# Package: GenomicRanges (via r-universe)

November 24, 2026

**Title** Representation and manipulation of genomic intervals

**Description** The ability to efficiently represent and manipulate genomic annotations and alignments is playing a central role when it comes to analyzing high-throughput sequencing data (a.k.a. NGS data). The GenomicRanges package defines general purpose containers for storing and manipulating genomic intervals and variables defined along a genome. More specialized containers for representing and manipulating short alignments against a reference genome, or a matrix-like summarization of an experiment, are defined in the GenomicAlignments and SummarizedExperiment packages, respectively. Both packages build on top of the GenomicRanges infrastructure.

**biocViews** Genetics, Infrastructure, DataRepresentation, Sequencing, Annotation, GenomeAnnotation, Coverage

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**BugReports** https://github.com/Bioconductor/GenomicRanges/issues

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**Imports** utils, stats

**Suggests** GenomeInfoDb, Biobase, AnnotationDbi, annotate, Biostrings (>= 2.77.2), SummarizedExperiment (>= 1.39.1), Rsamtools, cigarillo, GenomicAlignments, BSgenome, GenomicFeatures, UCSC.utils, txdbmaker, Gviz, VariantAnnotation, AnnotationHub, DESeq2, DEXSeq, edgeR, KEGGgraph, RNAseqData.HNRNPC.bam.chr14, pasillaBamSubset, KEGGREST, hgu95av2.db, hgu95av2probe, BSgenome.Scerevisiae.UCSC.sacCer2, BSgenome.Hsapiens.UCSC.hg38, BSgenome.Mmusculus.UCSC.mm10, TxDb.Athaliana.BioMart.plantsmart51,

TxDb.Dmelanogaster.UCSC.dm3.ensGene, TxDb.Hsapiens.UCSC.hg38.knownGene, TxDb.Mmusculus.UCSC.mm10.knownGene, RUnit, digest, knitr, rmarkdown, BiocStyle, XVector

**VignetteBuilder** knitr

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`absoluteRanges` *Transform genomic ranges into "absolute" ranges*

---

## Description

`absoluteRanges` transforms the genomic ranges in `x` into *absolute* ranges i.e. into ranges counted from the beginning of the virtual sequence obtained by concatenating all the sequences in the underlying genome (in the order reported by `seqlevels(x)`).

`relativeRanges` performs the reverse transformation.

NOTE: These functions only work on *small* genomes. See Details section below.

## Usage

```
absoluteRanges(x)
relativeRanges(x, seqlengths)

## Related utility:
isSmallGenome(seqlengths)
```

## Arguments

| | |
|---|---|
| `x` | For `absoluteRanges`: a GenomicRanges object with ranges defined on a *small* genome (see Details section below).<br>For `relativeRanges`: an IntegerRanges object. |
| `seqlengths` | An object holding sequence lengths. This can be a named integer (or numeric) vector with no duplicated names as returned by `seqlengths()`, or any object from which sequence lengths can be extracted with `seqlengths()`.<br>For `relativeRanges`, `seqlengths` must describe a *small* genome (see Details section below). |

## Details

Because `absoluteRanges` returns the *absolute* ranges in an IRanges object, and because an IRanges object cannot hold ranges with an end > `.Machine$integer.max` (i.e. >= 2^31 on most platforms), `absoluteRanges` cannot be used if the size of the underlying genome (i.e. the total length of the sequences in it) is > `.Machine$integer.max`. Utility function `isSmallGenome` is provided as a mean for the user to check upfront whether the genome is *small* (i.e. its size is <= `.Machine$integer.max`) or not, and thus compatible with `absoluteRanges` or not.

`relativeRanges` applies the same restriction by looking at the `seqlengths` argument.

## Value

An IRanges object for `absoluteRanges`.

A GRanges object for `relativeRanges`.

`absoluteRanges` and `relativeRanges` both return an object that is *parallel* to the input object (i.e. same length and names).

`isSmallGenome` returns TRUE if the total length of the underlying sequences is <= `.Machine$integer.max` (e.g. Fly genome), FALSE if not (e.g. Human genome), or NA if it cannot be computed (because some sequence lengths are NA).

## Author(s)

H. Pagès

## See Also

- GRanges objects.
- IntegerRanges objects in the **IRanges** package.
- Seqinfo objects and the `seqlengths` getter in the **Seqinfo** package.
- genomicvars for manipulating genomic variables.
- The `tileGenome` function for putting tiles on a genome.

## Examples

```
## ---------------------------------------------------------------------
## TOY EXAMPLE
## ---------------------------------------------------------------------

gr <- GRanges(Rle(c("chr2", "chr1", "chr3", "chr1"), 4:1),
              IRanges(1:10, width=5),
              seqinfo=Seqinfo(c("chr1", "chr2", "chr3"), c(100, 50, 20)))

ar <- absoluteRanges(gr)
ar

gr2 <- relativeRanges(ar, seqlengths(gr))
gr2

## Sanity check:
stopifnot(all(gr == gr2))

## ---------------------------------------------------------------------
## ON REAL DATA
## ---------------------------------------------------------------------

## With a "small" genome

library(TxDb.Dmelanogaster.UCSC.dm3.ensGene)
txdb <- TxDb.Dmelanogaster.UCSC.dm3.ensGene
ex <- exons(txdb)
```

```
ex

isSmallGenome(ex)

## Note that because isSmallGenome() can return NA (see Value section
## above), its result should always be wrapped inside isTRUE() when
## used in an if statement:
if (isTRUE(isSmallGenome(ex))) {
    ar <- absoluteRanges(ex)
    ar

    ex2 <- relativeRanges(ar, seqlengths(ex))
    ex2  # original strand is not restored

    ## Sanity check:
    strand(ex2) <- strand(ex)  # restore the strand
    stopifnot(all(ex == ex2))
}

## With a "big" genome (but we can reduce it)

library(TxDb.Hsapiens.UCSC.hg38.knownGene)
txdb <- TxDb.Hsapiens.UCSC.hg38.knownGene
ex <- exons(txdb)
isSmallGenome(ex)
## Not run:
    absoluteRanges(ex)  # error!

## End(Not run)

## However, if we are only interested in some chromosomes, we might
## still be able to use absoluteRanges():
seqlevels(ex, pruning.mode="coarse") <- paste0("chr", 1:10)
isSmallGenome(ex)  # TRUE!
ar <- absoluteRanges(ex)
ex2 <- relativeRanges(ar, seqlengths(ex))

## Sanity check:
strand(ex2) <- strand(ex)
stopifnot(all(ex == ex2))
```

---

`Constraints` *Enforcing constraints thru Constraint objects*

---

## Description

Attaching a Constraint object to an object of class A (the "constrained" object) is meant to be a convenient/reusable/extensible way to enforce a particular set of constraints on particular instances of A.

THIS IS AN EXPERIMENTAL FEATURE AND STILL VERY MUCH A WORK-IN-PROGRESS!

## Details

For the developer, using constraints is an alternative to the more traditional approach that consists in creating subclasses of A and implementing specific validity methods for each of them. However, using constraints offers the following advantages over the traditional approach:

- The traditional approach often tends to lead to a proliferation of subclasses of A.
- Constraints can easily be re-used across different classes without the need to create any new class.
- Constraints can easily be combined.

All constraints are implemented as concrete subclasses of the Constraint class, which is a virtual class with no slots. Like the Constraint virtual class itself, concrete Constraint subclasses cannot have slots.

Here are the 7 steps typically involved in the process of putting constraints on objects of class A:

1. Add a slot named `constraint` to the definition of class A. The type of this slot must be Constraint_OR_NULL. Note that any subclass of A will inherit this slot.
2. Implements the `constraint()` accessors (getter and setter) for objects of class A. This is done by implementing the `"constraint"` method (getter) and replacement method (setter) for objects of class A (see the examples below). As a convenience to the user, the setter should also accept the name of a constraint (i.e. the name of its class) in addition to an instance of that class. Note that those accessors will work on instances of any subclass of A.
3. Modify the validity method for class A so it also returns the result of `checkConstraint(x, constraint(x))` (append this result to the result returned by the validity method).
4. Testing: Create `x`, an instance of class A (or subclass of A). By default there is no constraint on it (`constraint(x)` is `NULL`). `validObject(x)` should return `TRUE`.
5. Create a new constraint (MyConstraint) by extending the Constraint class, typically with `setClass("MyConstraint", contains="Constraint")`. This constraint is not enforcing anything yet so you could put it on `x` (with `constraint(x) <- "MyConstraint"`), but not much would happen. In order to actually enforce something, a `"checkConstraint"` method for signature `c(x="A", constraint="MyConstraint")` needs to be implemented.
6. Implement a `"checkConstraint"` method for signature `c(x="A", constraint="MyConstraint")`. Like validity methods, `"checkConstraint"` methods must return `NULL` or a character vector describing the problems found. Like validity methods, they should never fail (i.e. they should never raise an error). Note that, alternatively, an existing constraint (e.g. SomeConstraint) can be adapted to work on objects of class A by just defining a new `"checkConstraint"` method for signature `c(x="A", constraint="SomeConstraint")`. Also, stricter constraints can be built on top of existing constraints by extending one or more existing constraints (see the examples below).
7. Testing: Try `constraint(x) <- "MyConstraint"`. It will or will not work depending on whether `x` satisfies the constraint or not. In the former case, trying to modify `x` in a way that breaks the constraint on it will also raise an error.

## Note

WARNING: This note is not true anymore as the `constraint` slot has been temporarily removed from GenomicRanges objects (starting with package GenomicRanges >= 1.7.9).

Currently, only GenomicRanges objects can be constrained, that is:

- they have a `constraint` slot;
- they have `constraint()` accessors (getter and setter) for this slot;
- their validity method has been modified so it also returns the result of `checkConstraint(x, constraint(x))`.

More classes in the GenomicRanges and IRanges packages will support constraints in the near future.

## Author(s)

H. Pagès

## See Also

`setClass`, `is`, `setMethod`, `showMethods`, `validObject`, GenomicRanges-class

## Examples

```
## The examples below show how to define and set constraints on
## GenomicRanges objects. Note that this is how the constraint()
## setter is defined for GenomicRanges objects:
#setReplaceMethod("constraint", "GenomicRanges",
#    function(x, value)
#    {
#        if (isSingleString(value))
#            value <- new(value)
#        if (!is(value, "Constraint_OR_NULL"))
#            stop("the supplied 'constraint' must be a ",
#                 "Constraint object, a single string, or NULL")
#        x@constraint <- value
#        validObject(x)
#        x
#    }
#)

#selectMethod("constraint", "GenomicRanges")  # the getter
#selectMethod("constraint<-", "GenomicRanges")  # the setter

## We'll use the GRanges instance 'gr' created in the GRanges examples
## to test our constraints:
example(GRanges, echo=FALSE)
gr
#constraint(gr)

## ---------------------------------------------------------------------
## EXAMPLE 1: The HasRangeTypeCol constraint.
## ---------------------------------------------------------------------
## The HasRangeTypeCol constraint checks that the constrained object
## has a unique "rangeType" metadata column and that this column
## is a 'factor' Rle with no NAs and with the following levels
```

```
## (in this order): gene, transcript, exon, cds, 5utr, 3utr.

setClass("HasRangeTypeCol", contains="Constraint")

## Like validity methods, "checkConstraint" methods must return NULL or
## a character vector describing the problems found. They should never
## fail i.e. they should never raise an error.
setMethod("checkConstraint", c("GenomicRanges", "HasRangeTypeCol"),
    function(x, constraint, verbose=FALSE)
    {
        x_mcols <- mcols(x)
        idx <- match("rangeType", colnames(x_mcols))
        if (length(idx) != 1L || is.na(idx)) {
            msg <- c("'mcols(x)' must have exactly 1 column ",
                     "named \"rangeType\"")
            return(paste(msg, collapse=""))
        }
        rangeType <- x_mcols[[idx]]
        .LEVELS <- c("gene", "transcript", "exon", "cds", "5utr", "3utr")
        if (!is(rangeType, "Rle") ||
            anyNA(runValue(rangeType)) ||
            !identical(levels(rangeType), .LEVELS))
        {
            msg <- c("'mcols(x)$rangeType' must be a ",
                     "'factor' Rle with no NAs and with levels: ",
                     paste(.LEVELS, collapse=", "))
            return(paste(msg, collapse=""))
        }
        NULL
    }
)

#\dontrun{
#constraint(gr) <- "HasRangeTypeCol"  # will fail
#}
checkConstraint(gr, new("HasRangeTypeCol"))  # with GenomicRanges >= 1.7.9

levels <- c("gene", "transcript", "exon", "cds", "5utr", "3utr")
rangeType <- Rle(factor(c("cds", "gene"), levels=levels), c(8, 2))
mcols(gr)$rangeType <- rangeType
#constraint(gr) <- "HasRangeTypeCol"  # OK
checkConstraint(gr, new("HasRangeTypeCol"))  # with GenomicRanges >= 1.7.9

## Use is() to check whether the object has a given constraint or not:
#is(constraint(gr), "HasRangeTypeCol")  # TRUE
#\dontrun{
#mcols(gr)$rangeType[3] <- NA  # will fail
#}
mcols(gr)$rangeType[3] <- NA
checkConstraint(gr, new("HasRangeTypeCol"))  # with GenomicRanges >= 1.7.9

## ---------------------------------------------------------------------
## EXAMPLE 2: The GeneRanges constraint.
```

```
## ---------------------------------------------------------------------
## The GeneRanges constraint is defined on top of the HasRangeTypeCol
## constraint. It checks that all the ranges in the object are of type
## "gene".

setClass("GeneRanges", contains="HasRangeTypeCol")

## The checkConstraint() generic will check the HasRangeTypeCol constraint
## first, and, only if it's statisfied, it will then check the GeneRanges
## constraint.
setMethod("checkConstraint", c("GenomicRanges", "GeneRanges"),
    function(x, constraint, verbose=FALSE)
    {
        rangeType <- mcols(x)$rangeType
        if (!all(rangeType == "gene")) {
            msg <- c("all elements in 'mcols(x)$rangeType' ",
                     "must be equal to \"gene\"")
            return(paste(msg, collapse=""))
        }
        NULL
    }
)

#\dontrun{
#constraint(gr) <- "GeneRanges"  # will fail
#}
checkConstraint(gr, new("GeneRanges"))  # with GenomicRanges >= 1.7.9

mcols(gr)$rangeType[] <- "gene"
## This replace the previous constraint (HasRangeTypeCol):
#constraint(gr) <- "GeneRanges"  # OK
checkConstraint(gr, new("GeneRanges"))  # with GenomicRanges >= 1.7.9

#is(constraint(gr), "GeneRanges")  # TRUE
## However, 'gr' still indirectly has the HasRangeTypeCol constraint
## (because the GeneRanges constraint extends the HasRangeTypeCol
## constraint):
#is(constraint(gr), "HasRangeTypeCol")  # TRUE
#\dontrun{
#mcols(gr)$rangeType[] <- "exon"  # will fail
#}
mcols(gr)$rangeType[] <- "exon"
checkConstraint(gr, new("GeneRanges"))  # with GenomicRanges >= 1.7.9

## ---------------------------------------------------------------------
## EXAMPLE 3: The HasGCCol constraint.
## ---------------------------------------------------------------------
## The HasGCCol constraint checks that the constrained object has a
## unique "GC" metadata column, that this column is of type numeric,
## with no NAs, and that all the values in that column are >= 0 and <= 1.

setClass("HasGCCol", contains="Constraint")
```

```
setMethod("checkConstraint", c("GenomicRanges", "HasGCCol"),
    function(x, constraint, verbose=FALSE)
    {
        x_mcols <- mcols(x)
        idx <- match("GC", colnames(x_mcols))
        if (length(idx) != 1L || is.na(idx)) {
            msg <- c("'mcols(x)' must have exactly ",
                     "one column named \"GC\"")
            return(paste(msg, collapse=""))
        }
        GC <- x_mcols[[idx]]
        if (!is.numeric(GC) || anyNA(GC) || any(GC < 0) || any(GC > 1)) {
            msg <- c("'mcols(x)$GC' must be a numeric vector ",
                     "with no NAs and with values between 0 and 1")
            return(paste(msg, collapse=""))
        }
        NULL
    }
)

## This replace the previous constraint (GeneRanges):
#constraint(gr) <- "HasGCCol"  # OK
checkConstraint(gr, new("HasGCCol"))  # with GenomicRanges >= 1.7.9

#is(constraint(gr), "HasGCCol")  # TRUE
#is(constraint(gr), "GeneRanges")  # FALSE
#is(constraint(gr), "HasRangeTypeCol")  # FALSE

## ---------------------------------------------------------------------
## EXAMPLE 4: The HighGCRanges constraint.
## ---------------------------------------------------------------------
## The HighGCRanges constraint is defined on top of the HasGCCol
## constraint. It checks that all the ranges in the object have a GC
## content >= 0.5.

setClass("HighGCRanges", contains="HasGCCol")

## The checkConstraint() generic will check the HasGCCol constraint
## first, and, if it's satisfied, it will then check the HighGCRanges
## constraint.
setMethod("checkConstraint", c("GenomicRanges", "HighGCRanges"),
    function(x, constraint, verbose=FALSE)
    {
        GC <- mcols(x)$GC
        if (!all(GC >= 0.5)) {
            msg <- c("all elements in 'mcols(x)$GC' ",
                     "must be >= 0.5")
            return(paste(msg, collapse=""))
        }
        NULL
    }
)
```

```
#\dontrun{
#constraint(gr) <- "HighGCRanges"  # will fail
#}
checkConstraint(gr, new("HighGCRanges"))  # with GenomicRanges >= 1.7.9
mcols(gr)$GC[6:10] <- 0.5
#constraint(gr) <- "HighGCRanges"  # OK
checkConstraint(gr, new("HighGCRanges"))  # with GenomicRanges >= 1.7.9

#is(constraint(gr), "HighGCRanges")  # TRUE
#is(constraint(gr), "HasGCCol")  # TRUE

## ---------------------------------------------------------------------
## EXAMPLE 5: The HighGCGeneRanges constraint.
## ---------------------------------------------------------------------
## The HighGCGeneRanges constraint is the combination (AND) of the
## GeneRanges and HighGCRanges constraints.

setClass("HighGCGeneRanges", contains=c("GeneRanges", "HighGCRanges"))

## No need to define a method for this constraint: the checkConstraint()
## generic will automatically check the GeneRanges and HighGCRanges
## constraints.

#constraint(gr) <- "HighGCGeneRanges"  # OK
checkConstraint(gr, new("HighGCGeneRanges"))  # with GenomicRanges >= 1.7.9

#is(constraint(gr), "HighGCGeneRanges")  # TRUE
#is(constraint(gr), "HighGCRanges")  # TRUE
#is(constraint(gr), "HasGCCol")  # TRUE
#is(constraint(gr), "GeneRanges")  # TRUE
#is(constraint(gr), "HasRangeTypeCol")  # TRUE

## See how all the individual constraints are checked (from less
## specific to more specific constraints):
#checkConstraint(gr, constraint(gr), verbose=TRUE)
checkConstraint(gr, new("HighGCGeneRanges"), verbose=TRUE)  # with
                                                            # GenomicRanges
                                                            # >= 1.7.9

## See all the "checkConstraint" methods:
showMethods("checkConstraint")
```

---

coverage-methods *Coverage of a GRanges or GRangesList object*

---

## Description

coverage methods for GRanges and GRangesList objects.

