stored by its .xData slot. If the output might be differ-
  enced by Rdiff, then one can set optional argument Rdiff to TRUE to indicate that the address
  should be formatted as <pointer: 0x...> rather than as 0x..., as the longer format is recog-
  nized and ignored by Rdiff. The default value NULL is equivalent to getOption("flint.Rdiff",
  FALSE). For greater control over output, consider doing print(format(x, ...), ...) in-
  stead of print(x, ...).

quantile signature(x = "flint"):

  returns a flint vector containing sample quantiles computed according to additional argu-

ments probs and type; see [quantile](). Currently, an error is is signaled for x of length zero
and x containing NaN.

rep signature(x = "flint"):

repeats x (or elements of x) according to optional arguments times, length.out, and each.
The behaviour is parallel to that of the internal default method, hence see [rep](). One difference
is that rep(*0-length*, length.out=*nonzero*) signals an error, because the underlying **C** types
have no representation for missing values.

rep.int, rep_len signature(x = "flint"):

analogues of rep(x, times=) and rep(x, length.out=) not preserving names, faster than
rep when x has names.

seq signature(... = "flint"):

generates flint vectors whose elements are equally spaced. This method is dispatched by
calls to seq or seq.int in which the first positional argument is a flint vector. Accepted
usage is any of

```
seq(length.out=)
seq(length.out=, by=)
seq(from=, to=)
seq(from=, to=, by=)
seq(from=, to=, length.out=)
seq(from=, by=, length.out=)
seq(to=, by=, length.out=)
```

where length.out=n and along.with=x are equivalent for x of length n. Good users name
all arguments.

sequence signature(nvec = "flint"):

returns the concatenation of seq(from = from[i], by = by[i], length.out = nvec[i]) af-
ter recycling arguments nvec, from, and by to a common length.

show signature(object = "flint"):

prints [format](object) and returns NULL invisibly.

summary signature(object = "flint"):

returns a flint vector containing the minimum, first quartile, median, mean, third quartile,
maximum, and (if nonzero) the number of NaN, unless object is complex (inherits from [acf]()
or [acb]()) or x has error bounds (inherits from [arb]() or [acb]()) or optional argument triple is TRUE,
in which case the value is just [flintTriple]() with names.

unique signature(x = "flint"):

returns x[!duplicated(x, ...)].

Methods are on purpose *not* defined for generic functions whose default methods correctly han-
dle objects inheriting from virtual class flint, typically by calling *other* generic functions for
which methods *are* defined. Examples are [as.character](), [as.list](), [diff](), [rev](), [seq.int](), [sort](),
and [split]().

See Also

The nonvirtual subclasses: [ulong](), [slong](), [fmpz](), [fmpq](), [mag](), [arf](), [acf](), [arb](), and [acb]().

Examples

```
showClass("flint")
showMethods(classes = "flint")
```

---

fmpq-class   *Arbitrary Precision Rational Numbers*

Description

Class fmpq extends virtual class [flint](#). It represents vectors of arbitrary precision rational numbers. Elements are specified by a pair of arbitrary precision signed integers: a numerator and a positive, coprime denominator. There is no representation for R's missing value [NA_integer_](#).

Usage

```
## The class generator function:
.fmpq(...)

## Mode 1: initialize with zeros
## .fmpq(length = 0L)
##
## Mode 2: initialize with vector
## .fmpq(length = length(x), x)
##
## Mode 3: initialize by parts
## .fmpq(length = max0(length(num), length(den)), num, den)
##
## where max0 <- function(m, n) if (min(m, n)) max(m, n) else 0L
```

Arguments

...   arguments passed to methods for [initialize](#).

Value

The class generator function returns [new](#)("fmpq", ...).

Slots

.xData, names inherited from virtual class [flint](#).

Methods

! signature(x = "fmpq"):
    equivalent to (but faster than) x == 0.

+ signature(e1 = "fmpq", e2 = "missing"):
    returns a copy of the argument.