NOTE: The coverage generic function and methods for IntegerRanges and IntegerRangesList objects are defined and documented in the **IRanges** package. Methods for GAlignments and GAlignmentPairs objects are defined and documented in the **GenomicAlignments** package.

## Usage

```
## S4 method for signature 'GenomicRanges'
coverage(x, shift=0L, width=NULL, weight=1L,
            method=c("auto", "sort", "hash", "naive"))

## S4 method for signature 'GRangesList'
coverage(x, shift=0L, width=NULL, weight=1L,
            method=c("auto", "sort", "hash", "naive"))
```

## Arguments

| | |
|---|---|
| x | A GenomicRanges or GRangesList object. |
| shift, weight | A numeric vector or a list-like object. If numeric, it must be parallel to x (recycled if necessary). If a list-like object, it must have 1 list element per seqlevel in x, and its names must be exactly seqlevels(x).<br>Alternatively, each of these arguments can also be specified as a single string naming a metadata column in x (i.e. a column in mcols(x)) to be used as the shift (or weight) vector.<br>See ?coverage in the **IRanges** package for more information about these arguments.<br>Note that when x is a StitchedGPos object, each of these arguments can only be a single number or a named list-like object. |
| width | Either NULL (the default), or an integer vector. If NULL, it is replaced with seqlengths(x). Otherwise, the vector must have the length and names of seqlengths(x) and contain NAs or non-negative integers.<br>See ?coverage in the **IRanges** package for more information about this argument. |
| method | See ?coverage in the **IRanges** package for a description of this argument. |

## Details

When x is a GRangesList object, coverage(x, ...) is equivalent to coverage(unlist(x), ...).

## Value

A named RleList object with one coverage vector per seqlevel in x.

## Author(s)

H. Pagès and P. Aboyoun

## See Also

- coverage in the **IRanges** package.
- coverage-methods in the **GenomicAlignments** package.
- RleList objects in the **IRanges** package.
- GRanges, GPos, and GRangesList objects.

## Examples

```
## Coverage of a GRanges object:
gr <- GRanges(
        seqnames=Rle(c("chr1", "chr2", "chr1", "chr3"), c(1, 3, 2, 4)),
        ranges=IRanges(1:10, end=10),
        strand=Rle(strand(c("-", "+", "*", "+", "-")), c(1, 2, 2, 3, 2)),
        seqlengths=c(chr1=11, chr2=12, chr3=13))
cvg <- coverage(gr)
pcvg <- coverage(gr[strand(gr) == "+"])
mcvg <- coverage(gr[strand(gr) == "-"])
scvg <- coverage(gr[strand(gr) == "*"])
stopifnot(identical(pcvg + mcvg + scvg, cvg))

## Coverage of a GPos object:
pos_runs <- GRanges(c("chr1", "chr1", "chr2"),
                    IRanges(c(1, 5, 9), c(10, 8, 15)))
gpos <- GPos(pos_runs)
coverage(gpos)

## Coverage of a GRangesList object:
gr1 <- GRanges(seqnames="chr2",
               ranges=IRanges(3, 6),
               strand = "+")
gr2 <- GRanges(seqnames=c("chr1", "chr1"),
               ranges=IRanges(c(7,13), width=3),
               strand=c("+", "-"))
gr3 <- GRanges(seqnames=c("chr1", "chr2"),
               ranges=IRanges(c(1, 4), c(3, 9)),
               strand=c("-", "-"))
grl <- GRangesList(gr1=gr1, gr2=gr2, gr3=gr3)
stopifnot(identical(coverage(grl), coverage(unlist(grl))))
```

---

`DelegatingGenomicRanges-class`
*DelegatingGenomicRanges objects*

---

## Description

The `DelegatingGenomicRanges` class implements the virtual `GenomicRanges` class using a delegate `GenomicRanges`. This enables developers to create `GenomicRanges` subclasses that add specialized columns or other structure, while remaining agnostic to how the data are actually stored. See the Extending GenomicRanges vignette.

## Author(s)

M. Lawrence

findOverlaps-methods *Finding overlapping genomic ranges*

## Description

Various methods for finding/counting overlaps between objects containing genomic ranges. This man page describes the methods that operate on GenomicRanges and GRangesList objects.

NOTE: The findOverlaps generic function and methods for IntegerRanges and IntegerRangesList objects are defined and documented in the **IRanges** package. The methods for GAlignments, GAlignmentPairs, and GAlignmentsList objects are defined and documented in the **GenomicAlignments** package.

GenomicRanges and GRangesList objects also support countOverlaps, overlapsAny, and subsetByOverlaps thanks to the default methods defined in the **IRanges** package and to the findOverlaps and countOverlaps methods defined in this package and documented below.

## Usage

```
## S4 method for signature 'GenomicRanges,GenomicRanges'
findOverlaps(query, subject,
    maxgap=-1L, minoverlap=0L,
    type=c("any", "start", "end", "within", "equal"),
    select=c("all", "first", "last", "arbitrary"),
    ignore.strand=FALSE)

## S4 method for signature 'GRangesList,GenomicRanges'
findOverlaps(query, subject,
    maxgap=-1L, minoverlap=0L,
    type=c("any", "start", "end", "within", "equal"),
    select=c("all", "first", "last", "arbitrary"),
    ignore.strand=FALSE)

## S4 method for signature 'GenomicRanges,GRangesList'
findOverlaps(query, subject,
    maxgap=-1L, minoverlap=0L,
    type=c("any", "start", "end", "within", "equal"),
    select=c("all", "first", "last", "arbitrary"),
    ignore.strand=FALSE)

## S4 method for signature 'GRangesList,GRangesList'
findOverlaps(query, subject,
    maxgap=-1L, minoverlap=0L,
    type=c("any", "start", "end", "within", "equal"),
    select=c("all", "first", "last", "arbitrary"),
    ignore.strand=FALSE)

## S4 method for signature 'GenomicRanges,GenomicRanges'
```

```
countOverlaps(query, subject,
    maxgap=-1L, minoverlap=0L,
    type=c("any", "start", "end", "within", "equal"),
    ignore.strand=FALSE)
```

## Arguments

| | |
|---|---|
| query, subject | A GRanges or GRangesList object. |
| maxgap, minoverlap, type | See ?findOverlaps in the **IRanges** package for a description of these arguments.<br>IMPORTANT NOTE about how minoverlap is interpreted when query or subject is a GRangesList object: In this case, *the total number of overlapping positions* between a given element in query and a given element in subject is taken into account. For example, if query is a GRanges object, and subject a GRangesList object, then findOverlaps() will report an overlap between query[i] (a single range) and subject[[j]] (multiple ranges) only if the total number of positions in subject[[j]] that overlap with query[i] is equal to minoverlap or greater. In other words, the full overlap across all the ranges in subject[[j]] is looked at. See the Examples section below for an example illustrating this. |
| select | When select is "all" (the default), the results are returned as a Hits object. Otherwise the returned value is an integer vector parallel to query (i.e. same length) containing the first, last, or arbitrary overlapping interval in subject, with NA indicating intervals that did not overlap any intervals in subject. |
| ignore.strand | When set to TRUE, the strand information is ignored in the overlap calculations. |

## Details

When the query and the subject are GRanges or GRangesList objects, findOverlaps uses the triplet (sequence name, range, strand) to determine which features (see paragraph below for the definition of feature) from the query overlap which features in the subject, where a strand value of "*" is treated as occurring on both the "+" and "-" strand. An overlap is recorded when a feature in the query and a feature in the subject have the same sequence name, have a compatible pairing of strands (e.g. "+"/"+", "-"/"-", "*"/"+", "*"/"-", etc.), and satisfy the interval overlap requirements.

In the context of findOverlaps, a feature is a collection of ranges that are treated as a single entity. For GRanges objects, a feature is a single range; while for GRangesList objects, a feature is a list element containing a set of ranges. In the results, the features are referred to by number, which run from 1 to length(query)/length(subject).

For type="equal" with GRangesList objects, query[[i]] matches subject[[j]] iff for each range in query[[i]] there is an identical range in subject[[j]], and vice versa.

## Value

For findOverlaps: either a Hits object when select="all" or an integer vector otherwise.

For countOverlaps: an integer vector containing the tabulated query overlap hits.

## Author(s)

P. Aboyoun, S. Falcon, M. Lawrence, and H. Pagès

## See Also

- The Hits class in the **S4Vectors** package for representing a set of hits between 2 vector-like objects.
- The `findOverlaps` generic function defined in the **IRanges** package.
- The GNCList constructor and class for preprocessing and representing a GenomicRanges or object as a data structure based on Nested Containment Lists.
- The GRanges and GRangesList classes.

## Examples

```
## ---------------------------------------------------------------------
## BASIC EXAMPLES
## ---------------------------------------------------------------------

## GRanges object:
gr <- GRanges(
        seqnames=Rle(c("chr1", "chr2", "chr1", "chr3"), c(1, 3, 2, 4)),
        ranges=IRanges(1:10, width=10:1, names=head(letters,10)),
        strand=Rle(strand(c("-", "+", "*", "+", "-")), c(1, 2, 2, 3, 2)),
        score=1:10,
        GC=seq(1, 0, length=10)
      )
gr

## GRangesList object:
gr1 <- GRanges(seqnames="chr2", ranges=IRanges(4:3, 6),
               strand="+", score=5:4, GC=0.45)
gr2 <- GRanges(seqnames=c("chr1", "chr1"),
               ranges=IRanges(c(7,13), width=3),
               strand=c("+", "-"), score=3:4, GC=c(0.3, 0.5))
gr3 <- GRanges(seqnames=c("chr1", "chr2"),
               ranges=IRanges(c(1, 4), c(3, 9)),
               strand=c("-", "-"), score=c(6L, 2L), GC=c(0.4, 0.1))
grl <- GRangesList("gr1"=gr1, "gr2"=gr2, "gr3"=gr3)

## Overlapping two GRanges objects:
table(!is.na(findOverlaps(gr, gr1, select="arbitrary")))
countOverlaps(gr, gr1)
findOverlaps(gr, gr1)
subsetByOverlaps(gr, gr1)

countOverlaps(gr, gr1, type="start")
findOverlaps(gr, gr1, type="start")
subsetByOverlaps(gr, gr1, type="start")

findOverlaps(gr, gr1, select="first")
findOverlaps(gr, gr1, select="last")
```

```
findOverlaps(gr1, gr)
findOverlaps(gr1, gr, type="start")
findOverlaps(gr1, gr, type="within")
findOverlaps(gr1, gr, type="equal")

## ---------------------------------------------------------------------
## MORE EXAMPLES
## ---------------------------------------------------------------------

table(!is.na(findOverlaps(gr, gr1, select="arbitrary")))
countOverlaps(gr, gr1)
findOverlaps(gr, gr1)
subsetByOverlaps(gr, gr1)

## Overlaps between a GRanges and a GRangesList object:

table(!is.na(findOverlaps(grl, gr, select="first")))
countOverlaps(grl, gr)
findOverlaps(grl, gr)
subsetByOverlaps(grl, gr)
countOverlaps(grl, gr, type="start")
findOverlaps(grl, gr, type="start")
subsetByOverlaps(grl, gr, type="start")
findOverlaps(grl, gr, select="first")

table(!is.na(findOverlaps(grl, gr1, select="first")))
countOverlaps(grl, gr1)
findOverlaps(grl, gr1)
subsetByOverlaps(grl, gr1)
countOverlaps(grl, gr1, type="start")
findOverlaps(grl, gr1, type="start")
subsetByOverlaps(grl, gr1, type="start")
findOverlaps(grl, gr1, select="first")

## Overlaps between two GRangesList objects:
countOverlaps(grl, rev(grl))
findOverlaps(grl, rev(grl))
subsetByOverlaps(grl, rev(grl))

## ---------------------------------------------------------------------
## INTERPRETATION OF 'minoverlap' WHEN 'query' OR 'subject' IS A
## GRangesList OBJECT
## ---------------------------------------------------------------------
gr1 <- GRanges("chr5:1-26")
gr2 <- GRanges("chr5:31-40")
gr3 <- c(GRanges("chr5:11-20"), gr2)
grl123 <- GRangesList(gr1, gr2, gr3)
grl123

query <- GRanges("chr5:17-35")

findOverlaps(query, grl123[[1]], minoverlap=8)  # 1 hit
```

```
findOverlaps(query, grl123[[2]], minoverlap=8)  # no hit
findOverlaps(query, grl123[[3]], minoverlap=8)  # no hit

## Using GRangesList object 'grl123' as the subject:
findOverlaps(query, grl123, minoverlap=8)

## As we can see, a hit is reported with the 3rd element in the subject.
## That's because the total number of positions in this overlap is 9:
## - positions 17 to 20 in the first range of grl123[[3]], so 4 positions
## - positions 31 to 35 in its second range, so 5 positions

## Sanity checks:
hits <- findOverlaps(query, grl123[[1]], minoverlap=8)
stopifnot(length(hits) == 1)
hits <- findOverlaps(query, grl123[[2]], minoverlap=8)
stopifnot(length(hits) == 0)
hits <- findOverlaps(query, grl123[[3]], minoverlap=8)
stopifnot(length(hits) == 0)
hits <- findOverlaps(query, grl123, minoverlap=8)
stopifnot(identical(subjectHits(hits), c(1L, 3L)))
hits <- findOverlaps(query, grl123, minoverlap=9)
stopifnot(identical(subjectHits(hits), c(1L, 3L)))
hits <- findOverlaps(query, grl123, minoverlap=10)
stopifnot(identical(subjectHits(hits), 1L))
hits <- findOverlaps(query, grl123, minoverlap=11)
stopifnot(length(hits) == 0)
```

---

`genomic-range-squeezers` *Squeeze the genomic ranges out of a range-based object*

---

## Description

S4 generic functions for squeezing the genomic ranges out of a range-based object.

These are analog to range squeezers `ranges` and `rglist` defined in the **IRanges** package, except that `granges` returns the ranges in a GRanges object (instead of an IRanges object for `ranges`), and `grglist` returns them in a GRangesList object (instead of an IRangesList object for `rglist`).

## Usage

```
granges(x, use.names=TRUE, use.mcols=FALSE, ...)
grglist(x, use.names=TRUE, use.mcols=FALSE, ...)
```

## Arguments

| | |
|---|---|
| `x` | An object containing genomic ranges e.g. a GenomicRanges, RangedSummarizedExperiment, GAlignments, GAlignmentPairs, or GAlignmentsList object, or a Pairs object containing genomic ranges. |
| `use.names`, `use.mcols`, `...` | See `ranges` in the **IRanges** package for a description of these arguments. |

### Details

See ranges in the **IRanges** package for some details.

For some objects (e.g. GAlignments and GAlignmentPairs objects defined in the **GenomicAlignments** package), `as(x, "GRanges")` and `as(x, "GRangesList")`, are equivalent to `granges(x, use.names=TRUE, use.mcols=TRUE)` and `grglist(x, use.names=TRUE, use.mcols=TRUE)`, respectively.

### Value

A GRanges object for `granges`.

A GRangesList object for `grglist`.

If `x` is a vector-like object (e.g. GAlignments), the returned object is expected to be *parallel* to `x`, that is, the i-th element in the output corresponds to the i-th element in the input.

If `use.names` is TRUE, then the names on `x` (if any) are propagated to the returned object. If `use.mcols` is TRUE, then the metadata columns on `x` (if any) are propagated to the returned object.

### Author(s)

H. Pagès

### See Also

- GRanges and GRangesList objects.
- RangedSummarizedExperiment objects in the **SummarizedExperiment** packages.
- GAlignments, GAlignmentPairs, and GAlignmentsList objects in the **GenomicAlignments** package.

### Examples

```
## See ?GAlignments in the GenomicAlignments package for examples of
## "ranges" and "rglist" methods.
```

---

## GenomicRanges-comparison

*Comparing and ordering genomic ranges*

---

### Description

Methods for comparing and/or ordering GenomicRanges objects.

## Usage

```
## duplicated()
## ------------

## S4 method for signature 'GenomicRanges'
duplicated(x, incomparables=FALSE, fromLast=FALSE,
           nmax=NA, method=c("auto", "quick", "hash"))

## match() & selfmatch()
## ---------------------

## S4 method for signature 'GenomicRanges,GenomicRanges'
match(x, table, nomatch=NA_integer_, incomparables=NULL,
      method=c("auto", "quick", "hash"), ignore.strand=FALSE)

## S4 method for signature 'GenomicRanges'
selfmatch(x, method=c("auto", "quick", "hash"), ignore.strand=FALSE)

## order() and related methods
## ---------------------------

## S4 method for signature 'GenomicRanges'
is.unsorted(x, na.rm=FALSE, strictly=FALSE, ignore.strand=FALSE)

## S4 method for signature 'GenomicRanges'
order(..., na.last=TRUE, decreasing=FALSE,
           method=c("auto", "shell", "radix"))

## S4 method for signature 'GenomicRanges'
sort(x, decreasing=FALSE, ignore.strand=FALSE, by)

## S4 method for signature 'GenomicRanges'
rank(x, na.last=TRUE,
     ties.method=c("average", "first", "last", "random", "max", "min"),
     ignore.strand=FALSE)

## Generalized parallel comparison of 2 GenomicRanges objects
## ----------------------------------------------------------

## S4 method for signature 'GenomicRanges,GenomicRanges'
pcompare(x, y)
```

## Arguments

| | |
|---|---|
| x, table, y | GenomicRanges objects. |
| incomparables | Not supported. |
| fromLast, method, nomatch, nmax, na.rm, strictly, na.last, decreasing | See ?`IPosRanges-comparison` in the **IRanges** package for a description of |

| | |
|---|---|
| | these arguments. |
| ignore.strand | Whether or not the strand should be ignored when comparing 2 genomic ranges. |
| ... | One or more GenomicRanges objects. The GenomicRanges objects after the first one are used to break ties. |
| ties.method | A character string specifying how ties are treated. Only "first" is supported for now. |
| by | An optional formula that is resolved against as.env(x); the resulting variables are passed to order to generate the ordering permutation. |

## Details

Two elements of a GenomicRanges derivative (i.e. two genomic ranges) are considered equal iff they are on the same underlying sequence and strand, and share the same start and width. duplicated() and unique() on a GenomicRanges derivative are conforming to this.

The "natural order" for the elements of a GenomicRanges derivative is to order them (a) first by sequence level, (b) then by strand, (c) then by start, (d) and finally by width. This way, the space of genomic ranges is totally ordered. Note that, because we already do (c) and (d) for regular ranges (see ?`IPosRanges-comparison`), genomic ranges that belong to the same underlying sequence and strand are ordered like regular ranges.

pcompare(), ==, !=, <=, >=, < and > on GenomicRanges derivatives behave accordingly to this "natural order".

is.unsorted(), order(), sort(), rank() on GenomicRanges derivatives also behave accordingly to this "natural order".

Finally, note that some *inter range transformations* like reduce or disjoin also use this "natural order" implicitly when operating on GenomicRanges derivatives.

## Author(s)

H. Pagès, is.unsorted contributed by Pete Hickey

## See Also

- The GenomicRanges class.
- IPosRanges-comparison in the **IRanges** package for comparing and ordering genomic ranges.
- findOverlaps-methods for finding overlapping genomic ranges.
- intra-range-methods and inter-range-methods for intra range and inter range transformations of a GRanges object.
- setops-methods for set operations on GenomicRanges objects.