- signature(e1 = "fmpq", e2 = "missing"):
    returns the negation of the argument.

Complex signature(z = "fmpq"):
    mathematical functions of one argument; see [S4groupGeneric](). Member functions requiring
    promotion to a floating-point type may not be implemented.

Math signature(x = "fmpq"):
    mathematical functions of one argument; see [S4groupGeneric](). Member functions requiring
    promotion to a floating-point type may not be implemented.

Math2 signature(x = "fmpq"):
    decimal rounding according to a second argument digits; see [S4groupGeneric](). There are
    just two member member functions: [round](), [signif]().

Ops signature(e1 = "ANY", e2 = "fmpq"):
    signature(e1 = "fmpq", e2 = "ANY"):
    binary arithmetic, comparison, and logical operators; see [S4groupGeneric](). The "other"
    operand must be atomic or inherit from virtual class [flint](). The operands are recycled and
    promoted as necessary.

Summary signature(x = "fmpq"):
    univariate summary statistics; see [S4groupGeneric](). The return value is a logical vector of
    length 1 (any, all) or an fmpq vector of length 1 or 2 (sum, prod, min, max, range).

anyNA signature(x = "fmpq"):
    returns FALSE, as fmpq has no representation for NaN.

as.vector signature(x = "fmpq"):
    returns as.vector(y, mode), where y is a double vector containing the result of converting
    each element of x to the range of double, rounding if the value is not exactly representable in
    double precision. The rounding mode is to the nearest representable number in the direction of
    zero, unless the element exceeds .Machine[["double.xmax"]] in absolute value, in which
    case -Inf or Inf is introduced with a warning. Coercion to types "character", "symbol"
    (synonym "name"), "pairlist", "list", and "expression", which are not "number-like",
    is handled specially.

coerce signature(from = "ANY", to = "fmpq"):
    returns .fmpq(x = from). An error is signaled if the class or type of from is not supported by
    the method for [initialize]().

format signature(x = "fmpq"):
    returns a character vector suitable for printing, using string format "p/q". Optional arguments
    control the output; see [format-methods]().

initialize signature(.Object = "fmpq", length = "*numeric*"):
    returns .Object after setting its .xData slot. The new slot value is an external pointer to an
    array of the corresponding C type, which is newly allocated and initialized entirely with zeros
    (zero numerator, unit denominator). .Object is not copied, so all references are affected.

initialize signature(.Object = "fmpq", length = "*numeric*", x = "*atomic|flint*"):
    as above, except that the new slot value points to an array initialized with values from x. An
    error is signaled if elements of x are NaN, -Inf, or Inf.

initialize signature(.Object = "fmpq", length = "*numeric*", num = "*atomic|flint*", den = "*atomic|flint*"):
    as above, except that the new slot value points to an array whose numerators and denominators
    are initialized separately with values from num and den, which are coerced to class [fmpz]() and

recycled as necessary. An error is signaled if elements of num or den are NaN, -Inf, or Inf or elements of den are zero.

is.finite signature(x = "fmpq"):
     returns a logical vector whose elements are all TRUE, as fmpq has no representation for NaN, -Inf, and Inf.

is.infinite, is.na, is.nan signature(x = "fmpq"):
     returns a logical vector whose elements are all FALSE, as fmpq has no representation for NaN, -Inf, and Inf.

is.unsorted signature(x = "fmpq"):
     returns a logical indicating if x is not sorted in nondecreasing order (increasing order if optional argument strictly is set to TRUE).

mean signature(x = "fmpq"):
     returns the arithmetic mean. An error is signaled if the argument length is 0, because the return type is fmpq which cannot represent the result of division by 0.

References

The FLINT documentation of the underlying C type: <https://flintlib.org/doc/fmpq.html>

See Also

Virtual class [flint](). Generic functions [Num]() and [Den]() and their replacement forms for getting and setting numerators and denominators.

Examples

```
showClass("fmpq")
showMethods(classes = "fmpq")
```

---

fmpz-class   *Arbitrary Precision Signed Integers*

Description

Class fmpz extends virtual class [flint](). It represents vectors of arbitrary precision signed integers. There is no representation for R's missing value [NA_integer_]().

Usage

```
## The class generator function:
.fmpz(...)

## Mode 1: initialize with zeros
## .fmpz(length = 0L)
##
## Mode 2: initialize with vector
## .fmpz(length = length(x), x)
```

Arguments

...   arguments passed to methods for [initialize](#).

Value

The class generator function returns [new](#)("fmpz", ...).

Slots

.xData, names inherited from virtual class [flint](#).

Methods

! signature(x = "fmpz"):
    equivalent to (but faster than) x == 0.

+ signature(e1 = "fmpz", e2 = "missing"):
    returns a copy of the argument.

- signature(e1 = "fmpz", e2 = "missing"):
    returns the negation of the argument.

Complex signature(z = "fmpz"):
    mathematical functions of one argument; see [S4groupGeneric](#). Member functions requiring
    promotion to a floating-point type may not be implemented.

Math signature(x = "fmpz"):
    mathematical functions of one argument; see [S4groupGeneric](#). Member functions requiring
    promotion to a floating-point type may not be implemented.

Math2 signature(x = "fmpz"):
    decimal rounding according to a second argument digits; see [S4groupGeneric](#). There are
    just two member member functions: [round](#), [signif](#).

Ops signature(e1 = "ANY", e2 = "fmpz"):
    signature(e1 = "fmpz", e2 = "ANY"):
    binary arithmetic, comparison, and logical operators; see [S4groupGeneric](#). The "other"
    operand must be atomic or inherit from virtual class [flint](#). The operands are recycled and
    promoted as necessary.

Summary signature(x = "fmpz"):
    univariate summary statistics; see [S4groupGeneric](#). The return value is a logical vector of
    length 1 (any, all) or an fmpz vector of length 1 or 2 (sum, prod, min, max, range).

anyNA signature(x = "fmpz"):
    returns FALSE, as fmpz has no representation for NaN.

as.vector signature(x = "fmpz"):
    returns as.vector(y, mode), where y is a double vector containing the result of converting
    each element of x to the range of double, rounding if the value is not exactly representable in
    double precision. The rounding mode is to the nearest representable number in the direction of
    zero, unless the element exceeds .Machine[["double.xmax"]] in absolute value, in which
    case -Inf or Inf is introduced with a warning. Coercion to types "character", "symbol"
    (synonym "name"), "pairlist", "list", and "expression", which are not "number-like",
    is handled specially.

coerce signature(from = "ANY", to = "fmpz"):
> returns .fmpz(x = from). An error is signaled if the class or type of from is not supported by the method for initialize.

format signature(x = "fmpz"):
> returns a character vector suitable for printing. Optional arguments control the output; see format-methods.

initialize signature(.Object = "fmpz", length = "*numeric*"):
> returns .Object after setting its .xData slot. The new slot value is an external pointer to an array of the corresponding C type, which is newly allocated and initialized entirely with zeros. .Object is not copied, so all references are affected.

initialize signature(.Object = "fmpz", length = "*numeric*", x = "*atomic|flint*"):
> as above, except that the new slot value points to an array initialized with values from x truncated towards zero. An error is signaled if elements of x are NaN, -Inf, or Inf.

is.finite returns a logical vector whose elements are all TRUE, as fmpz has no representation for NaN, -Inf, and Inf.

is.infinite, is.na, is.nan signature(x = "fmpz"):
> returns a logical vector whose elements are all FALSE, as fmpz has no representation for NaN, -Inf, and Inf.

is.unsorted signature(x = "fmpz"):
> returns a logical indicating if x is not sorted in nondecreasing order (increasing order if optional argument strictly is set to TRUE).

mean signature(x = "fmpz"):
> returns the arithmetic mean. An error is signaled if the argument length is 0, because the return type is fmpq which cannot represent the result of division by 0.

References

The FLINT documentation of the underlying C type: https://flintlib.org/doc/fmpz.html

See Also

Virtual class flint.