## Examples

```
gr0 <- GRanges(
    Rle(c("chr1", "chr2", "chr1", "chr3"), c(1, 3, 2, 4)),
    IRanges(c(1:9,7L), end=10),
    strand=Rle(strand(c("-", "+", "*", "+", "-")), c(1, 2, 2, 3, 2)),
    seqlengths=c(chr1=11, chr2=12, chr3=13)
```

```
)
gr <- c(gr0, gr0[7:3])
names(gr) <- LETTERS[seq_along(gr)]

## ---------------------------------------------------------------------
## A. ELEMENT-WISE (AKA "PARALLEL") COMPARISON OF 2 GenomicRanges OBJECTS
## ---------------------------------------------------------------------
gr[2] == gr[2]  # TRUE
gr[2] == gr[5]  # FALSE
gr == gr[4]
gr >= gr[3]

## ---------------------------------------------------------------------
## B. match(), selfmatch(), %in%, duplicated(), unique()
## ---------------------------------------------------------------------
table <- gr[1:7]
match(gr, table)
match(gr, table, ignore.strand=TRUE)

gr %in% table

duplicated(gr)
unique(gr)

## ---------------------------------------------------------------------
## C. findMatches(), countMatches()
## ---------------------------------------------------------------------
findMatches(gr, table)
countMatches(gr, table)

findMatches(gr, table, ignore.strand=TRUE)
countMatches(gr, table, ignore.strand=TRUE)

gr_levels <- unique(gr)
countMatches(gr_levels, gr)

## ---------------------------------------------------------------------
## D. order() AND RELATED METHODS
## ---------------------------------------------------------------------
is.unsorted(gr)
order(gr)
sort(gr)
is.unsorted(sort(gr))

is.unsorted(gr, ignore.strand=TRUE)
gr2 <- sort(gr, ignore.strand=TRUE)
is.unsorted(gr2)  # TRUE
is.unsorted(gr2, ignore.strand=TRUE)  # FALSE

## TODO: Broken. Please fix!
#sort(gr, by = ~ seqnames + start + end) # equivalent to (but slower than) above

score(gr) <- rev(seq_len(length(gr)))
```

```
## TODO: Broken. Please fix!
#sort(gr, by = ~ score)

rank(gr, ties.method="first")
rank(gr, ties.method="first", ignore.strand=TRUE)

## ---------------------------------------------------------------------
## E. GENERALIZED ELEMENT-WISE COMPARISON OF 2 GenomicRanges OBJECTS
## ---------------------------------------------------------------------
gr3 <- GRanges(c(rep("chr1", 12), "chr2"), IRanges(c(1:11, 6:7), width=3))
strand(gr3)[12] <- "+"
gr4 <- GRanges("chr1", IRanges(5, 9))

pcompare(gr3, gr4)
rangeComparisonCodeToLetter(pcompare(gr3, gr4))
```

---

GenomicRangesList-class *GenomicRangesList objects*

---

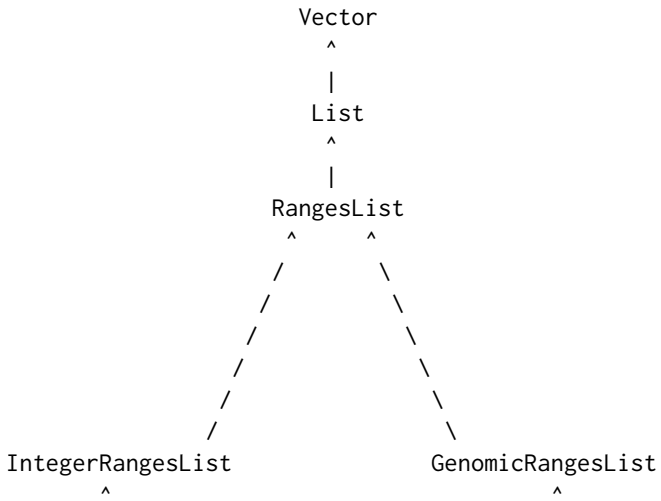
## Description

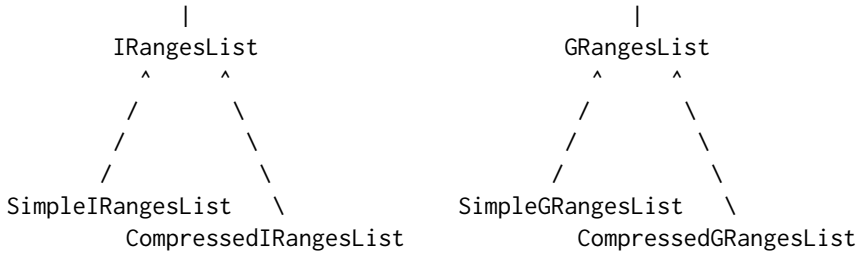
The GenomicRangesList *virtual* class is a general container for storing a list of GenomicRanges objects.

Most users are probably more interested in the GRangesList container, a GenomicRangesList derivative for storing a list of GRanges objects.

## Details

The place of GenomicRangesList in the *Vector class hierarchy*:






Note that the *Vector class hierarchy* has many more classes. In particular Vector, List, IRangesList, and IntegerRangesList have other subclasses not shown here.

## Author(s)

H. Pagès and M. Lawrence

## See Also

- GRangesList objects.
- GenomicRanges and GRanges objects.

---

`genomicvars` *Manipulating genomic variables*

---

## Description

A *genomic variable* is a variable defined along a genome. Here are 2 ways a genomic variable is generally represented in Bioconductor:

1. as a named RleList object with one list element per chromosome;
2. as a metadata column on a *disjoint* GRanges object.

This man page documents tools for switching from one form to the other.

## Usage

```
bindAsGRanges(...)
mcolAsRleList(x, varname)
binnedAverage(bins, numvar, varname, na.rm=FALSE)
```

## Arguments

| | |
|---|---|
| `...` | One or more genomic variables in the form of named RleList objects. |
| `x` | A *disjoint* GRanges object with metadata columns on it. A GRanges object is said to be *disjoint* if it contains ranges that do not overlap with each other. This can be tested with `isDisjoint`. See ?`isDisjoint,GenomicRanges-method` for more information about the `isDisjoint` method for GRanges objects. |

varname — The name of the genomic variable.

For `mcolAsRleList` this must be the name of the metadata column on `x` to be turned into an RleList object.

For `binnedAverage` this will be the name of the metadata column that contains the binned average in the returned object.

bins — A GRanges object representing the genomic bins. Typically obtained by calling `tileGenome` with `cut.last.tile.in.chrom=TRUE`.

numvar — A named RleList object representing a numerical variable defined along the genome covered by `bins` (which is the genome described by `seqinfo(bins)`).

na.rm — A logical value indicating whether `NA` values should be stripped before the average is computed.

## Details

`bindAsGRanges` allows to switch the representation of one or more genomic variables from the *named RleList* form to the *metadata column on a disjoint GRanges object* form by binding the supplied named RleList objects together and putting them on the same GRanges object. This transformation is lossless.

`mcolAsRleList` performs the opposite transformation and is also lossless (however the circularity flags and genome information in `seqinfo(x)` won't propagate). It works for any metadata column on `x` that can be put in Rle form i.e. that is an atomic vector or a factor.

`binnedAverage` computes the binned average of a numerical variable defined along a genome.

## Value

For `bindAsGRanges`: a GRanges object with 1 metadata column per supplied genomic variable.

For `mcolAsRleList`: a named RleList object with 1 list element per seqlevel in `x`.

For `binnedAverage`: input GRanges object `bins` with an additional metadata column named `varname` containing the binned average.

## Author(s)

H. Pagès

## See Also

- RleList objects in the **IRanges** package.
- coverage,GenomicRanges-method for computing the coverage of a GRanges object.
- The `tileGenome` function for putting tiles on a genome.
- GRanges objects and isDisjoint,GenomicRanges-method for the `isDisjoint` method for GenomicRanges objects.

## Examples

```
## ---------------------------------------------------------------------
## A. TWO WAYS TO REPRESENT A GENOMIC VARIABLE
## ---------------------------------------------------------------------

## 1) As a named RleList object
## ----------------------------
## Let's create a genomic variable in the "named RleList" form:
library(BSgenome.Scerevisiae.UCSC.sacCer2)
set.seed(55)
my_var <- RleList(
    lapply(seqlengths(Scerevisiae),
        function(seqlen) {
            tmp <- sample(50L, seqlen, replace=TRUE)
            Rle(cumsum(tmp - rev(tmp)))
        }
    ),
    compress=FALSE)
my_var

## 2) As a metadata column on a disjoint GRanges object
## ----------------------------------------------------
gr1 <- bindAsGRanges(my_var=my_var)
gr1

gr2 <- GRanges(c("chrI:1-150",
                 "chrI:211-285",
                 "chrI:291-377",
                 "chrV:51-60"),
               score=c(0.4, 8, -10, 2.2),
               id=letters[1:4],
               seqinfo=seqinfo(Scerevisiae))
gr2

## Going back to the "named RleList" form:
mcolAsRleList(gr1, "my_var")
score <- mcolAsRleList(gr2, "score")
score
id <- mcolAsRleList(gr2, "id")
id
bindAsGRanges(score=score, id=id)

## Bind 'my_var', 'score', and 'id' together:
gr3 <- bindAsGRanges(my_var=my_var, score=score, id=id)

## Sanity checks:
stopifnot(identical(my_var, mcolAsRleList(gr3, "my_var")))
stopifnot(identical(score, mcolAsRleList(gr3, "score")))
stopifnot(identical(id, mcolAsRleList(gr3, "id")))
gr2b <- bindAsGRanges(score=score, id=id)
seqinfo(gr2b) <- seqinfo(gr2)
stopifnot(identical(gr2, gr2b))
```

```
## ------------------------------------------------------------------------
## B. BIND TOGETHER THE COVERAGES OF SEVERAL BAM FILES
## ------------------------------------------------------------------------

library(pasillaBamSubset)
library(GenomicAlignments)
untreated1_cvg <- coverage(BamFile(untreated1_chr4()))
untreated3_cvg <- coverage(BamFile(untreated3_chr4()))
all_cvg <- bindAsGRanges(untreated1=untreated1_cvg,
                         untreated3=untreated3_cvg)

## Keep regions with coverage:
all_cvg[with(mcols(all_cvg), untreated1 + untreated3 >= 1)]

## Plot the coverage profiles with the Gviz package:
library(Gviz)
plotNumvars <- function(numvars, region, name="numvars", ...)
{
    stopifnot(is(numvars, "GRanges"))
    stopifnot(is(region, "GRanges"), length(region) == 1L)
    gtrack <- GenomeAxisTrack()
    dtrack <- DataTrack(numvars,
                        chromosome=as.character(seqnames(region)),
                        name=name,
                        groups=colnames(mcols(numvars)), type="l", ...)
    plotTracks(list(gtrack, dtrack), from=start(region), to=end(region))
}
plotNumvars(all_cvg, GRanges("chr4:1-25000"),
            "coverage", col=c("red", "blue"))
plotNumvars(all_cvg, GRanges("chr4:1.03e6-1.08e6"),
            "coverage", col=c("red", "blue"))

## Sanity checks:
stopifnot(identical(untreated1_cvg, mcolAsRleList(all_cvg, "untreated1")))
stopifnot(identical(untreated3_cvg, mcolAsRleList(all_cvg, "untreated3")))

## ------------------------------------------------------------------------
## C. COMPUTE THE BINNED AVERAGE OF A NUMERICAL VARIABLE DEFINED ALONG A
##    GENOME
## ------------------------------------------------------------------------

## In some applications (e.g. visualization), there is the need to compute
## the average of a genomic variable for a set of predefined fixed-width
## regions (sometimes called "bins").
## Let's use tileGenome() to create such a set of bins:
bins1 <- tileGenome(seqinfo(Scerevisiae), tilewidth=100,
                    cut.last.tile.in.chrom=TRUE)

## Compute the binned average for 'my_var' and 'score':
bins1 <- binnedAverage(bins1, my_var, "binned_var")
bins1
bins1 <- binnedAverage(bins1, score, "binned_score")
```

```
bins1

## Binned average in "named RleList" form:
binned_var1 <- mcolAsRleList(bins1, "binned_var")
binned_var1
stopifnot(all.equal(mean(my_var), mean(binned_var1)))  # sanity check

mcolAsRleList(bins1, "binned_score")

## With bigger bins:
bins2 <- tileGenome(seqinfo(Scerevisiae), tilewidth=50000,
                    cut.last.tile.in.chrom=TRUE)
bins2 <- binnedAverage(bins2, my_var, "binned_var")
bins2 <- binnedAverage(bins2, score, "binned_score")
bins2

binned_var2 <- mcolAsRleList(bins2, "binned_var")
binned_var2
stopifnot(all.equal(mean(my_var), mean(binned_var2)))  # sanity check

mcolAsRleList(bins2, "binned_score")

## Not surprisingly, the "binned" variables are much more compact in
## memory than the original variables (they contain much less runs):
object.size(my_var)
object.size(binned_var1)
object.size(binned_var2)

## ---------------------------------------------------------------------
## D. SANITY CHECKS
## ---------------------------------------------------------------------

bins3 <- tileGenome(c(chr1=10, chr2=8), tilewidth=5,
                    cut.last.tile.in.chrom=TRUE)
my_var3 <- RleList(chr1=Rle(c(1:3, NA, 5:7)), chr2=Rle(c(-3, NA, -3, NaN)))
bins3 <- binnedAverage(bins3, my_var3, "binned_var3", na.rm=TRUE)
binned_var3 <- mcols(bins3)$binned_var3
stopifnot(
  identical(mean(my_var3$chr1[1:5], na.rm=TRUE),
            binned_var3[1]),
  identical(mean(c(my_var3$chr1, 0, 0, 0)[6:10], na.rm=TRUE),
            binned_var3[2]),
  #identical(mean(c(my_var3$chr2, 0), na.rm=TRUE),
  #          binned_var3[3]),
  identical(0, binned_var3[4])
)
```

---

GNCList-class *GNCList objects*

---

## Description

The GNCList class is a container for storing the Nested Containment List representation of a vector of genomic ranges (typically represented as a GRanges object). To preprocess a GRanges object, simply call the `GNCList` constructor function on it. The resulting GNCList object can then be used for efficient overlap-based operations on the genomic ranges.

## Usage

```
GNCList(x)
```

## Arguments

| | |
|---|---|
| x | The GRanges (or more generally GenomicRanges) object to preprocess. |

## Details

The **IRanges** package also defines the `NCList` and `NCLists` constructors and classes for preprocessing and representing a IntegerRanges or IntegerRangesList object as a data structure based on Nested Containment Lists.

Note that GNCList objects (introduced in BioC 3.1) are replacements for GIntervalTree objects (BioC < 3.1).

See ?`NCList` in the **IRanges** package for some important differences between the new algorithm based on Nested Containment Lists and the old algorithm based on interval trees. In particular, the new algorithm supports preprocessing of a GenomicRanges object with ranges defined on circular sequences (e.g. on the mitochnodrial chromosome). See below for some examples.

## Value

A GNCList object.

## Author(s)

H. Pagès

## References

Alexander V. Alekseyenko and Christopher J. Lee – Nested Containment List (NCList): a new algorithm for accelerating interval query of genome alignment and interval databases. Bioinformatics (2007) 23 (11): 1386-1393. doi: 10.1093/bioinformatics/btl647

## See Also

- The `NCList` and `NCLists` constructors and classs defined in the **IRanges** package.
- `findOverlaps` for finding/counting interval overlaps between two *range-based* objects.
- GRanges objects.

## Examples

```
## The examples below are for illustration purpose only and do NOT
## reflect typical usage. This is because, for a one time use, it is
## NOT advised to explicitly preprocess the input for findOverlaps()
## or countOverlaps(). These functions will take care of it and do a
## better job at it (by preprocessing only what's needed when it's
## needed, and release memory as they go).

## ---------------------------------------------------------------------
## PREPROCESS QUERY OR SUBJECT
## ---------------------------------------------------------------------

query <- GRanges(Rle(c("chrM", "chr1", "chrM", "chr1"), 4:1),
                 IRanges(1:10, width=5), strand=rep(c("+", "-"), 5))
subject <- GRanges(Rle(c("chr1", "chr2", "chrM"), 3:1),
                   IRanges(6:1, width=5), strand="+")

## Either the query or the subject of findOverlaps() can be preprocessed:

ppsubject <- GNCList(subject)
hits1a <- findOverlaps(query, ppsubject)
hits1a
hits1b <- findOverlaps(query, ppsubject, ignore.strand=TRUE)
hits1b

ppquery <- GNCList(query)
hits2a <- findOverlaps(ppquery, subject)
hits2a
hits2b <- findOverlaps(ppquery, subject, ignore.strand=TRUE)
hits2b

## Note that 'hits1a' and 'hits2a' contain the same hits but not
## necessarily in the same order.
stopifnot(identical(sort(hits1a), sort(hits2a)))
## Same for 'hits1b' and 'hits2b'.
stopifnot(identical(sort(hits1b), sort(hits2b)))

## ---------------------------------------------------------------------
## WITH CIRCULAR SEQUENCES
## ---------------------------------------------------------------------

seqinfo <- Seqinfo(c("chr1", "chr2", "chrM"),
                   seqlengths=c(100, 50, 10),
                   isCircular=c(FALSE, FALSE, TRUE))
seqinfo(query) <- seqinfo[seqlevels(query)]
seqinfo(subject) <- seqinfo[seqlevels(subject)]

ppsubject <- GNCList(subject)
hits3 <- findOverlaps(query, ppsubject)
hits3

## Circularity introduces more hits:
```

```
stopifnot(all(hits1a %in% hits3))
new_hits <- setdiff(hits3, hits1a)
new_hits  # 1 new hit
query[queryHits(new_hits)]
subject[subjectHits(new_hits)]  # positions 11:13 on chrM are the same
                                # as positions 1:3

## Sanity checks:
stopifnot(identical(new_hits, Hits(9, 6, 10, 6, sort.by.query=TRUE)))
ppquery <- GNCList(query)
hits4 <- findOverlaps(ppquery, subject)
stopifnot(identical(sort(hits3), sort(hits4)))
```

---

GPos-class *Memory-efficient representation of genomic positions*

---

## Description

The GPos class is a container for storing a set of *genomic positions* (a.k.a. *genomic loci*). It exists in 2 flavors: UnstitchedGPos and StitchedGPos. Each flavor uses a particular internal representation:

- In an UnstitchedGPos instance the positions are stored as an integer vector.
- In a StitchedGPos instance the positions are stored as an IRanges object where each range represents a run of *consecutive positions* (i.e. a run of positions that are adjacent and in *ascending order*). This storage is particularly memory-efficient when the vector of positions contains long runs of consecutive positions.

Because genomic positions can be seen as genomic ranges of width 1, the GPos class extends the GenomicRanges virtual class (via the GRanges class).

## Usage

```
## Constructor function
GPos(seqnames=NULL, pos=NULL, strand=NULL,
     ..., seqinfo=NULL, seqlengths=NULL, stitch=NA)
```

## Arguments

`seqnames`, `strand`, `...`, `seqinfo`, `seqlengths`
: See documentation of the `GRanges()` constructor function for a description of these arguments.