Examples

```
showClass("fmpz")
showMethods(classes = "fmpz")
```

---

format-methods   *Format FLINT-type Numbers as Strings*

Description

Format a flint vector for pretty printing.

Usage

```
## S4 method for signature 'ulong'
format(x, base = 10L, ...)
## S4 method for signature 'slong'
format(x, base = 10L, ...)
## S4 method for signature 'fmpz'
format(x, base = 10L, ...)
## S4 method for signature 'fmpq'
format(x, base = 10L, ...)
## S4 method for signature 'mag'
format(x, base = 10L, digits = NULL, sep = NULL,
       rnd = flintRnd(), ...)
## S4 method for signature 'arf'
format(x, base = 10L, digits = NULL, sep = NULL,
       rnd = flintRnd(), ...)
## S4 method for signature 'acf'
format(x, base = 10L, digits = NULL, sep = NULL,
       rnd = flintRnd(), ...)
## S4 method for signature 'arb'
format(x, base = 10L, digits = NULL, sep = NULL,
       rnd = flintRnd(), ...)
## S4 method for signature 'acb'
format(x, base = 10L, digits = NULL, sep = NULL,
       rnd = flintRnd(), ...)
```

Arguments

x	a [flint](#) vector.
base	an integer from 2 to 62 indicating a base for output. Values 2, 10, and 16 correspond to binary, decimal, and hexadecimal output. Digits are represented by characters '[0-9A-Za-z]', in that significance order, hence the maximum 10+26+26=62.
digits	an integer indicating how many digits of the significand are reported when formatting floating type vectors. When more than one digit is printed, a radix point inserted after the first digit. Value 0 is equivalent to the minimum integer d such that all elements of x are represented exactly by d digits in the specified base. The default value NULL is equivalent to getOption("digits", 99999L).
sep	a nonempty character string used to separate the significand from the exponent. The default value NULL is a equivalent to ″e″ for base equal to 10 and to ″@″ for all other bases.
rnd	a nonempty character string whose first character indicates a rounding mode. Methods for [arb](#) and [acb](#) require rnd of length 2, specifying rounding modes separately for midpoints and radii. See [flintRnd](#) for information about valid character strings.
...	further optional arguments, though these are currently unused.

Value

A character vector containing ASCII strings of equal length.

Examples

```
q <- .fmpq(num = c(-1L, 1L) * 0:5, den = 1:6)
for (b in 2:8) {
    cat("base = ", b, ":\n", sep = "")
    print(format(q, base = b), quote = FALSE, width = 12L)
}

z <- .acb(real = .arb(mid = pi, rad = 0.5 * pi))
format(z)
format(z, base = 62L, sep = "*[62]^")
strsplit(format(Re(z), digits = 80L), "[( )]")[[1L]][c(FALSE, TRUE)]
```

---

mag-class   *Fixed Precision Magnitude (Error) Bounds*

Description

Class mag extends virtual class [flint](#). It represents vectors of fixed precision error bounds. Elements are unsigned floating-point numbers with a 30-bit significand and an arbitary precision exponent. The underlying C type can represent Inf but not NaN.

Usage

```
## The class generator function:
.mag(...)

## Mode 1: initialize with zeros
## .mag(length = 0L)
##
## Mode 2: initialize with vector
## .mag(length = length(x), x)
```

Arguments

...	arguments passed to methods for [initialize](#).

Value

The class generator function returns [new](#)("mag", ...).

Slots

.xData, names inherited from virtual class [flint](#).

Methods

`! signature(x = "mag")`:
    equivalent to (but faster than) `x == 0`.

`+ signature(e1 = "mag", e2 = "missing")`:
    returns a copy of the argument.

`- signature(e1 = "mag", e2 = "missing")`:
    returns a copy of the argument, to be consistent with the binary operation which returns an
    upper bound for the absolute value of the difference.