`pos`
: `NULL`, or an integer or numeric vector, or an IRanges or IPos object (or other IntegerRanges derivative). If not `NULL`, `GPos()` will try to turn it into an IPos derivative with `IPos(pos, stitch=stitch)`.

  When `pos` is an IRanges object (or other IntegerRanges derivative), each range in it is interpreted as a run of consecutive positions.

stitch — TRUE, FALSE, or NA (the default).

Controls which internal representation should be used: StitchedGPos (when stitch is TRUE) or UnstitchedGPos (when stitch is FALSE).

When stitch is NA (the default), which internal representation will be used depends on the flavour of the IPos derivative returned by IPos(pos): UnstitchedGPos if IPos(pos) returns an UnstitchedIPos instance, and StitchedGPos if it returns a StitchedIPos instance.

## Details

Even though a GRanges object can be used for storing genomic positions, using a GPos object is more efficient. In particular the memory footprint of an UnstitchedGPos object is typically about half that of a GRanges object.

OTOH the memory footprint of a StitchedGPos object can vary a lot but will never be worse than that of a GRanges object. However it will reduce dramatically if the vector of positions contains long runs of consecutive positions. In the worst case scenario (i.e. when the object contains no consecutive positions) its memory footprint will be the same as that of a GRanges object.

Like for any Vector derivative, the length of a GPos object cannot exceed .Machine$integer.max (i.e. 2^31 on most platforms). GPos() will return an error if pos contains too many positions.

## Value

An UnstitchedGPos or StitchedGPos object.

## Accessors

**Getters:** GPos objects support the same set of getters as other GenomicRanges derivatives (i.e. seqnames(), ranges(), start(), end(), strand(), mcols(), seqinfo(), etc...), plus the pos() getter which is equivalent to start() or end(). See ?GenomicRanges for the list of getters supported by GenomicRanges derivatives.

Note that ranges() returns an IPos derivative instead of the IRanges object that one gets with other GenomicRanges derivatives. To get an IRanges object, you need to call ranges() again on this IPos derivative i.e. do ranges(ranges(x)) on GPos object x.

**Setters:** Like GRanges objects, GPos derivatives support the following setters:

- The seqnames() and strand() setters.
- The names(), mcols() and metadata() setters.
- The family of setters that operate on the seqinfo component of an object: seqlevels(), seqlevelsStyle(), seqlengths(), isCircular(), genome(), and seqinfo(). These setters are defined and documented in the **Seqinfo** and **GenomeInfoDb** packages.

However, there is no pos() setter for GPos derivatives at the moment (although one might be added in the future).

## Coercion

From UnstitchedGPos to StitchedGPos and vice-versa: coercion back and forth between UnstitchedGPos and StitchedGPos is supported via as(x, "StitchedGPos") and as(x, "UnstitchedGPos"). This is the most efficient and recommended way to switch between the 2 internal representations.

Note that this switch can have dramatic consequences on memory usage so is for advanced users only. End users should almost never need to do this switch when following a typical workflow.

From GenomicRanges to UnstitchedGPos, StitchedGPos, or GPos: A GenomicRanges derivative `x` in which all the ranges have a width of 1 can be coerced to an UnstitchedGPos or StitchedGPos object with `as(x, "UnstitchedGPos")` or `as(x, "StitchedGPos")`, respectively. For convenience `as(x, "GPos")` is supported and is equivalent to `as(x, "UnstitchedGPos")`.

From GPos to GRanges: A GPos derivative `x` can be coerced to a GRanges object with `as(x, "GRanges")`. However be aware that the resulting object can use thousands times (or more) memory than `x`! See "MEMORY USAGE" in the Examples section below.

From GPos to ordinary R objects: Like with any other GenomicRanges derivative, `as.character()`, `as.factor()`, and `as.data.frame()` work on a GPos derivative `x`. Note however that `as.data.frame(x)` returns a data frame with a `pos` column (containing `pos(x)`) instead of the `start`, `end`, and `width` columns that one gets with other GenomicRanges derivatives.

## Subsetting

A GPos derivative can be subsetted exactly like a GRanges object.

## Concatenation

GPos derivatives can be concatenated with `c()` or `append()`. See `?c` in the **S4Vectors** package for more information about concatenating Vector derivatives.

## Splitting and Relisting

Like with any other GRanges object, `split()` and `relist()` work on a GPos derivative.

## Note

Internal representation of GPos objects has changed in **GenomicRanges** 1.29.10 (Bioc 3.6). Update any old object `x` with: `x <- updateObject(x, verbose=TRUE)`.

## Author(s)

Hervé Pagès; based on ideas borrowed from Georg Stricker <georg.stricker@in.tum.de> and Julien Gagneur <gagneur@in.tum.de>

## See Also

- The IPos class in the **IRanges** package for storing a set of *integer positions* (i.e. integer ranges of width 1).
- The GRanges class for storing a set of *genomic ranges* of arbitrary width.
- Seqinfo objects and the `seqinfo` accessor and family in the **Seqinfo** package for accessing/modifying information about the underlying sequences of a GenomicRanges derivative.
- GenomicRanges-comparison for comparing and ordering genomic ranges and/or positions.
- findOverlaps-methods for finding overlapping genomic ranges and/or positions.
- intra-range-methods and inter-range-methods for *intra range* and *inter range* transformations of GenomicRanges derivatives.

- coverage-methods for computing the coverage of a set of genomic ranges and/or positions.
- nearest-methods for finding the nearest genomic range/position neighbor.
- The snpsBySeqname, snpsByOverlaps, and snpsById methods for SNPlocs objects defined in the **BSgenome** package for extractors that return a GPos derivative.
- SummarizedExperiment objects and derivatives in the **SummarizedExperiment** package.

## Examples

```
showClass("GPos")  # shows the known subclasses

## ---------------------------------------------------------------------
## BASIC EXAMPLES
## ---------------------------------------------------------------------

## Example 1:
gpos1a <- GPos(seqnames=Rle(c("chr1", "chr2", "chr1"), c(10, 6, 4)),
               pos=c(44:53, 5:10, 2:5))
gpos1a  # unstitched

length(gpos1a)
seqnames(gpos1a)
pos(gpos1a)  # same as 'start(gpos1a)' and 'end(gpos1a)'
strand(gpos1a)
as.character(gpos1a)
as.data.frame(gpos1a)
as(gpos1a, "GRanges")
as.data.frame(as(gpos1a, "GRanges"))
gpos1a[9:17]

gpos1b <- GPos(seqnames=Rle(c("chr1", "chr2", "chr1"), c(10, 6, 4)),
               pos=c(44:53, 5:10, 2:5), stitch=TRUE)
gpos1b  # stitched

## 'gpos1a' and 'gpos1b' are semantically equivalent, only their
## internal representations differ:
all(gpos1a == gpos1b)

gpos1c <- GPos(c("chr1:44-53", "chr2:5-10", "chr1:2-5"))
gpos1c  # stitched

identical(gpos1b, gpos1c)

## Example 2:
pos_runs <- GRanges("chrI", IRanges(c(1, 6, 12, 17), c(5, 10, 16, 20)),
                    strand=c("*", "-", "-", "+"))
gpos2 <- GPos(pos_runs)
gpos2  # stitched
strand(gpos2)

## Example 3:
gpos3A <- gpos3B <- GPos(c("chrI:1-1000", "chrI:1005-2000"))
npos <- length(gpos3A)
```

```
mcols(gpos3A)$sample <- Rle("sA")
sA_counts <- sample(10, npos, replace=TRUE)
mcols(gpos3A)$counts <- sA_counts

mcols(gpos3B)$sample <- Rle("sB")
sB_counts <- sample(10, npos, replace=TRUE)
mcols(gpos3B)$counts <- sB_counts

gpos3 <- c(gpos3A, gpos3B)
gpos3

## Example 4:
library(BSgenome.Scerevisiae.UCSC.sacCer2)
genome <- BSgenome.Scerevisiae.UCSC.sacCer2
gpos4 <- GPos(seqinfo(genome))
gpos4  # all the positions along the genome are represented
mcols(gpos4)$dna <- do.call("c", unname(as.list(genome)))
gpos4

## Note however that, like for any Vector derivative, the length of a
## GPos derivative cannot exceed '.Machine$integer.max' (i.e. 2^31 on
## most platforms) so the above only works with a "small" genome.
## For example it doesn't work with the Human genome:
library(TxDb.Hsapiens.UCSC.hg38.knownGene)
## Not run:
  GPos(seqinfo(TxDb.Hsapiens.UCSC.hg38.knownGene))  # error!

## End(Not run)

## You can use isSmallGenome() to check upfront whether the genome is
## "small" or not.
isSmallGenome(genome)  # TRUE
isSmallGenome(TxDb.Hsapiens.UCSC.hg38.knownGene)  # FALSE

## ---------------------------------------------------------------------
## MEMORY USAGE
## ---------------------------------------------------------------------

## Coercion to GRanges works...
gr4 <- as(gpos4, "GRanges")
gr4
## ... but is generally not a good idea:
object.size(gpos4)
object.size(gr4)     # 8 times bigger than the StitchedGPos object!

## Shuffling the order of the positions impacts memory usage:
gpos4r <- rev(gpos4)
object.size(gpos4r)  # significantly
gpos4s <- sample(gpos4)
object.size(gpos4s)  # even worse!

## If one anticipates a lot of shuffling of the genomic positions,
```

```
## then an UnstitchedGPos object should be used instead:
gpos4b <- as(gpos4, "UnstitchedGPos")
object.size(gpos4b)  # initial size is bigger than stitched version
object.size(rev(gpos4b))  # size didn't change
object.size(sample(gpos4b))  # size increased, but is still < stitched
                             # version

## AN IMPORTANT NOTE: In the worst situations, GPos still performs as
## good as a GRanges object.
object.size(as(gpos4r, "GRanges"))  # same size as 'gpos4r'
object.size(as(gpos4s, "GRanges"))  # same size as 'gpos4s'

## Best case scenario is when the object is strictly sorted (i.e.
## positions are in strict ascending order).
## This can be checked with:
is.unsorted(gpos4, strict=TRUE)  # 'gpos4' is strictly sorted

## ---------------------------------------------------------------------
## USING MEMORY-EFFICIENT METADATA COLUMNS
## ---------------------------------------------------------------------
## In order to keep memory usage as low as possible, it is recommended
## to use a memory-efficient representation of the metadata columns that
## we want to set on the object. Rle's are particularly well suited for
## this, especially if the metadata columns contain long runs of
## identical values. This is the case for example if we want to use a
## GPos object to represent the coverage of sequencing reads along a
## genome.

## Example 5:
library(pasillaBamSubset)
library(Rsamtools)  # for the BamFile() constructor function
bamfile1 <- BamFile(untreated1_chr4())
bamfile2 <- BamFile(untreated3_chr4())
gpos5 <- GPos(seqinfo(bamfile1))
library(GenomicAlignments)  # for "coverage" method for BamFile objects
cvg1 <- unlist(coverage(bamfile1), use.names=FALSE)
cvg2 <- unlist(coverage(bamfile2), use.names=FALSE)
mcols(gpos5) <- DataFrame(cvg1, cvg2)
gpos5

object.size(gpos5)  # lightweight

## Keep only the positions where coverage is at least 10 in one of the
## 2 samples:
gpos5[mcols(gpos5)$cvg1 >= 10 | mcols(gpos5)$cvg2 >= 10]

## ---------------------------------------------------------------------
## USING A GPos OBJECT IN A RangedSummarizedExperiment OBJECT
## ---------------------------------------------------------------------
## Because the GPos class extends the GenomicRanges virtual class, a
## GPos derivative can be used as the rowRanges component of a
## RangedSummarizedExperiment object.
```

```
## As a 1st example, we show how the counts for samples sA and sB in
## 'gpos3' can be stored in a SummarizedExperiment object where the rows
## correspond to unique genomic positions and the columns to samples:
library(SummarizedExperiment)
counts <- cbind(sA=sA_counts, sB=sB_counts)
mcols(gpos3A) <- NULL
rse3 <- SummarizedExperiment(list(counts=counts), rowRanges=gpos3A)
rse3
rowRanges(rse3)
head(assay(rse3))

## Finally we show how the coverage data from Example 5 can be easily
## stored in a lightweight SummarizedExperiment derivative:
cvg <- mcols(gpos5)
mcols(gpos5) <- NULL
rse5 <- SummarizedExperiment(list(cvg=cvg), rowRanges=gpos5)
rse5
rowRanges(rse5)
assay(rse5)

## Keep only the positions where coverage is at least 10 in one of the
## 2 samples:
rse5[assay(rse5)$cvg1 >= 10 | assay(rse5)$cvg2 >= 10]
```

---

GRanges-class *GRanges objects*

---

## Description

The GRanges class is a container for the genomic locations and their associated annotations.

## Details

GRanges is a vector of genomic locations and associated annotations. Each element in the vector is comprised of a sequence name, an interval, a strand, and optional metadata columns (e.g. score, GC content, etc.). This information is stored in four components:

`seqnames` a 'factor' Rle object containing the sequence names.

`ranges` an IRanges object containing the ranges.

`strand` a 'factor' Rle object containing the strand information.

`mcols` a DataFrame object containing the metadata columns. Columns cannot be named `"seqnames"`, `"ranges"`, `"strand"`, `"seqlevels"`, `"seqlengths"`, `"isCircular"`, `"start"`, `"end"`, `"width"`, or `"element"`.

`seqinfo` a Seqinfo object containing information about the set of genomic sequences present in the GRanges object.

## Constructor

`GRanges(seqnames=NULL, ranges=NULL, strand=NULL, ..., seqinfo=NULL, seqlengths=NULL)`: Creates a GRanges object.

`seqnames` `NULL`, or an Rle object, character vector, or factor containing the sequence names.

`ranges` `NULL`, or an IRanges object containing the ranges.

`strand` `NULL`, or an Rle object, character vector, or factor containing the strand information.

`...` Metadata columns to set on the GRanges object. All the metadata columns must be vector-like objects of the same length as the object to construct. They cannot be named `"start"`, `"end"`, `"width"`, or `"element"`.

`seqinfo` Either `NULL`, or a Seqinfo object, or a character vector of unique sequence names (a.k.a. *seqlevels*), or a named numeric vector of sequence lengths. When not `NULL`, `seqinfo` must be compatible with the sequence names in `seqnames`, that is, it must have one entry for each unique sequence name in `seqnames`. Note that it can have additional entries i.e. entries for seqlevels not present in `seqnames`.

`seqlengths` `NULL`, or an integer vector named with `levels(seqnames)` and containing the lengths (or NA) for each level in `levels(seqnames)`.

If `ranges` is not supplied and/or NULL then the constructor proceeds in 2 steps:

1. An initial GRanges object is created with `as(seqnames, "GRanges")`.
2. Then this GRanges object is updated according to whatever non-NULL remaining arguments were passed to the call to `GRanges()`.

As a consequence of this behavior, `GRanges(x)` is equivalent to `as(x, "GRanges")`.

## Accessors

In the following code snippets, `x` is a GRanges object.

`length(x)`: Get the number of elements.

`seqnames(x)`, `seqnames(x) <- value`: Get or set the sequence names. `value` can be an Rle object, a character vector, or a factor.

`ranges(x)`, `ranges(x) <- value`: Get or set the ranges. `value` can be an IntegerRanges object.

`start(x)`, `start(x) <- value`: Get or set `start(ranges(x))`.

`end(x)`, `end(x) <- value`: Get or set `end(ranges(x))`.

`width(x)`, `width(x) <- value`: Get or set `width(ranges(x))`.

`strand(x)`, `strand(x) <- value`: Get or set the strand. `value` can be an Rle object, character vector, or factor.

`names(x)`, `names(x) <- value`: Get or set the names of the elements.

`mcols(x, use.names=FALSE)`, `mcols(x) <- value`: Get or set the metadata columns. If `use.names=TRUE` and the metadata columns are not `NULL`, then the names of `x` are propagated as the row names of the returned DataFrame object. When setting the metadata columns, the supplied value must be `NULL` or a data-frame-like object (i.e. DataFrame or data.frame) holding element-wise metadata.

`elementMetadata(x)`, `elementMetadata(x) <- value`, `values(x)`, `values(x) <- value`: Alternatives to `mcols` functions. Their use is discouraged.

`seqinfo(x)`, `seqinfo(x) <- value`: Get or set the information about the underlying sequences. `value` must be a Seqinfo object.

`seqlevels(x)`, `seqlevels(x, pruning.mode=c("error", "coarse", "fine", "tidy")) <- value`: Get or set the sequence levels. `seqlevels(x)` is equivalent to `seqlevels(seqinfo(x))` or to `levels(seqnames(x))`, those 2 expressions being guaranteed to return identical character vectors on a GRanges object. `value` must be a character vector with no NAs. See `?seqlevels` in the **Seqinfo** package for more information.

`seqlengths(x)`, `seqlengths(x) <- value`: Get or set the sequence lengths. `seqlengths(x)` is equivalent to `seqlengths(seqinfo(x))`. `value` can be a named non-negative integer or numeric vector eventually with NAs.

`isCircular(x)`, `isCircular(x) <- value`: Get or set the circularity flags. `isCircular(x)` is equivalent to `isCircular(seqinfo(x))`. `value` must be a named logical vector eventually with NAs.

`genome(x)`, `genome(x) <- value`: Get or set the genome identifier or assembly name for each sequence. `genome(x)` is equivalent to `genome(seqinfo(x))`. `value` must be a named character vector eventually with NAs.

`seqlevelsStyle(x)`, `seqlevelsStyle(x) <- value`: Get or set the seqname style for `x`. See the seqlevelsStyle generic getter and setter in the **GenomeInfoDb** package for more information.

`score(x)`, `score(x) <- value`: Get or set the "score" column from the element metadata.

`granges(x, use.names=FALSE, use.mcols=FALSE)`: Squeeze the genomic ranges out of GenomicRanges object `x` and return them in a GRanges object *parallel* to `x` (i.e. same length as `x`). If `use.mcols` is `TRUE`, the metadata columns are propagated. If `x` is a GenomicRanges derivative with *extra column slots*, these will be propagated as metadata columns on the returned GRanges object.

## Coercion

In the code snippets below, `x` is a GRanges object.

`as(from, "GRanges")`: Creates a GRanges object from a character vector, a factor, or IntegerRangesList object.

When `from` is a character vector (or a factor), each element in it must represent a genomic range in format `chr1:2501-2800` (unstranded range) or `chr1:2501-2800:+` (stranded range). `..` is also supported as a separator between the start and end positions. Strand can be `+`, `-`, `*`, or missing. The names on `from` are propagated to the returned GRanges object. See `as.character()` and `as.factor()` below for the reverse transformations.

Coercing a data.frame or DataFrame into a GRanges object is also supported. See `makeGRangesFromDataFrame` for the details.

`as(from, "IntegerRangesList")`: Creates a IntegerRangesList object from a GRanges object. The `strand` and metadata columns become *inner* metadata columns (i.e. metadata columns on the ranges). The `seqlengths(from)`, `isCircular(from)`, and `genome(from)` vectors become the metadata columns.

`as.character(x, ignore.strand=FALSE)`: Turn GRanges object `x` into a character vector where each range in `x` is represented by a string in format `chr1:2501-2800:+`. If `ignore.strand` is TRUE or if *all* the ranges in `x` are unstranded (i.e. their strand is set to `*`), then all the strings in the output are in format `chr1:2501-2800`.