`Complex signature(z = "mag")`:
    mathematical functions of one argument; see [`S4groupGeneric`](). The return value is an upper
    bound for the absolute value of the exact answer.

`Math signature(x = "mag")`:
    mathematical functions of one argument; see [`S4groupGeneric`](). The return value is an up-
    per bound for the absolute value of the exact answer. Notably, the (inverse) trigonometric,
    (inverse) hyperbolic, and gamma-related member functions are not yet implemented. Users
    wanting those can (for now) operate on `as(x, `[`"arb"`](`)`.

`Math2 signature(x = "mag")`:
    decimal rounding according to a second argument `digits`; see [`S4groupGeneric`](). There are
    just two member functions: [`round`](), [`signif`](). The return value is an upper bound for the exact
    answer.

`Ops signature(e1 = "ANY", e2 = "mag")`:
    `signature(e1 = "mag", e2 = "ANY")`:
    binary arithmetic, comparison, and logical operators; see [`S4groupGeneric`](). The "other"
    operand must be atomic or inherit from virtual class [`flint`](). The operands are recycled and
    promoted as necessary. For arithmetic, the return value is a mag vector only if both operands
    are mag vectors. In that case, the return value is an upper bound for the absolute value of the
    exact answer. Users wanting "standard" floating-point arithmetic must ensure that at least one
    operand is not a mag vector.

`Summary signature(x = "mag")`:
    univariate summary statistics; see [`S4groupGeneric`](). The return value is a logical vector of
    length 1 (any, all) or an mag vector of length 1 or 2 (sum, prod, min, max, range). For `sum`
    and `prod`, the return value is an upper bound for the exact answer.

`anyNA signature(x = "mag")`:
    returns `FALSE`, as mag has no representation for NaN.

`as.vector signature(x = "mag")`:
    returns `as.vector(y, mode)`, where `y` is a double vector containing the result of converting
    each element of `x` to the range of double, rounding in the direction of `Inf`, not always to
    nearest. Coercion to types `"character"`, `"symbol"` (synonym `"name"`), `"pairlist"`, `"list"`,
    and `"expression"`, which are not "number-like", is handled specially.

`coerce signature(from = "ANY", to = "mag")`:
    returns `.mag(x = from)`. An error is signaled if the class or type of `from` is not supported by
    the method for [`initialize`]().

`format signature(x = "mag")`:
    returns a character vector suitable for printing, using scientific format. Optional arguments
    control the output; see [`format-methods`]().

initialize signature(.Object = "mag", length = "*numeric*"):
  returns .Object after setting its .xData slot. The new slot value is an external pointer to an array of the corresponding C type, which is newly allocated and initialized entirely with zeros. .Object is not copied, so all references are affected.

initialize signature(.Object = "mag", length = "*numeric*", x = "*atomic|flint*"):
  as above, except that the new slot value points to an array initialized with upper bounds for abs(x). An error is signaled if any x[i] is NaN.

is.finite signature(x = "mag"):
  returns a logical vector indicating which elements of x are not Inf.

is.infinite signature(x = "mag"):
  returns a logical vector indicating which elements of x are Inf.

is.na, is.nan signature(x = "mag"):
  returns a logical vector whose elements are all FALSE, as mag has no representation for NaN.

is.unsorted signature(x = "mag"):
  returns a logical indicating if x is not sorted in nondecreasing order (increasing order if optional argument strictly is set to TRUE).

log signature(x = "mag"):
  returns an upper bound for the absolute value of the logarithm of the argument. The natural logarithm is computed by default (when optional argument base is unset).

mean signature(x = "mag"):
  returns an upper bound for the arithmetic mean.

References

The FLINT documentation of the underlying C type: <https://flintlib.org/doc/mag.html>

Johansson, F. (2017). Arb: efficient arbitrary-precision midpoint-radius interval arithmetic. *IEEE Transactions on Computers*, *66*(8), 1281-1292. doi:10.1109/TC.2017.2690633

See Also

Virtual class flint.