The names on x are propagated to the returned character vector. Its metadata (metadata(x)) and metadata columns (mcols(x)) are ignored.

See as(from, "GRanges") above for the reverse transformation.

as.factor(x): Equivalent to

```
factor(as.character(x), levels=as.character(sort(unique(x))))
```

See as(from, "GRanges") above for the reverse transformation.

Note that table(x) is supported on a GRanges object. It is equivalent to, but much faster than, table(as.factor(x)).

as.data.frame(x, row.names = NULL, optional = FALSE, ...): Creates a data.frame with columns seqnames (factor), start (integer), end (integer), width (integer), strand (factor), as well as the additional metadata columns stored in mcols(x). Pass an explicit stringsAsFactors=TRUE/FALSE argument via ... to override the default conversions for the metadata columns in mcols(x).

as(from, "Grouping"): Creates a ManyToOneGrouping object that groups from by seqname, strand, start and end (same as the default sort order). This makes it convenient, for example, to aggregate a GenomicRanges object by range.

In the code snippets below, x is a Seqinfo object.

as(x, "GRanges"), as(x, "GenomicRanges"), as(x, "IntegerRangesList"): Turns Seqinfo object x (with no NA lengths) into a GRanges or IntegerRangesList.

## Subsetting

In the code snippets below, x is a GRanges object.

x[i]: Return a new GRanges object made of the elements selected by i.

x[i, j]: Like the above, but allow the user to conveniently subset the metadata columns thru j.

x[i] <- value: Replacement version of x[i].

x$name, x$name <- value: Shortcuts for mcols(x)$name and mcols(x)$name <- value, respectively. Provided as a convenience, for GRanges objects *only*, and as the result of strong popular demand. Note that those methods are not consistent with the other $ and $<- methods in the IRanges/GenomicRanges infrastructure, and might confuse some users by making them believe that a GRanges object can be manipulated as a data.frame-like object. Therefore we recommend using them only interactively, and we discourage their use in scripts or packages. For the latter, use mcols(x)$name and mcols(x)$name <- value, instead of x$name and x$name <- value, respectively.

See ?`[` in the **S4Vectors** package for more information about subsetting Vector derivatives and for an important note about the x[i, j] form.

Note that a GRanges object can be used as a subscript to subset a list-like object that has names on it. In that case, the names on the list-like object are interpreted as sequence names. In the code snippets below, x is a list or List object with names on it, and the subscript gr is a GRanges object with all its seqnames being valid x names.

x[gr]: Return an object of the same class as x and *parallel* to gr. More precisely, it's conceptually doing:

```
lapply(gr, function(gr1) x[[seqnames(gr1)]][ranges(gr1)])
```

### Concatenation

`c(x, ..., ignore.mcols=FALSE)`**:** Concatenate GRanges object `x` and the GRanges objects in `...` together. See `?c` in the **S4Vectors** package for more information about concatenating Vector derivatives.

### Splitting

`split(x, f, drop=FALSE)`**:** Splits GRanges object `x` according to `f` to create a GRangesList object. If `f` is a list-like object then `drop` is ignored and `f` is treated as if it was `rep(seq_len(length(f)), sapply(f, length))`, so the returned object has the same shape as `f` (it also receives the names of `f`). Otherwise, if `f` is not a list-like object, empty list elements are removed from the returned object if `drop` is `TRUE`.

### Displaying

In the code snippets below, `x` is a GRanges object.

`show(x)`**:** By default the `show` method displays 5 head and 5 tail elements. This can be changed by setting the global options `showHeadLines` and `showTailLines`. If the object length is less than (or equal to) the sum of these 2 options plus 1, then the full object is displayed. Note that these options also affect the display of GAlignments and GAlignmentPairs objects (defined in the **GenomicAlignments** package), as well as other objects defined in the **IRanges** and **Biostrings** packages (e.g. IRanges and DNAStringSet objects).

### Author(s)

P. Aboyoun and H. Pagès

### See Also

- The IRanges class in the **IRanges** package for storing a set of *integer ranges*.
- The GPos class for representing a set of *genomic positions* (i.e. *genomic ranges* of width 1, a.k.a. *genomic loci*).
- `makeGRangesFromDataFrame` for making a GRanges object from a data.frame or DataFrame object.
- Seqinfo objects and the `seqinfo` accessor and family in the **Seqinfo** package for accessing/modifying information about the underlying sequences of a GenomicRanges derivative.
- GenomicRanges-comparison for comparing and ordering genomic ranges and/or positions.
- findOverlaps-methods for finding overlapping genomic ranges and/or positions.
- intra-range-methods and inter-range-methods for *intra range* and *inter range* transformations of GenomicRanges derivatives.
- coverage-methods for computing the coverage of a set of genomic ranges and/or positions.
- setops-methods for set operations on GRanges objects.
- subtract for subtracting a set of genomic ranges from a GRanges object (similar to bedtools subtract).
- nearest-methods for finding the nearest genomic range/position neighbor.

- absoluteRanges for transforming genomic ranges into *absolute* ranges (i.e. into ranges on the sequence obtained by virtually concatenating all the sequences in a genome).
- tileGenome for putting tiles on a genome.
- genomicvars for manipulating genomic variables.
- GRangesList objects.
- Vector, Rle, and DataFrame objects in the **S4Vectors** package.

## Examples

```
showClass("GRanges")  # shows the known subclasses

## ---------------------------------------------------------------------
## CONSTRUCTION
## ---------------------------------------------------------------------
## Specifying the bare minimum i.e. seqnames and ranges only. The
## GRanges object will have no names, no strand information, and no
## metadata columns:
gr0 <- GRanges(Rle(c("chr2", "chr2", "chr1", "chr3"), c(1, 3, 2, 4)),
               IRanges(1:10, width=10:1))
gr0

## Specifying names, strand, metadata columns. They can be set on an
## existing object:
names(gr0) <- head(letters, 10)
strand(gr0) <- Rle(strand(c("-", "+", "*", "+", "-")), c(1, 2, 2, 3, 2))
mcols(gr0)$score <- 1:10
mcols(gr0)$GC <- seq(1, 0, length=10)
gr0

## ... or specified at construction time:
gr <- GRanges(Rle(c("chr2", "chr2", "chr1", "chr3"), c(1, 3, 2, 4)),
              IRanges(1:10, width=10:1, names=head(letters, 10)),
              Rle(strand(c("-", "+", "*", "+", "-")), c(1, 2, 2, 3, 2)),
              score=1:10, GC=seq(1, 0, length=10))
stopifnot(identical(gr0, gr))

## Specifying the seqinfo. It can be set on an existing object:
seqinfo <- Seqinfo(paste0("chr", 1:3), c(1000, 2000, 1500), NA, "mock1")
seqinfo(gr0) <- merge(seqinfo(gr0), seqinfo)
seqlevels(gr0) <- seqlevels(seqinfo)

## ... or specified at construction time:
gr <- GRanges(Rle(c("chr2", "chr2", "chr1", "chr3"), c(1, 3, 2, 4)),
              IRanges(1:10, width=10:1, names=head(letters, 10)),
              Rle(strand(c("-", "+", "*", "+", "-")), c(1, 2, 2, 3, 2)),
              score=1:10, GC=seq(1, 0, length=10),
              seqinfo=seqinfo)
stopifnot(identical(gr0, gr))

## ---------------------------------------------------------------------
## COERCION
```

```
## ---------------------------------------------------------------------
## From GRanges:
as.character(gr)
as.factor(gr)
as.data.frame(gr)

## From character to GRanges:
x1 <- "chr2:56-125"
as(x1, "GRanges")
as(rep(x1, 4), "GRanges")
x2 <- c(A=x1, B="chr1:25-30:-")
as(x2, "GRanges")

## From data.frame to GRanges:
df <- data.frame(chrom="chr2", start=11:15, end=20:24)
gr3 <- as(df, "GRanges")

## Alternatively, coercion to GRanges can be done by just calling the
## GRanges() constructor on the object to coerce:
gr1 <- GRanges(x1)  # same as as(x1, "GRanges")
gr2 <- GRanges(x2)  # same as as(x2, "GRanges")
gr3 <- GRanges(df)  # same as as(df, "GRanges")

## Sanity checks:
stopifnot(identical(as(x1, "GRanges"), gr1))
stopifnot(identical(as(x2, "GRanges"), gr2))
stopifnot(identical(as(df, "GRanges"), gr3))

## ---------------------------------------------------------------------
## SUMMARIZING ELEMENTS
## ---------------------------------------------------------------------
table(seqnames(gr))
table(strand(gr))
sum(width(gr))
table(gr)
summary(mcols(gr)[,"score"])

## The number of lines displayed in the 'show' method are controlled
## with two global options:
longGR  <- sample(gr, 25, replace=TRUE)
longGR
options(showHeadLines=7)
options(showTailLines=2)
longGR

## Revert to default values
options(showHeadLines=NULL)
options(showTailLines=NULL)

## ---------------------------------------------------------------------
## INVERTING THE STRAND
## ---------------------------------------------------------------------
invertStrand(gr)
```

```
## ---------------------------------------------------------------------
## RENAMING THE UNDERLYING SEQUENCES
## ---------------------------------------------------------------------
seqlevels(gr)
seqlevels(gr) <- sub("chr", "Chrom", seqlevels(gr))
gr
seqlevels(gr) <- sub("Chrom", "chr", seqlevels(gr)) # revert

## ---------------------------------------------------------------------
## COMBINING OBJECTS
## ---------------------------------------------------------------------
gr2 <- GRanges(seqnames=Rle(c('chr1', 'chr2', 'chr3'), c(3, 3, 4)),
               IRanges(1:10, width=5),
               strand='-',
               score=101:110, GC=runif(10),
               seqinfo=seqinfo)
gr3 <- GRanges(seqnames=Rle(c('chr1', 'chr2', 'chr3'), c(3, 4, 3)),
               IRanges(101:110, width=10),
               strand='-',
               score=21:30,
               seqinfo=seqinfo)
some.gr <- c(gr, gr2)

c(gr, gr2, gr3)
c(gr, gr2, gr3, ignore.mcols=TRUE)

## ---------------------------------------------------------------------
## USING A GRANGES OBJECT AS A SUBSCRIPT TO SUBSET ANOTHER OBJECT
## ---------------------------------------------------------------------
## Subsetting *by* a GRanges subscript is supported only if the object
## to subset is a named list-like object:
x <- RleList(chr1=101:120, chr2=2:-8, chr3=31:40)
x[gr]
```

---

GRangesFactor-class *GRangesFactor objects*

---

## Description

A GRangesFactor object is a Factor derivative where the levels are a GRanges object.

See ?Factor and in the **S4Vectors** package for general information about Factor objects.

## Usage

```
GRangesFactor(x, levels, index=NULL, ...)  # constructor function
```

## Arguments

| | |
|---|---|
| x, levels | Like with the Factor() constructor function, at least one of x and levels must be specified. If index is NULL, both can be specified.<br>When x and/or levels are specified, they must be GRanges objects or derivatives. In addition, levels cannot contain duplicate ranges (i.e. anyDuplicated(levels) must return 0).<br>When x and levels are both specified, they should both be GRanges objects or GRanges derivatives of the same class, and all the elements in x must be represented in levels (i.e. the integer vector returned by match(x, levels) should contain no NAs). |
| index | NULL or an integer (or numeric) vector of valid positive indices (no NAs) into levels. |
| ... | Optional metadata columns. |

## Details

Like with the Factor() constructor function, there are 4 different ways to use the GRangesFactor() constructor function. See Details section in the man page for Factor objects for more information.

## Value

A GRangesFactor object.

## Accessors

GRangesFactor objects support the accessors documented in the man page for Factor objects.

In addition, the following getters are supported for convenience: seqnames(), start(), end(), width(), strand(), seqinfo(), granges(), and ranges(). When called on GRangesFactor object x, they all behave as if they were called on unfactor(x).

## Decoding a Factor

Because a GRangesFactor object x is a Factor derivative, unfactor(x) can be used to *decode* it. unfactor(x) returns an object of the same class as levels(x) (i.e. a GRanges object or derivative) and same length as x.

See ?unfactor for more information.

## Coercion

GRangesFactor objects support the coercions documented in the man page for Factor objects.

In addition, coercion back and forth between GRanges and GRangesFactor is supported via as(x, "GRanges") and as(x, "GRangesFactor").

## Subsetting

A GRangesFactor object can be subsetted with [, like a Factor object.

### Concatenation

2 or more GRangesFactor objects can be concatenated with `c()`. The result of this concatenation is another GRangesFactor object.

See Concatenation section in ?`Factor`.

### Comparing & ordering

See Comparing & Ordering section in ?`Factor`.

### Author(s)

Hervé Pagès

### See Also

- GRanges objects.
- Factor objects in the **S4Vectors** package for the parent class of GRangesFactor.
- `anyDuplicated` in the **BiocGenerics** package.

### Examples

```
showClass("GRangesFactor")  # GRangesFactor extends Factor

## ---------------------------------------------------------------------
## CONSTRUCTOR & ACCESSORS
## ---------------------------------------------------------------------
set.seed(123)
ir0 <- IRanges(sample(5, 8, replace=TRUE), width=10, names=letters[1:8])
gr0 <- GRanges("chrA", ir0, ID=paste0("ID", 1:8))

## Use explicit levels:
gr1 <- GRanges("chrA", IRanges(1:6, width=10))
grf1 <- GRangesFactor(gr0, levels=gr1)
grf1
length(grf1)
names(grf1)
levels(grf1)  # gr1
nlevels(grf1)
as.integer(grf1)  # encoding

## If we don't specify the levels, they'll be set to unique(gr0):
grf2 <- GRangesFactor(gr0)
grf2
length(grf2)
names(grf2)
levels(grf2)  # unique(gr0)
nlevels(grf2)
as.integer(grf2)

## ---------------------------------------------------------------------
```

```
## DECODING
## ---------------------------------------------------------------------
unfactor(grf1)

stopifnot(identical(gr0, unfactor(grf1)))
stopifnot(identical(gr0, unfactor(grf2)))

unfactor(grf1, use.names=FALSE)
unfactor(grf1, ignore.mcols=TRUE)

## ---------------------------------------------------------------------
## COERCION
## ---------------------------------------------------------------------
grf2b <- as(gr0, "GRangesFactor")  # same as GRangesFactor(gr0)
stopifnot(identical(grf2, grf2b))

as.factor(grf2)
as.factor(grf1)

as.character(grf1)  # same as unfactor(as.factor(grf1)),
                    # and also same as as.character(unfactor(grf1))

## ---------------------------------------------------------------------
## CONCATENATION
## ---------------------------------------------------------------------
gr3 <- GRanges("chrA", IRanges(c(5, 2, 8:6), width=10))
grf3 <- GRangesFactor(levels=gr3, index=2:4)
grf13 <- c(grf1, grf3)
grf13
levels(grf13)

stopifnot(identical(c(unfactor(grf1), unfactor(grf3)), unfactor(grf13)))

## ---------------------------------------------------------------------
## COMPARING & ORDERING
## ---------------------------------------------------------------------
grf1 == grf2  # same as unfactor(grf1) == unfactor(grf2)

order(grf1)   # same as order(unfactor(grf1))
order(grf2)   # same as order(unfactor(grf2))

## The levels of the GRangesFactor influence the order of the table:
table(grf1)
table(grf2)
```

---

GRangesList-class *GRangesList objects*

---

## Description

The GRangesList class is a container for storing a collection of GRanges objects. It is a subclass of GenomicRangesList. It exists in 2 flavors: SimpleGRangesList and CompressedGRangesList. Each flavor uses a particular internal representation. The CompressedGRangesList flavor is the default. It is particularly efficient for storing a large number of list elements and operating on them.

## Constructors

`GRangesList(..., compress=TRUE)`: Creates a GRangesList object using the GRanges objects supplied in `...`, either consecutively or in a list. By default a CompressedGRangesList *instance* is returned, that is, a GRangesList object of the CompressedGRangesList flavor. Use `compress=FALSE` to get a SimpleGRangesList *instance* instead.

`makeGRangesListFromFeatureFragments(seqnames=Rle(factor()), fragmentStarts=list(), fragmentEnds=list` Constructs a GRangesList object from a list of fragmented features. See the Examples section below.

## Accessors

In the code snippets below, `x` is a GRangesList object.

`length(x)`: Get the number of list elements.

`names(x)`, `names(x) <- value`: Get or set the names on `x`.

`seqnames(x)`, `seqnames(x) <- value`: Get or set the sequence names in the form of an RleList. `value` can be an RleList or CharacterList object.

`ranges(x, use.mcols=FALSE)`, `ranges(x) <- value`: Get or set the ranges in the form of a CompressedIRangesList. `value` can be an IntegerRangesList object.

`start(x)`, `start(x) <- value`: Get or set `start(ranges(x))`.

`end(x)`, `end(x) <- value`: Get or set `end(ranges(x))`.

`width(x)`, `width(x) <- value`: Get or set `width(ranges(x))`.

`strand(x)`, `strand(x) <- value`: Get or set the strand in the form of an RleList object. `value` can be an RleList, CharacterList or single character. `value` as a single character converts all ranges in `x` to the same `value`; for selective strand conversion (i.e., mixed `+` and `-`) use RleList or CharacterList.

`mcols(x, use.names=FALSE)`, `mcols(x) <- value`: Get or set the metadata columns. `value` can be `NULL`, or a data.frame-like object (i.e. DataFrame or data.frame) holding element-wise metadata.

`elementNROWS(x)`: Get a vector of the `length` of each of the list element.

`isEmpty(x)`: Returns a logical indicating either if the GRangesList has no elements or if all its elements are empty.

`seqinfo(x)`, `seqinfo(x) <- value`: Get or set the information about the underlying sequences. `value` must be a Seqinfo object.

`seqlevels(x)`, `seqlevels(x, pruning.mode=c("error", "coarse", "fine", "tidy")) <- value`: Get or set the sequence levels. `seqlevels(x)` is equivalent to `seqlevels(seqinfo(x))` or to `levels(seqnames(x))`, those 2 expressions being guaranteed to return identical character vectors on a GRangesList object. `value` must be a character vector with no NAs. See `?seqlevels` for more information.

`seqlengths(x)`, `seqlengths(x) <- value`: Get or set the sequence lengths. `seqlengths(x)` is equivalent to `seqlengths(seqinfo(x))`. `value` can be a named non-negative integer or numeric vector eventually with NAs.

`isCircular(x)`, `isCircular(x) <- value`: Get or set the circularity flags. `isCircular(x)` is equivalent to `isCircular(seqinfo(x))`. `value` must be a named logical vector eventually with NAs.

`genome(x)`, `genome(x) <- value`: Get or set the genome identifier or assembly name for each sequence. `genome(x)` is equivalent to `genome(seqinfo(x))`. `value` must be a named character vector eventually with NAs.

`seqlevelsStyle(x)`, `seqlevelsStyle(x) <- value`: Get or set the seqname style for `x`. See the seqlevelsStyle generic getter and setter in the **GenomeInfoDb** package for more information.

`score(x)`, `score(x) <- value`: Get or set the `score` metadata column.

## Coercion

In the code snippets below, `x` is a GRangesList object.

`as.data.frame(x, row.names=NULL, optional=FALSE, ..., value.name="value", use.outer.mcols=FALSE, group`
Coerces `x` to a `data.frame`. See as.data.frame on the `List` man page for details (`?List`).

`as.list(x, use.names = TRUE)`: Creates a list containing the elements of `x`.

`as(x, "IRangesList")`: Turns `x` into an IRangesList object.

When `x` is a `list` of `GRanges`, it can be coerced to a `GRangesList`.

`as(x, "GRangesList")`: Turns `x` into a `GRangesList`.

## Subsetting

In the following code snippets, `x` is a GRangesList object.

`x[i, j]`, `x[i, j] <- value`: Get or set elements `i` with optional metadata columns `mcols(x)[,j]`, where `i` can be missing; an NA-free logical, numeric, or character vector; a logical-Rle object, or an AtomicList object.

`x[[i]]`, `x[[i]] <- value`: Get or set element `i`, where `i` is a numeric or character vector of length 1.

`x$name`, `x$name <- value`: Get or set element `name`, where `name` is a name or character vector of length 1.

`head(x, n = 6L)`: If `n` is non-negative, returns the first `n` elements of the GRangesList object. If `n` is negative, returns all but the last `abs(n)` elements of the GRangesList object.

`rep(x, times, length.out, each)`: Repeats the values in `x` through one of the following conventions:

`times` Vector giving the number of times to repeat each element if of length `length(x)`, or to repeat the whole vector if of length 1.

`length.out` Non-negative integer. The desired length of the output vector.

`each` Non-negative integer. Each element of `x` is repeated `each` times.

`subset(x, subset)`: Returns a new object of the same class as `x` made of the subset using logical vector `subset`, where missing values are taken as `FALSE`.

`tail(x, n = 6L)`: If `n` is non-negative, returns the last `n` list elements of the GRangesList object. If `n` is negative, returns all but the first `abs(n)` list elements of the GRangesList object.

## Combining

In the code snippets below, `x` is a GRangesList object.

`c(x, ...)`: Combines `x` and the GRangesList objects in `...` together. Any object in `...` must belong to the same class as `x`, or to one of its subclasses, or must be `NULL`. The result is an object of the same class as `x`.

`append(x, values, after = length(x))`: Inserts the `values` into `x` at the position given by `after`, where `x` and `values` are of the same class.

`unlist(x, recursive = TRUE, use.names = TRUE)`: Concatenates the elements of `x` into a single GRanges object.

## Looping

In the code snippets below, `x` is a GRangesList object.

`endoapply(X, FUN, ...)`: Similar to `lapply`, but performs an endomorphism, i.e. returns an object of `class(X)`.

`lapply(X, FUN, ...)`: Like the standard `lapply` function defined in the base package, the `lapply` method for GRangesList objects returns a list of the same length as `X`, with each element being the result of applying `FUN` to the corresponding element of `X`.

`Map(f, ...)`: Applies a function to the corresponding elements of given GRangesList objects.

`mapply(FUN, ..., MoreArgs=NULL, SIMPLIFY=TRUE, USE.NAMES=TRUE)`: Like the standard `mapply` function defined in the base package, the `mapply` method for GRangesList objects is a multivariate version of `sapply`.

`mendoapply(FUN, ..., MoreArgs = NULL)`: Similar to `mapply`, but performs an endomorphism across multiple objects, i.e. returns an object of `class(list(...)[[1]])`.

`Reduce(f, x, init, right = FALSE, accumulate = FALSE)`: Uses a binary function to successively combine the elements of `x` and a possibly given initial value.

`f` A binary argument function.

`init` An R object of the same kind as the elements of `x`.

`right` A logical indicating whether to proceed from left to right (default) or from right to left.

`nomatch` The value to be returned in the case when "no match" (no element satisfying the predicate) is found.

`sapply(X, FUN, ..., simplify=TRUE, USE.NAMES=TRUE)`: Like the standard `sapply` function defined in the base package, the `sapply` method for GRangesList objects is a user-friendly version of `lapply` by default returning a vector or matrix if appropriate.

## Author(s)

P. Aboyoun & H. Pagès

## See Also

- GRanges objects.
- seqinfo in the **Seqinfo** package.
- IntegerRangesList objects in the **IRanges** package.
- RleList objects in the **IRanges** package.
- DataFrameList objects in the **IRanges** package.
- intra-range-methods, inter-range-methods, coverage-methods, setops-methods, and findOverlaps-methods.
- GenomicRangesList objects.

## Examples

```
## Construction with GRangesList():
gr1 <- GRanges("chr2", IRanges(3, 6),
               strand="+", score=5L, GC=0.45)
gr2 <- GRanges(c("chr1", "chr1"), IRanges(c(7,13), width=3),
               strand=c("+", "-"), score=3:4, GC=c(0.3, 0.5))
gr3 <- GRanges(c("chr1", "chr2"), IRanges(c(1, 4), c(3, 9)),
               strand=c("-", "-"), score=c(6L, 2L), GC=c(0.4, 0.1))
grl <- GRangesList(gr1=gr1, gr2=gr2, gr3=gr3)
grl

## Summarizing elements:
elementNROWS(grl)
table(seqnames(grl))

## Extracting subsets:
grl[seqnames(grl) == "chr1", ]
grl[seqnames(grl) == "chr1" & strand(grl) == "+", ]

## Renaming the underlying sequences:
seqlevels(grl)
seqlevels(grl) <- sub("chr", "Chrom", seqlevels(grl))
grl

## Coerce to IRangesList (seqnames and strand information is lost):
as(grl, "IRangesList")

## isDisjoint():
isDisjoint(grl)

## disjoin():
disjoin(grl)  # metadata columns and order NOT preserved

## Construction with makeGRangesListFromFeatureFragments():
filepath <- system.file("extdata", "feature_frags.txt",
                        package="GenomicRanges")
featfrags <- read.table(filepath, header=TRUE, stringsAsFactors=FALSE)
grl2 <- with(featfrags,
             makeGRangesListFromFeatureFragments(seqnames=targetName,
```

```
                                                    fragmentStarts=targetStart,
                                                    fragmentWidths=blockSizes,
                                                    strand=strand))
names(grl2) <- featfrags$RefSeqID
grl2
```

---

`inter-range-methods` *Inter range transformations of a GRanges or GRangesList object*

---

## Description

This man page documents *inter range transformations* of a GenomicRanges object (i.e. of an object that belongs to the GenomicRanges class or one of its subclasses, this includes for example GRanges objects), or a GRangesList object.

See ?`intra-range-methods` and ?`inter-range-methods` in the **IRanges** package for a quick introduction to *intra range* and *inter range transformations*.

See ?`intra-range-methods` for *intra range transformations* of a GenomicRanges object or GRangesList object.

## Usage

```
## S4 method for signature 'GenomicRanges'
range(x, ..., with.revmap=FALSE, ignore.strand=FALSE, na.rm=FALSE)
## S4 method for signature 'GRangesList'
range(x, ..., with.revmap=FALSE, ignore.strand=FALSE, na.rm=FALSE)

## S4 method for signature 'GenomicRanges'
reduce(x, drop.empty.ranges=FALSE, min.gapwidth=1L, with.revmap=FALSE,
          with.inframe.attrib=FALSE, ignore.strand=FALSE)
## S4 method for signature 'GRangesList'
reduce(x, drop.empty.ranges=FALSE, min.gapwidth=1L, with.revmap=FALSE,
          with.inframe.attrib=FALSE, ignore.strand=FALSE)

## S4 method for signature 'GenomicRanges'
gaps(x, start=1L, end=seqlengths(x), ignore.strand=FALSE)

## S4 method for signature 'GenomicRanges'
disjoin(x, with.revmap=FALSE, ignore.strand=FALSE)
## S4 method for signature 'GRangesList'
disjoin(x, with.revmap=FALSE, ignore.strand=FALSE)

## S4 method for signature 'GenomicRanges'
isDisjoint(x, ignore.strand=FALSE)
## S4 method for signature 'GRangesList'
isDisjoint(x, ignore.strand=FALSE)

## S4 method for signature 'GenomicRanges'
disjointBins(x, ignore.strand=FALSE)
```

## Arguments

| | |
|---|---|
| x | A GenomicRanges or GenomicRangesList object. |
| drop.empty.ranges, min.gapwidth, with.revmap, with.inframe.attrib, start, end | See ?`inter-range-methods` in the **IRanges** package. |
| ignore.strand | TRUE or FALSE. Whether the strand of the input ranges should be ignored or not. See details below. |
| ... | For range, additional GenomicRanges objects to consider. Ignored otherwise. |
| na.rm | Ignored. |

## Details

**On a GRanges object:** range returns an object of the same type as x containing range bounds for each distinct (seqname, strand) pairing. The names (names(x)) and the metadata columns in x are dropped.

reduce returns an object of the same type as x containing reduced ranges for each distinct (seqname, strand) pairing. The names (names(x)) and the metadata columns in x are dropped. See ?reduce for more information about range reduction and for a description of the optional arguments.

gaps returns an object of the same type as x containing complemented ranges for each distinct (seqname, strand) pairing. The names (names(x)) and the metadata columns in x are dropped. For the start and end arguments of this gaps method, it is expected that the user will supply a named integer vector (where the names correspond to the appropriate seqlevels). See ?gaps for more information about range complements and for a description of the optional arguments.

disjoin returns an object of the same type as x containing disjoint ranges for each distinct (seqname, strand) pairing. The names (names(x)) and the metadata columns in x are dropped. If with.revmap=TRUE, a metadata column that maps the ouput ranges to the input ranges is added to the returned object. See ?disjoin for more information.

isDisjoint returns a logical value indicating whether the ranges in x are disjoint (i.e. non-overlapping).

disjointBins returns bin indexes for the ranges in x, such that ranges in the same bin do not overlap. If ignore.strand=FALSE, the two features cannot overlap if they are on different strands.

**On a GRangesList/GenomicRangesList object:** When they are supported on GRangesList object x, the above inter range transformations will apply the transformation to each of the list elements in x and return a list-like object *parallel* to x (i.e. with 1 list element per list element in x). If x has names on it, they're propagated to the returned object.

## Author(s)

H. Pagès and P. Aboyoun

## See Also

- The GenomicRanges and GRanges classes.
- The IntegerRanges class in the **IRanges** package.

- The inter-range-methods man page in the **IRanges** package.
- GenomicRanges-comparison for comparing and ordering genomic ranges.
- `endoapply` in the **S4Vectors** package.

## Examples

```
gr <- GRanges(
        seqnames=Rle(paste("chr", c(1, 2, 1, 3), sep="")), c(1, 3, 2, 4)),
        ranges=IRanges(1:10, width=10:1, names=letters[1:10]),
        strand=Rle(strand(c("-", "+", "*", "+", "-")), c(1, 2, 2, 3, 2)),
        score=1:10,
        GC=seq(1, 0, length=10)
      )
gr

gr1 <- GRanges(seqnames="chr2", ranges=IRanges(3, 6),
               strand="+", score=5L, GC=0.45)
gr2 <- GRanges(seqnames="chr1",
               ranges=IRanges(c(10, 7, 19), width=5),
               strand=c("+", "-", "+"), score=3:5, GC=c(0.3, 0.5, 0.66))
gr3 <- GRanges(seqnames=c("chr1", "chr2"),
               ranges=IRanges(c(1, 4), c(3, 9)),
               strand=c("-", "-"), score=c(6L, 2L), GC=c(0.4, 0.1))
grl <- GRangesList(gr1=gr1, gr2=gr2, gr3=gr3)
grl

## ---------------------------------------------------------------------
## range()
## ---------------------------------------------------------------------

## On a GRanges object:
range(gr)
range(gr, with.revmap=TRUE)

## On a GRangesList object:
range(grl)
range(grl, ignore.strand=TRUE)
range(grl, with.revmap=TRUE, ignore.strand=TRUE)

# ---------------------------------------------------------------------
## reduce()
## ---------------------------------------------------------------------
reduce(gr)

gr2 <- reduce(gr, with.revmap=TRUE)
revmap <- mcols(gr2)$revmap  # an IntegerList

## Use the mapping from reduced to original ranges to group the original
## ranges by reduced range:
relist(gr[unlist(revmap)], revmap)

## Or use it to split the DataFrame of original metadata columns by
```

```
## reduced range:
relist(mcols(gr)[unlist(revmap), ], revmap)  # a SplitDataFrameList

## [For advanced users] Use this reverse mapping to compare the reduced
## ranges with the ranges they originate from:
expanded_gr2 <- rep(gr2, elementNROWS(revmap))
reordered_gr <- gr[unlist(revmap)]
codes <- pcompare(expanded_gr2, reordered_gr)
## All the codes should translate to "d", "e", "g", or "h" (the 4 letters
## indicating that the range on the left contains the range on the right):
alphacodes <-
    rangeComparisonCodeToLetter(pcompare(expanded_gr2, reordered_gr))
stopifnot(all(alphacodes %in% c("d", "e", "g", "h")))

## On a big GRanges object with a lot of seqlevels:
mcols(gr) <- NULL
biggr <- c(gr, GRanges("chr1", IRanges(c(4, 1), c(5, 2)), strand="+"))
seqlevels(biggr) <- paste0("chr", 1:2000)
biggr <- rep(biggr, 25000)
set.seed(33)
seqnames(biggr) <-
    sample(factor(seqlevels(biggr), levels=seqlevels(biggr)),
           length(biggr), replace=TRUE)

biggr2 <- reduce(biggr, with.revmap=TRUE)
revmap <- mcols(biggr2)$revmap
expanded_biggr2 <- rep(biggr2, elementNROWS(revmap))
reordered_biggr <- biggr[unlist(revmap)]
codes <- pcompare(expanded_biggr2, reordered_biggr)
alphacodes <-
    rangeComparisonCodeToLetter(pcompare(expanded_biggr2, reordered_biggr))
stopifnot(all(alphacodes %in% c("d", "e", "g", "h")))
table(alphacodes)

## On a GRangesList object:
reduce(grl)  # Doesn't really reduce anything but note the reordering
             # of the inner elements in the 2nd and 3rd list elements:
             # the ranges are reordered by sequence name first (which
             # should appear in the same order as in 'seqlevels(grl)'),
             # and then by strand.
reduce(grl, ignore.strand=TRUE)  # 2nd list element got reduced

## -------------------------------------------------------------------------
## gaps()
## -------------------------------------------------------------------------
gaps(gr, start=3, end=12)
gaps(gr, start=3, end=12, ignore.strand=TRUE)

## Note that if the lengths of the underlying sequences are known, then
## by default 'gaps(gr)' returns the regions of the sequences that are
## not covered by 'gr':
seqlengths(gr)  # lengths of underlying sequences are not known
seqlengths(gr) <- c(chr1=50, chr2=30, chr3=18)
```

```
gaps(gr)

gaps(gr, ignore.strand=TRUE)

## ---------------------------------------------------------------------
## disjoin(), isDisjoint(), disjointBins()
## ---------------------------------------------------------------------
disjoin(gr)
disjoin(gr, with.revmap=TRUE)
disjoin(gr, with.revmap=TRUE, ignore.strand=TRUE)
isDisjoint(gr)
stopifnot(isDisjoint(disjoin(gr)))
disjointBins(gr)
stopifnot(all(sapply(split(gr, disjointBins(gr)), isDisjoint)))

## On a GRangesList object:
disjoin(grl)  # doesn't really disjoin anything but note the reordering
disjoin(grl, with.revmap=TRUE)
```

---

`intra-range-methods` *Intra range transformations of a GRanges or GRangesList object*

---

## Description

This man page documents *intra range transformations* of a GenomicRanges object (i.e. of an object that belongs to the GenomicRanges class or one of its subclasses, this includes for example GRanges objects), or a GRangesList object.

See ?`intra-range-methods` and ?`inter-range-methods` in the **IRanges** package for a quick introduction to *intra range* and *inter range transformations*.

*Intra range* methods for GAlignments and GAlignmentsList objects are defined and documented in the **GenomicAlignments** package.

See ?`inter-range-methods` for *inter range transformations* of a GenomicRanges or GRangesList object.

## Usage

```
## S4 method for signature 'GenomicRanges'
shift(x, shift=0L, use.names=TRUE)

## S4 method for signature 'GenomicRanges'
narrow(x, start=NA, end=NA, width=NA, use.names=TRUE)

## S4 method for signature 'GenomicRanges'
resize(x, width, fix="start", use.names=TRUE, ignore.strand=FALSE)

## S4 method for signature 'GenomicRanges'
```

```
flank(x, width, start=TRUE, both=FALSE, use.names=TRUE,
      ignore.strand=FALSE)

## S4 method for signature 'GenomicRanges'
promoters(x, upstream=2000, downstream=200, use.names=TRUE)
## S4 method for signature 'GenomicRanges'
terminators(x, upstream=2000, downstream=200, use.names=TRUE)

## S4 method for signature 'GenomicRanges'
restrict(x, start=NA, end=NA, keep.all.ranges=FALSE, use.names=TRUE)

## S4 method for signature 'GenomicRanges'
trim(x, use.names=TRUE)
```

## Arguments

| | |
|---|---|
| x | A GenomicRanges object. |
| shift, use.names, start, end, width, both, fix, keep.all.ranges, upstream, downstream | See ?`intra-range-methods`. |
| ignore.strand | TRUE or FALSE. Whether the strand of the input ranges should be ignored or not. See details below. |

## Details

**shift:** behaves like the shift method for IntegerRanges objects. See ?`intra-range-methods` for the details.

**narrow:** on a GenomicRanges object behaves like on an IntegerRanges object. See ?`intra-range-methods` for the details.

A major difference though is that it returns a GenomicRanges object instead of an IntegerRanges object. The returned object is *parallel* (i.e. same length and names) to the original object x.

**resize:** returns an object of the same type and length as x containing intervals that have been resized to width width based on the strand(x) values. Elements where strand(x) == "+" or strand(x) == "*" are anchored at start(x) and elements where strand(x) == "-" are anchored at the end(x). The use.names argument determines whether or not to keep the names on the ranges.

**flank:** returns an object of the same type and length as x containing intervals of width width that flank the intervals in x. The start argument takes a logical indicating whether x should be flanked at the "start" (TRUE) or the "end" (FALSE), which for strand(x) != "-" is start(x) and end(x) respectively and for strand(x) == "-" is end(x) and start(x) respectively. The both argument takes a single logical value indicating whether the flanking region width positions extends *into* the range. If both=TRUE, the resulting range thus straddles the end point, with width positions on either side.

**promoters:** assumes that the ranges in x represent transcript regions and returns the ranges of the corresponding promoter regions. The result is another GenomicRanges derivative *parallel* to

the input, that is, of the same length as x and with the i-th element in the output corresponding to the i-th element in the input.

The promoter regions extend around the transcription start sites (TSS) which are located at `start(x)` for ranges on the `+` or `*` strand, and at `end(x)` for ranges on the `-` strand. The `upstream` and `downstream` arguments define the number of nucleotides in the 5' and 3' direction, respectively. More precisely, the output range is defined as

```
(start(x) - upstream) to (start(x) + downstream - 1)
```

for ranges on the `+` or `*` strand, and as

```
(end(x) - downstream + 1) to (end(x) + upstream)
```

for ranges on the `-` strand.

Be aware that the returned object might contain *out-of-bound* ranges i.e. ranges that start before the first nucleotide position and/or end after the last nucleotide position of the underlying sequence.

The returned object will always have the same class as x, except when x is a GPos object in which case a GRanges instance is returned.

`terminators`: like `promoters` but returns the ranges of the terminator regions. These regions extend around the transcription end sites (TES) which are located at `end(x)` for ranges on the `+` or `*` strand, and at `start(x)` for ranges on the `-` strand.