Examples

```
showClass("mag")
showMethods(classes = "mag")
```

Part   *Get or Set One Part of a Vector*

Description

The subclasses of virtual class flint are interfaces to C types in the FLINT C library. For types implemented recursively as C structs, it is often very natural to get and set the struct members. The functions documented here provide support for this common operation; they are all S4 generic.

Usage

```
Num(q)
Num(q) <- value
Den(q)
Den(q) <- value

Mid(x)
Mid(x) <- value
Rad(x)
Rad(x) <- value

Real(z)
Real(z) <- value
Imag(z)
Imag(z) <- value
```

Arguments

q   a vector-like R object with elements representing quotients of numbers. Package
            flint provides methods for class [fmpq](#).

x   a vector-like R object with elements representing balls in a metric space. Pack-
            age **flint** provides methods for class [arb](#).

z   a vector-like R object with elements representing complex numbers. Package
            flint provides methods for classes [acf](#) and [acb](#).

value   a vector-like R object; the replacement value. Methods in package **flint** support
            atomic vectors and vectors inheriting from virtual class [flint](#). They inherit re-
            cycling behaviour from methods for [initialize](#); see, e.g., [selectMethod](#)(*"Num<-"*,
            "fmpq").

Details

Num and Den extract [fmpz](#) numerators and denominators from [fmpq](#) q. The replacement form of Num
constructs a new fmpq vector from value (coerced to fmpz) and Den(q). The replacement form of
Den constructs a new fmpq vector from Num(q) and value (coerced to fmpz).

Mid and Rad extract [arf](#) midpoints and [mag](#) radii from [arb](#) x. The replacement form of Mid con-
structs a new arb vector from value (coerced to arf) and Rad(x). The replacement form of Rad
constructs a new arb vector from Mid(x) and value (coerced to mag).

Real and Imag extract [arf](#) real and imaginary parts from [acf](#) z and [arb](#) real and imaginary parts
from [acb](#) z. The replacement form of Real constructs a new acf or acb vector from value (coerced
to arf or arb) and Imag(z). The replacement form of Imag constructs a new acf or acb vector
from Real(z) and value (coerced to arf or arb).

Value

Num, Den, Mid, Rad, Real, and Imag return a vector-like R object of length matching the argument.
The replacement forms return a vector-like R object of length matching either the argument or the
replacement value; the class of the result is, if not the class of the argument, then a superclass. See
'Details' for behaviour specific to methods in package **flint**.

See Also

Virtual class `flint`.

Examples

```
(q <- q. <- .fmpq(num = 1:10, den = 2L))
Num(q)
Den(q)
Num(q) <- Den(q)
q
(m <- Num(q))
(n <- Den(q))
stopifnot(m == 1L, n == 1L, q == 1L)
```

---

ulong-class   *Fixed Precision Unsigned and Signed Integers*

Description

Classes `ulong` and `slong` extend virtual class `flint`. They represent vectors of fixed precision unsigned and signed integers, respectively. The integer size is 32 or 64 bits, depending on the ABI; see `flintABI`. There is no representation for R's missing value `NA_integer_`.

Usage

```
## The class generator functions:
.ulong(...)
.slong(...)

## Mode 1: initialize with zeros
## .ulong(length = 0L)
## .slong(length = 0L)
##
## Mode 2: initialize with vector
## .ulong(length = length(x), x)
## .slong(length = length(x), x)
```

Arguments

`...`   arguments passed to methods for `initialize`.

Value

The class generator functions return `new("ulong", ...)` and `new("slong", ...)`.

Slots

`.xData`, `names` inherited from virtual class `flint`.

Methods

! signature(x = "ulong"):
    signature(x = "slong"):
    equivalent to (but faster than) x == 0.

+ signature(e1 = "ulong", e2 = "missing"):
    signature(e1 = "slong", e2 = "missing"):
    returns a copy of the argument.

- signature(e1 = "ulong", e2 = "missing"):
    signature(e1 = "slong", e2 = "missing"):
    returns the negation of the argument.