`restrict`: returns an object of the same type and length as x containing restricted ranges for distinct seqnames. The `start` and `end` arguments can be a named numeric vector of seqnames for the ranges to be resticted or a numeric vector or length 1 if the restriction operation is to be applied to all the sequences in x. See `?`intra-range-methods`` for more information about range restriction and for a description of the optional arguments.

`trim`: trims out-of-bound ranges located on non-circular sequences whose length is not NA.

## Author(s)

P. Aboyoun, V. Obenchain, and H. Pagès

## See Also

- GenomicRanges, GRanges, and GRangesList objects.
- The intra-range-methods man page in the **IRanges** package.
- The IntegerRanges class in the **IRanges** package.

## Examples

```
## ---------------------------------------------------------------------
## A. ON A GRanges OBJECT
## ---------------------------------------------------------------------
gr <- GRanges(
        seqnames=Rle(paste("chr", c(1, 2, 1, 3), sep="")), c(1, 3, 2, 4)),
        ranges=IRanges(1:10, width=10:1, names=letters[1:10]),
        strand=Rle(strand(c("-", "+", "*", "+", "-")), c(1, 2, 2, 3, 2)),
```

```
        score=1:10,
        GC=seq(1, 0, length=10)
      )
gr

shift(gr, 1)
narrow(gr[-10], start=2, end=-2)
resize(gr, width=10)
flank(gr, width=10)
restrict(gr, start=3, end=7)

gr <- GRanges("chr1", IRanges(rep(10, 3), width=8), c("+", "-", "*"))
promoters(gr, 2, 5)
promoters(gr, upstream=0, downstream=1)  # TSS
terminators(gr, 2, 5)
terminators(gr, upstream=0, downstream=1)  # TES

## ---------------------------------------------------------------------
## B. ON A GRangesList OBJECT
## ---------------------------------------------------------------------
gr1 <- GRanges("chr2", IRanges(3, 6))
gr2 <- GRanges(c("chr1", "chr1"), IRanges(c(7,13), width=3),
               strand=c("+", "-"))
gr3 <- GRanges(c("chr1", "chr2"), IRanges(c(1, 4), c(3, 9)),
               strand="-")
grl <- GRangesList(gr1= gr1, gr2=gr2, gr3=gr3)
grl

resize(grl, width=20)
flank(grl, width=20)
restrict(grl, start=3)
```

---

`makeGRangesFromDataFrame` *Make a GRanges object from a data.frame or DataFrame*

---

## Description

`makeGRangesFromDataFrame` and `makeGPosFromDataFrame` both take a data-frame-like object as input and try to automatically find the columns that describe genomic ranges (for `makeGRangesFromDataFrame`) or genomic positions (for `makeGPosFromDataFrame`). If successful, they return them in a GRanges or GPos object.

The two functions are also the workhorses behind the coercion methods from data.frame (or DataFrame) to GRanges or GPos.

## Usage

```
makeGRangesFromDataFrame(df, keep.extra.columns=FALSE,
        ignore.strand=FALSE, seqinfo=NULL,
```

```
        seqnames.field=c("seqnames", "seqname",
                         "chromosome", "chrom", "chr", "chromosome_name",
                         "seqid"),
        start.field="start",
        end.field=c("end", "stop"),
        strand.field="strand",
        starts.in.df.are.0based=FALSE,
        na.rm=FALSE)

makeGPosFromDataFrame(df, keep.extra.columns=FALSE,
        ignore.strand=FALSE, seqinfo=NULL,
        seqnames.field=c("seqnames", "seqname",
                         "chromosome", "chrom", "chr", "chromosome_name",
                         "seqid"),
        pos.field=c("pos", "position", "positions"),
        strand.field="strand",
        na.rm=FALSE)
```

## Arguments

| | |
|---|---|
| `df` | A data.frame or DataFrame object. If not, then the function first tries to turn `df` into a data frame with `as.data.frame(df)`. |
| `keep.extra.columns` | `TRUE` or `FALSE` (the default). If `TRUE`, then the columns in `df` that are not used to form the genomic ranges or genomic positions of the returned GRanges or GPos object are returned as metadata columns on the object. Otherwise, they are ignored.<br>Note that if `df` has a `width` column, then `makeGRangesFromDataFrame` will always ignore it. |
| `ignore.strand` | `TRUE` or `FALSE` (the default). If `TRUE`, then the strand of the returned GRanges or GPos object is set to `"*"`. |
| `seqinfo` | Either `NULL`, or a Seqinfo object, or a character vector of unique sequence names (a.k.a. *seqlevels*), or a named numeric vector of sequence lengths. When not `NULL`, `seqinfo` must be compatible with the genomic ranges in `df`, that is, it must have one entry for each unique sequence name represented in `df`. Note that it can have additional entries i.e. entries for seqlevels not represented in `df`. |
| `seqnames.field` | A character vector of recognized names for the column in `df` that contains the chromosome name (a.k.a. sequence name) associated with each genomic range. Only the first name in `seqnames.field` that is found in `colnames(df)` is used. If no one is found, then an error is raised. |
| `start.field` | A character vector of recognized names for the column in `df` that contains the start positions of the genomic ranges. Only the first name in `start.field` that is found in `colnames(df)` is used. If no one is found, then an error is raised. |
| `end.field` | A character vector of recognized names for the column in `df` that contains the end positions of the genomic ranges. Only the first name in `start.field` that is found in `colnames(df)` is used. If no one is found, then an error is raised. |

`pos.field` A character vector of recognized names for the column in `df` that contains the genomic positions to use to make the GPos object. Only the first name in `pos.field` that is found in `colnames(df)` is used. If no one is found, then an error is raised.

`strand.field` A character vector of recognized names for the column in `df` that contains the strand associated with each genomic range. Only the first name in `strand.field` that is found in `colnames(df)` is used. If no one is found or if `ignore.strand` is `TRUE`, then the strand of the returned GRanges object is set to `"*"`.

`starts.in.df.are.0based`
`TRUE` or `FALSE` (the default). If `TRUE`, then the start positions of the genomic ranges in `df` are considered to be *0-based* and are converted to *1-based* in the returned GRanges object. This feature is intended to make it more convenient to handle input that contains data obtained from resources using the "0-based start" convention. A notorious example of such resource is the UCSC Table Browser (`http://genome.ucsc.edu/cgi-bin/hgTables`).

`na.rm` `TRUE` or `FALSE` (the default).

If `TRUE`, then rows in the `df` with missing start, end, or position values (i.e. the value is `NA`) are ignored. Otherwise, they trigger an error.

## Value

A GRanges or GPos object.

If `na.rm` is set to `FALSE` (the default), then the returned object is guaranteed to have one element per row in the input. However, if `na.rm` is set to `TRUE`, then the length of the returned object can be less than `nrow(df)`.

If the `seqinfo` argument was supplied, the returned object will have exactly the seqlevels specified in `seqinfo` and in the same order. Otherwise, the seqlevels are ordered according to the output of the `rankSeqlevels` function (except if `df` contains the seqnames in the form of a factor or factor-Rle, in which case the `levels()` of the seqnames become the seqlevels of the returned object as-is, that is, without any re-ordering).

If `df` has non-automatic row names (i.e. `rownames(df)` is not `NULL` and is not `seq_len(nrow(df))`), then they will be used to set names on the returned GRanges or GPos object.

## Note

Coercing a data.frame or DataFrame `df` to GRanges (with `as(df, "GRanges")`), or calling `GRanges(df)`, are both equivalent to calling `makeGRangesFromDataFrame(df, keep.extra.columns=TRUE)`.

Coercing a data.frame or DataFrame `df` to GPos (with `as(df, "GPos")`) is equivalent to calling `makeGPosFromDataFrame(df, keep.extra.columns=TRUE)`.

## Author(s)

H. Pagès, based on a proposal by Kasper Daniel Hansen

## See Also

- GRanges and GPos objects.
- Seqinfo objects and the `rankSeqlevels` function in the **Seqinfo** package.
- The `makeGRangesListFromFeatureFragments` function for making a GRangesList object from a list of fragmented features.
- `makeIRangesFromDataFrame` in the **IRanges** package to make an IRanges object from a data.frame or DataFrame.
- DataFrame objects in the **S4Vectors** package.

## Examples

```
## ---------------------------------------------------------------------
## BASIC makeGRangesFromDataFrame() EXAMPLES
## ---------------------------------------------------------------------

df <- data.frame(chr="chr1", start=11:15, end=12:16,
                 strand=c("+","-","+","*","."), score=1:5)
df
makeGRangesFromDataFrame(df)  # strand value "." is replaced with "*"

## With NAs in range-defining columns:
df$start[5] <- df$end[2] <- NA
df
#makeGRangesFromDataFrame(df)  # error!
makeGRangesFromDataFrame(df, na.rm=TRUE)  # rows with NAs got dropped

## The strand column is optional:
df <- data.frame(chr="chr1", start=11:15, end=12:16, score=1:5)
makeGRangesFromDataFrame(df)

gr <- makeGRangesFromDataFrame(df, keep.extra.columns=TRUE)
gr2 <- as(df, "GRanges")  # equivalent to the above
stopifnot(identical(gr, gr2))
gr2 <- GRanges(df)        # equivalent to the above
stopifnot(identical(gr, gr2))

makeGRangesFromDataFrame(df, ignore.strand=TRUE)
makeGRangesFromDataFrame(df, keep.extra.columns=TRUE,
                             ignore.strand=TRUE)

makeGRangesFromDataFrame(df, seqinfo=paste0("chr", 4:1))
makeGRangesFromDataFrame(df, seqinfo=c(chrM=NA, chr1=500, chrX=100))
makeGRangesFromDataFrame(df, seqinfo=Seqinfo(paste0("chr", 4:1)))

## ---------------------------------------------------------------------
## BASIC makeGPosFromDataFrame() EXAMPLES
## ---------------------------------------------------------------------

df <- data.frame(
    rsids=    c("rs7927381", "rs79273813", "rs79273815",
```

```
                "rs79273819", "rs79273817", "rs79273811", "rs79273814"),
    seqnames= c("11", "1", "11", "1", "5", "8", "8"),
    positions=c("67579271", "179599437", "70746832",
                "5066529", "107006951", "95077418", "43582071"),
    alleles=  c("T/C", "A/G", "C/G, C/T", "G/A, G/C", "T/C, T/G",
                "G/A, G/T", "G/A, G/T"),
    genes=    c(NA, "TDRD5", "SHANK2", NA, "LOC102467213", "NDUFAF6", NA),
    row.names=letters[1:7]
)

makeGPosFromDataFrame(df)
makeGPosFromDataFrame(df, keep.extra.columns=TRUE)
as(df, "GPos")  # same as above

## With missing positions:
df$positions[2L] <- NA
df
#makeGPosFromDataFrame(df)  # error!
makeGPosFromDataFrame(df, na.rm=TRUE)  # rows with NAs got dropped

## ---------------------------------------------------------------------
## ABOUT AUTOMATIC DETECTION OF THE seqnames/start/end/strand COLUMNS
## ---------------------------------------------------------------------

## Automatic detection of the seqnames/start/end/strand columns is
## case insensitive:
df <- data.frame(ChRoM="chr1", StarT=11:15, stoP=12:16,
                 STRAND=c("+","-","+","*","."), score=1:5)
makeGRangesFromDataFrame(df)

## It also ignores a common prefix between the start and end columns:
df <- data.frame(seqnames="chr1", tx_start=11:15, tx_end=12:16,
                 strand=c("+","-","+","*","."), score=1:5)
makeGRangesFromDataFrame(df)

## The common prefix between the start and end columns is used to
## disambiguate between more than one seqnames column:
df <- data.frame(chrom="chr1", tx_start=11:15, tx_end=12:16,
                 tx_chr="chr2", score=1:5)
makeGRangesFromDataFrame(df)

## ---------------------------------------------------------------------
## 0-BASED VS 1-BASED START POSITIONS
## ---------------------------------------------------------------------

if (require(UCSC.utils)) {
  ## Use list_UCSC_tracks() to lookup the primary table associated with
  ## a given track:
  subset(list_UCSC_tracks("sacCer2"), track == "Assembly")

  df <- fetch_UCSC_track_data("sacCer2", primary_table="gold")
  head(df)
```

```
  ## A common pitfall is to forget that UCSC uses the "0-based start"
  ## convention to store genomic ranges in their databases:
  gr0 <- makeGRangesFromDataFrame(df, keep.extra.columns=TRUE,
                                      start.field="chromStart",
                                      end.field="chromEnd")
  head(gr0)

  ## The start positions need to be converted into 1-based positions,
  ## to adhere to the convention used in Bioconductor:
  gr1 <- makeGRangesFromDataFrame(df, keep.extra.columns=TRUE,
                                      start.field="chromStart",
                                      end.field="chromEnd",
                                      starts.in.df.are.0based=TRUE)
  head(gr1)

  ## IMPORTANT NOTE: The start positions in the "fragStart" metadata
  ## column are still 0-based! That's because using
  ## 'keep.extra.columns=TRUE' only takes care of converting the
  ## start positions of the genomic ranges that define the GRanges
  ## object itself, but it doesn't meddle with its metadata columns.
}
```

---

`makeGRangesListFromDataFrame` *Make a GRangesList object from a data.frame or DataFrame*

---

## Description

`makeGRangesListFromDataFrame` extends the makeGRangesFromDataFrame functionality from `GenomicRanges`. It can take a data-frame-like object as input and tries to automatically find the columns that describe the genomic ranges. It returns a GRangesList object. This is different from the `makeGRangesFromDataFrame` function by requiring a `split.field`. The `split.field` acts like the "f" argument in the `split` function. This factor must be of the same length as the number of rows in the `DataFrame` argument. The `split.field` may also be a character vector.

## Usage

```
makeGRangesListFromDataFrame(df,
                             split.field = NULL,
                             names.field = NULL,
                             ...)
```

## Arguments

| | |
|---|---|
| `df` | A `DataFrame` or `data.frame` class object |
| `split.field` | A character string of a recognized column name in `df` that contains the grouping. This column defines how the rows of `df` are split and is typically a `factor` or `character` vector. When `split.field` is not provided the `df` will be split by the number of rows. |

| | |
|---|---|
| names.field | An optional single character string indicating the name of the column in df that designates the names for the ranges in the elements of the GRangesList. |
| ... | Additional arguments passed on to makeGRangesFromDataFrame |

## Value

A GRangesList of the same length as the number of levels or unique character strings in the df column indicated by split.field. When split.field is not provided the df is split by row and the resulting GRangesList has the same length as nrow(df).

Names on the individual ranges are taken from the names.field argument. Names on the outer list elements of the GRangesList are propagated from split.field.

## Author(s)

M. Ramos

## See Also

- makeGRangesFromDataFrame

## Examples

```
## ---------------------------------------------------------------------
## BASIC EXAMPLES
## ---------------------------------------------------------------------

df <- data.frame(chr="chr1", start=11:15, end=12:16,
                 strand=c("+","-","+","*","."), score=1:5,
                 specimen = c("a", "a", "b", "b", "c"),
                 gene_symbols = paste0("GENE", letters[1:5]))
df

grl <- makeGRangesListFromDataFrame(df, split.field = "specimen",
                                    names.field = "gene_symbols")
grl
names(grl)

## Keep metadata columns
makeGRangesListFromDataFrame(df, split.field = "specimen",
                             keep.extra.columns = TRUE)
```

---

# nearest-methods *Finding the nearest genomic range/position neighbor*

---

## Description

The nearest, precede, follow, distance, nearestKNeighbors, and distanceToNearest methods for GenomicRanges objects and subclasses.

## Usage

```
## S4 method for signature 'GenomicRanges,GenomicRanges'
precede(x, subject,
    select=c("first", "all"), ignore.strand=FALSE)
## S4 method for signature 'GenomicRanges,missing'
precede(x, subject,
    select=c("first", "all"), ignore.strand=FALSE)

## S4 method for signature 'GenomicRanges,GenomicRanges'
follow(x, subject,
    select=c("last", "all"), ignore.strand=FALSE)
## S4 method for signature 'GenomicRanges,missing'
follow(x, subject,
    select=c("last", "all"), ignore.strand=FALSE)

## S4 method for signature 'GenomicRanges,GenomicRanges'
nearest(x, subject,
    select=c("arbitrary", "all"), ignore.strand=FALSE)
## S4 method for signature 'GenomicRanges,missing'
nearest(x, subject,
    select=c("arbitrary", "all"), ignore.strand=FALSE)

## S4 method for signature 'GenomicRanges,GenomicRanges'
nearestKNeighbors(x, subject, k=1L,
    select=c("arbitrary", "all"), ignore.strand=FALSE)
## S4 method for signature 'GenomicRanges,missing'
nearestKNeighbors(x, subject, k=1L,
    select=c("arbitrary", "all"), ignore.strand=FALSE)

## S4 method for signature 'GenomicRanges,GenomicRanges'
distanceToNearest(x, subject,
    ignore.strand=FALSE, ...)
## S4 method for signature 'GenomicRanges,missing'
distanceToNearest(x, subject,
    ignore.strand=FALSE, ...)

## S4 method for signature 'GenomicRanges,GenomicRanges'
distance(x, y,
    ignore.strand=FALSE, ...)
```

## Arguments

| | |
|---|---|
| x | The query GenomicRanges instance. |
| subject | The subject GenomicRanges instance within which the nearest neighbors are found. Can be missing, in which case x is also the subject. |
| y | For the distance method, a GRanges instance. Cannot be missing. If x and y are not the same length, the shortest will be recycled to match the length of the longest. |

| | |
|---|---|
| k | For the nearestKNeighbors method, an integer declaring how many nearest neighbors to find. |
| select | Logic for handling ties. By default, all methods select a single interval (arbitrary for nearest, the first by order in subject for precede, and the last for follow).<br>When select="all" a Hits object is returned with all matches for x. |
| ignore.strand | A logical indicating if the strand of the input ranges should be ignored. When TRUE, strand is set to '+'. |
| ... | Additional arguments for methods. |

## Details

**nearest:** Performs conventional nearest neighbor finding. Returns an integer vector containing the index of the nearest neighbor range in subject for each range in x. If there is no nearest neighbor NA is returned. For details of the algorithm see the man page in the **IRanges** package (?nearest).

**precede:** For each range in x, precede returns the index of the range in subject that is directly preceded by the range in x. Overlapping ranges are excluded. NA is returned when there are no qualifying ranges in subject.

**follow:** The opposite of precede, follow returns the index of the range in subject that is directly followed by the range in x. Overlapping ranges are excluded. NA is returned when there are no qualifying ranges in subject.

**nearestKNeighbors:** Performs conventional k-nearest neighbor finding. Returns an IntegerList containing the index of the k-nearest neighbors in subject for each range in x. If there is no nearest neighbor NA is returned. If select="all" is specified, ties will be included in the resulting IntegerList.

**Orientation and strand for precede and follow:** Orientation is 5' to 3', consistent with the direction of translation. Because positional numbering along a chromosome is from left to right and transcription takes place from 5' to 3', precede and follow can appear to have 'opposite' behavior on the + and - strand. Using positions 5 and 6 as an example, 5 precedes 6 on the + strand but follows 6 on the - strand.