Complex signature(z = "ulong"):
    signature(z = "slong"):
    mathematical functions of one argument; see S4groupGeneric. Member functions requiring
    promotion to a floating-point type may not be implemented.

Math signature(x = "ulong"):
    signature(x = "slong"):
    mathematical functions of one argument; see S4groupGeneric. Member functions requiring
    promotion to a floating-point type may not be implemented.

Math2 signature(x = "ulong"):
    signature(x = "slong"):
    decimal rounding according to a second argument digits; see S4groupGeneric. There are
    just two member member functions: round, signif.

Ops signature(e1 = "ANY", e2 = "ulong"):
    signature(e1 = "ANY", e2 = "slong"):
    signature(e1 = "ulong", e2 = "ANY"):
    signature(e1 = "slong", e2 = "ANY"):
    binary arithmetic, comparison, and logical operators; see S4groupGeneric. The "other"
    operand must be atomic or inherit from virtual class flint. The operands are recycled and
    promoted as necessary.

Summary signature(x = "ulong"):
    signature(x = "slong"):
    univariate summary statistics; see S4groupGeneric. The return value is a logical vector of
    length 1 (any, all) or a ulong, slong, or fmpz vector of length 1 or 2 (sum, prod, min, max,
    range).

anyNA signature(x = "ulong"):
    signature(x = "slong"):
    returns FALSE, as ulong and slong have no representation for NaN.

as.vector signature(x = "ulong"):
    signature(x = "slong"):
    returns as.vector(y, mode), where y is a double vector containing the result of converting
    each element of x to the range of double, rounding if the value is not exactly representable in
    double precision. The rounding mode is to the nearest representable number in the direction of
    zero. Coercion to types "character", "symbol" (synonym "name"), "pairlist", "list",
    and "expression", which are not "number-like", is handled specially.

coerce signature(from = "ANY", to = "ulong"):
  signature(from = "ANY", to = "slong"):
  returns .ulong(x = from) or .slong(x = from). An error is signaled if the class or type of from is not supported by the methods for `initialize`.

format signature(x = "ulong"):
  signature(x = "slong"):
  returns a character vector suitable for printing. Optional arguments control the output; see `format-methods`.

initialize signature(.Object = "ulong", length = "*numeric*"):
  signature(.Object = "slong", length = "*numeric*"):
  returns .Object after setting its .xData slot. The new slot value is an external pointer to an array of the corresponding C type, which is newly allocated and initialized entirely with zeros. .Object is not copied, so all references are affected.

initialize signature(.Object = "ulong", length = "*numeric*", x = "*atomic|flint*"):
  signature(.Object = "slong", length = "*numeric*", x = "*atomic|flint*"):
  as above, except that the new slot value points to an array initialized with values from x truncated towards zero. An error is signaled if elements of x are not in the range of the C type, in particular if elements are NaN. The range is $(-1, 2^n)$ for ulong and $(-2^{n-1} - 1, 2^{n-1})$ for slong, where n is the value of `flintABI`().

is.finite signature(x = "ulong"):
  signature(x = "slong"):
  returns a logical vector whose elements are all TRUE, as ulong and slong have no representation for NaN, -Inf, and Inf.

is.infinite, is.na, is.nan signature(x = "ulong"):
  signature(x = "slong"):
  returns a logical vector whose elements are all FALSE, as ulong and slong have no representation for NaN, -Inf, and Inf.

is.unsorted signature(x = "ulong"):
  signature(x = "slong"):
  returns a logical indicating if x is not sorted in nondecreasing order (increasing order if optional argument strictly is set to TRUE).

mean signature(x = "ulong"):
  signature(x = "slong"):
  returns the arithmetic mean. An error is signaled if the argument length is 0, because the return type is `fmpq` which cannot represent the result of division by 0.

References

The FLINT documentation of the underlying C types: https://flintlib.org/doc/flint.html

See Also

Virtual class `flint`.

Examples

```
showClass("ulong")
```

```
showClass("slong")
showMethods(classes = c("ulong", "slong"))
```

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