The table below outlines the orientation when ranges on different strands are compared. In general, a feature on * is considered to belong to both strands. The single exception is when both x and subject are * in which case both are treated as +.

```
      x  |  subject  |  orientation
    -----+-----------+----------------
a)    +  |  +        |  --->
b)    +  |  -        |  NA
c)    +  |  *        |  --->
d)    -  |  +        |  NA
e)    -  |  -        |  <---
f)    -  |  *        |  <---
g)    *  |  +        |  --->
h)    *  |  -        |  <---
i)    *  |  *        |  --->  (the only situation where * arbitrarily means +)
```

**distanceToNearest:** Returns the distance for each range in x to its nearest neighbor in the subject.

`distance`**:** Returns the distance for each range in `x` to the range in `y`. The behavior of `distance` has changed in Bioconductor 2.12. See the man page `?distance` in the **IRanges** package for details.

## Value

For `nearest`, `precede` and `follow`, an integer vector of indices in `subject`, or a Hits if `select="all"`.

For `nearestKNeighbors`, an IntegerList of vertices in `subject`.

For `distanceToNearest`, a Hits object with a column for the `query` index (queryHits), `subject` index (subjectHits) and the `distance` between the pair.

For `distance`, an integer vector of distances between the ranges in `x` and `y`.

## Author(s)

P. Aboyoun and V. Obenchain

## See Also

- The GenomicRanges and GRanges classes.
- The IntegerRanges class in the **IRanges** package.
- The Hits class in the **S4Vectors** package.
- The nearest-methods man page in the **IRanges** package.
- findOverlaps-methods for finding just the overlapping ranges.
- The nearest-methods man page in the **GenomicFeatures** package.

## Examples

```
## ---------------------------------------------------------
## precede() and follow()
## ---------------------------------------------------------
query <- GRanges("A", IRanges(c(5, 20), width=1), strand="+")
subject <- GRanges("A", IRanges(rep(c(10, 15), 2), width=1),
                        strand=c("+", "+", "-", "-"))
precede(query, subject)
follow(query, subject)

strand(query) <- "-"
precede(query, subject)
follow(query, subject)

## ties choose first in order
query <- GRanges("A", IRanges(10, width=1), c("+", "-", "*"))
subject <- GRanges("A", IRanges(c(5, 5, 5, 15, 15, 15), width=1),
                        rep(c("+", "-", "*"), 2))
precede(query, subject)
precede(query, rev(subject))

## ignore.strand=TRUE treats all ranges as '+'
precede(query[1], subject[4:6], select="all", ignore.strand=FALSE)
```

```
precede(query[1], subject[4:6], select="all", ignore.strand=TRUE)

## ---------------------------------------------------------
## nearest()
## ---------------------------------------------------------
## When multiple ranges overlap an "arbitrary" range is chosen
query <- GRanges("A", IRanges(5, 15))
subject <- GRanges("A", IRanges(c(1, 15), c(5, 19)))
nearest(query, subject)

## select="all" returns all hits
nearest(query, subject, select="all")

## Ranges in 'x' will self-select when 'subject' is present
query <- GRanges("A", IRanges(c(1, 10), width=5))
nearest(query, query)

## Ranges in 'x' will not self-select when 'subject' is missing
nearest(query)

## ---------------------------------------------------------
## nearestKNeighbors()
## ---------------------------------------------------------
## Without an argument, k defaults to 1
query <- GRanges("A", IRanges(c(2, 5), c(8, 15)))
subject <- GRanges("A", IRanges(c(1, 4, 10, 15), c(5, 7, 12, 19)))
nearestKNeighbors(query, subject)

## Return multiple neighbors with k > 1
nearestKNeighbors(query, subject, k=3)

## select="all" returns all hits
nearestKNeighbors(query, subject, select="all")

## ---------------------------------------------------------
## distance(), distanceToNearest()
## ---------------------------------------------------------
## Adjacent, overlap, separated by 1
query <- GRanges("A", IRanges(c(1, 2, 10), c(5, 8, 11)))
subject <- GRanges("A", IRanges(c(6, 5, 13), c(10, 10, 15)))
distance(query, subject)

## recycling
distance(query[1], subject)

## zero-width ranges
zw <- GRanges("A", IRanges(4,3))
stopifnot(distance(zw, GRanges("A", IRanges(3,4))) == 0L)
sapply(-3:3, function(i)
    distance(shift(zw, i), GRanges("A", IRanges(4,3))))

query <- GRanges(c("A", "B"), IRanges(c(1, 5), width=1))
distanceToNearest(query, subject)
```

```
## distance() with GRanges and TxDb see the
## ?'distance,GenomicRanges,TxDb-method' man
## page in the GenomicFeatures package.
```

---

phicoef *Calculate the "phi coefficient" between two binary variables*

---

## Description

The phicoef function calculates the "phi coefficient" between two binary variables.

## Usage

```
phicoef(x, y=NULL)
```

## Arguments

| | |
|---|---|
| x, y | Two logical vectors of the same length. If y is not supplied, x must be a 2x2 integer matrix (or an integer vector of length 4) representing the contingency table of two binary variables. |

## Value

The "phi coefficient" between the two binary variables. This is a single numeric value ranging from -1 to +1.

## Author(s)

H. Pagès

## References

http://en.wikipedia.org/wiki/Phi_coefficient

## Examples

```
set.seed(33)
x <- sample(c(TRUE, FALSE), 100, replace=TRUE)
y <- sample(c(TRUE, FALSE), 100, replace=TRUE)
phicoef(x, y)
phicoef(rep(x, 10), c(rep(x, 9), y))

stopifnot(phicoef(table(x, y)) == phicoef(x, y))
stopifnot(phicoef(y, x) == phicoef(x, y))
stopifnot(phicoef(x, !y) == - phicoef(x, y))
stopifnot(phicoef(x, x) == 1)
```

setops-methods *Set operations on genomic ranges*

## Description

Performs set operations on GRanges and GRangesList objects.

NOTE: The punion, pintersect, psetdiff, and pgap generic functions and methods for IntegerRanges objects are defined and documented in the **IRanges** package.

## Usage

```
## Vector-wise set operations
## --------------------------

## S4 method for signature 'GenomicRanges,GenomicRanges'
union(x, y, ignore.strand=FALSE)

## S4 method for signature 'GenomicRanges,GenomicRanges'
intersect(x, y, ignore.strand=FALSE)

## S4 method for signature 'GenomicRanges,GenomicRanges'
setdiff(x, y, ignore.strand=FALSE)

## Element-wise (aka "parallel") set operations
## --------------------------------------------

## S4 method for signature 'GRanges,GRanges'
punion(x, y, fill.gap=FALSE, ignore.strand=FALSE)

## S4 method for signature 'GRanges,GRanges'
pintersect(x, y, drop.nohit.ranges=FALSE,
           ignore.strand=FALSE, strict.strand=FALSE)

## S4 method for signature 'GRanges,GRanges'
psetdiff(x, y, ignore.strand=FALSE)
```

## Arguments

| | |
|---|---|
| x, y | For union, intersect, and setdiff: 2 GenomicRanges objects or 2 GRangesList objects.<br>For punion and pintersect: 2 GRanges objects, or 1 GRanges object and 1 GRangesList object.<br>For psetdiff: x must be a GRanges object and y can be a GRanges or GRangesList object.<br>For pgap: 2 GRanges objects.<br>In addition, for the *parallel* operations, x and y must be of equal length (i.e. length(x) == length(y)). |

`fill.gap` Logical indicating whether or not to force a union by using the rule `start = min(start(x), start(y))`, `end = max(end(x), end(y))`.

`ignore.strand` For set operations: If set to TRUE, then the strand of `x` and `y` is set to `"*"` prior to any computation.

For parallel set operations: If set to TRUE, the strand information is ignored in the computation and the result has the strand information of `x`.

`drop.nohit.ranges`
If TRUE then elements in `x` that don't intersect with their corresponding element in `y` are removed from the result (so the returned object is no more parallel to the input).

If FALSE (the default) then nothing is removed and a `hit` metadata column is added to the returned object to indicate elements in `x` that intersect with the corresponding element in `y`. For those that don't, the reported intersection is a zero-width range that has the same start as `x`.

`strict.strand` If set to FALSE (the default), features on the `"*"` strand are treated as occurring on both the `"+"` and `"-"` strand. If set to TRUE, the strand of intersecting elements must be strictly the same.

## Details

The `pintersect` methods involving GRanges and/or GRangesList objects use the triplet (sequence name, range, strand) to determine the element by element intersection of features, where a strand value of `"*"` is treated as occurring on both the `"+"` and `"-"` strand (unless `strict.strand` is set to TRUE, in which case the strand of intersecting elements must be strictly the same).

The `psetdiff` methods involving GRanges and/or GRangesList objects use the triplet (sequence name, range, strand) to determine the element by element set difference of features, where a strand value of `"*"` is treated as occurring on both the `"+"` and `"-"` strand.

## Value

For `union`, `intersect`, and `setdiff`: a GRanges object if `x` and `y` are GenomicRanges objects, and a GRangesList object if they are GRangesList objects.

For `punion` and `pintersect`: when `x` or `y` is not a GRanges object, an object of the same class as this non-GRanges object. Otherwise, a GRanges object.

For `psetdiff`: either a GRanges object when both `x` and `y` are GRanges objects, or a GRangesList object when `y` is a GRangesList object.

For `pgap`: a GRanges object.

## Author(s)

P. Aboyoun and H. Pagès

## See Also

- subtract for subtracting a set of genomic ranges from a GRanges object (similar to bedtools subtract).

- setops-methods in the **IRanges** package for set operations on IntegerRanges and IntegerRanges-List objects.
- findOverlaps-methods for finding/counting overlapping genomic ranges.
- intra-range-methods and inter-range-methods for *intra range* and *inter range* transformations of a GRanges object.
- GRanges and GRangesList objects.
- `mendoapply` in the **S4Vectors** package.

## Examples

```
## ---------------------------------------------------------------------
## A. SET OPERATIONS
## ---------------------------------------------------------------------

x <- GRanges("chr1", IRanges(c(2, 9) , c(7, 19)), strand=c("+", "-"))
y <- GRanges("chr1", IRanges(5, 10), strand="-")

union(x, y)
union(x, y, ignore.strand=TRUE)

intersect(x, y)
intersect(x, y, ignore.strand=TRUE)

setdiff(x, y)
setdiff(x, y, ignore.strand=TRUE)

## With 2 GRangesList objects:
gr1 <- GRanges(seqnames="chr2",
               ranges=IRanges(3, 6))
gr2 <- GRanges(seqnames=c("chr1", "chr1"),
               ranges=IRanges(c(7,13), width = 3),
               strand=c("+", "-"))
gr3 <- GRanges(seqnames=c("chr1", "chr2"),
               ranges=IRanges(c(1, 4), c(3, 9)),
               strand=c("-", "-"))
grlist <- GRangesList(gr1=gr1, gr2=gr2, gr3=gr3)

union(grlist, shift(grlist, 3))
intersect(grlist, shift(grlist, 3))
setdiff(grlist, shift(grlist, 3))

## Sanity checks:
grlist2 <- shift(grlist, 3)
stopifnot(identical(
    union(grlist, grlist2),
    mendoapply(union, grlist, grlist2)
))
stopifnot(identical(
    intersect(grlist, grlist2),
    mendoapply(intersect, grlist, grlist2)
))
```

```
stopifnot(identical(
    setdiff(grlist, grlist2),
    mendoapply(setdiff, grlist, grlist2)
))

## ---------------------------------------------------------------------
## B. PARALLEL SET OPERATIONS
## ---------------------------------------------------------------------

punion(x, shift(x, 6))
## Not run:
punion(x, shift(x, 7))  # will fail

## End(Not run)
punion(x, shift(x, 7), fill.gap=TRUE)

pintersect(x, shift(x, 6))
pintersect(x, shift(x, 7))

psetdiff(x, shift(x, 7))

## ---------------------------------------------------------------------
## C. MORE EXAMPLES
## ---------------------------------------------------------------------

## GRanges object:
gr <- GRanges(seqnames=c("chr2", "chr1", "chr1"),
              ranges=IRanges(1:3, width = 12),
              strand=Rle(strand(c("-", "*", "-"))))

## Parallel intersection of a GRanges and a GRangesList object
pintersect(gr, grlist)
pintersect(grlist, gr)

## For a fast 'mendoapply(intersect, grlist, as(gr, "GRangesList"))'
## call pintersect() with 'strict.strand=TRUE' and call reduce() on
## the result with 'drop.empty.ranges=TRUE':
reduce(pintersect(grlist, gr, strict.strand=TRUE),
       drop.empty.ranges=TRUE)

## Parallel set difference of a GRanges and a GRangesList object
psetdiff(gr, grlist)
```

---

`strand-utils` *Strand utilities*

---

## Description

A bunch of useful `strand` and `invertStrand` methods.

## Usage

```
## S4 method for signature 'missing'
strand(x)
## S4 method for signature 'character'
strand(x)
## S4 method for signature 'factor'
strand(x)
## S4 method for signature 'integer'
strand(x)
## S4 method for signature 'logical'
strand(x)
## S4 method for signature 'Rle'
strand(x)
## S4 method for signature 'RleList'
strand(x)
## S4 method for signature 'DataFrame'
strand(x)
## S4 replacement method for signature 'DataFrame,ANY'
strand(x) <- value

## S4 method for signature 'character'
invertStrand(x)
## S4 method for signature 'factor'
invertStrand(x)
## S4 method for signature 'integer'
invertStrand(x)
## S4 method for signature 'logical'
invertStrand(x)
## S4 method for signature 'Rle'
invertStrand(x)
## S4 method for signature 'RleList'
invertStrand(x)
```

## Arguments

| | |
|---|---|
| x | The object from which to obtain a *strand factor*, *strand factor Rle*, or *strand factor RleList* object. Can be missing. See Details and Value sections below for more information. |
| value | Replacement value for the strand. |

## Details

All the `strand` and `invertStrand` methods documented here return either a *strand factor*, *strand factor Rle*, or *strand factor RleList* object. These are factor, factor-Rle, or factor-RleList objects containing the "standard strand levels" (i.e. `+`, `-`, and `*`) and no NAs.

## Value

All the strand and invertStrand methods documented here return an object that is *parallel* to input object x when x is a character, factor, integer, logical, Rle, or RleList object.

For the strand methods:

- If x is missing, returns an empty factor with the "standard strand levels" i.e. +, -, and *.
- If x is a character vector or factor, it is coerced to a factor with the levels listed above. NA values in x are not accepted.
- If x is an integer vector, it is coerced to a factor with the levels listed above. 1, -1, and NA values in x are mapped to the +, -, and * levels respectively.
- If x is a logical vector, it is coerced to a factor with the levels listed above. FALSE, TRUE, and NA values in x are mapped to the +, -, and * levels respectively.
- If x is a character-, factor-, integer-, or logical-Rle, it is transformed with runValue(x) <- strand(runValue(x)) and returned.
- If x is an RleList object, each list element in x is transformed by calling strand() on it and the resulting RleList object is returned. More precisely the returned object is endoapply(x, strand). Note that in addition to being *parallel* to x, this object also has the same *shape* as x (i.e. its list elements have the same lengths as in x).
- If x is a DataFrame object, the "strand" column is passed thru strand() and returned. If x has no "strand" column, this return value is populated with *s.

Each invertStrand method returns the same object as its corresponding strand method but with "+" and "-" switched.

## Author(s)

M. Lawrence and H. Pagès

## See Also

strand

## Examples

```
strand()

x1 <- c("-", "*", "*", "+", "-", "*")
x2 <- factor(c("-", "-", "+", "-"))
x3 <- c(-1L, NA, NA, 1L, -1L, NA)
x4 <- c(TRUE, NA, NA, FALSE, TRUE, NA)

strand(x1)
invertStrand(x1)
strand(x2)
invertStrand(x2)
strand(x3)
invertStrand(x3)
strand(x4)
```

```
invertStrand(x4)

strand(Rle(x1))
invertStrand(Rle(x1))
strand(Rle(x2))
invertStrand(Rle(x2))
strand(Rle(x3))
invertStrand(Rle(x3))
strand(Rle(x4))
invertStrand(Rle(x4))

x5 <- RleList(x1, character(0), as.character(x2))
strand(x5)
invertStrand(x5)

strand(DataFrame(score=2:-3))
strand(DataFrame(score=2:-3, strand=x3))
strand(DataFrame(score=2:-3, strand=Rle(x3)))

## Sanity checks:
target <- strand(x1)
stopifnot(identical(target, strand(x3)))
stopifnot(identical(target, strand(x4)))

stopifnot(identical(Rle(strand(x1)), strand(Rle(x1))))
stopifnot(identical(Rle(strand(x2)), strand(Rle(x2))))
stopifnot(identical(Rle(strand(x3)), strand(Rle(x3))))
stopifnot(identical(Rle(strand(x4)), strand(Rle(x4))))
```

---

`subtract-methods` *Subtract a set of genomic ranges from a GRanges object*

---

## Description

Similar to bedtools subtract.

## Usage

```
subtract(x, y, minoverlap=1L, ...)

## S4 method for signature 'GenomicRanges,GenomicRanges'
subtract(x, y, minoverlap=1L, ignore.strand=FALSE)
```

## Arguments

| | |
|---|---|
| x, y | Two GRanges objects, typically, but any GenomicRanges derivative should be supported. Note that y gets immediately replaced with: `reduce(y, ignore.strand=ignore.strand)` |

internally.

`minoverlap` Minimum overlap (in number of genomic positions) between a range in `x` and a range in `reduce(y, ignore.strand=ignore.strand)` for the 2 ranges to be considered overlapping, and for their overlapping portion to be removed from the range in `x`.

`ignore.strand` If set to TRUE, the strand information is ignored in the computation and the strand of `x` is propagated to the result.

`...` Further arguments to be passed to specific methods.

## Details

`subtract()` first replaces its second argument `y` with:

```
reduce(y, ignore.strand=ignore.strand)
```

Then it searches for genomic ranges in `y` that overlap genomic ranges in `x` by at least the number of base pairs specified via the `minoverlap` argument. If an overlapping range is found in `y`, the overlapping portion is removed from any range in `x` involved in the overlap.

Note that by default `subtract(x, y)` is equivalent to:

```
psetdiff(x, rep(GRangesList(y), length(x)))
```

but will typically be hundred times more efficient.

## Value

A GRangesList object *parallel* to `x`, that is, with one list element per range in `x`. The names and metadata columns on `x` are propagated to the result.

## Author(s)

H. Pagès

## See Also

- bedtools subtract at https://bedtools.readthedocs.io/en/latest/content/tools/subtract.html
- setops-methods for set operations on GRanges objects.
- findOverlaps-methods for finding/counting overlapping genomic ranges.
- intra-range-methods and inter-range-methods for *intra range* and *inter range* transformations of a GRanges object.
- GRanges and GRangesList objects.

## Examples

```
x <- GRanges(c(A="chr1:1-50", B="chr1:40-110", C="chrX:1-500"))
y <- GRanges(c("chr1:21-25", "chr1:38-150"))
z <- subtract(x, y)
z

unlist(z)
```

---

tile-methods *Generate windows for a GenomicRanges*

---

## Description

tile and slidingWindows methods for GenomicRanges. tile partitions each range into a set of tiles, which are defined in terms of their number or width. slidingWindows generates sliding windows of a specified width and frequency.

## Usage

```
## S4 method for signature 'GenomicRanges'
tile(x, n, width)
## S4 method for signature 'GenomicRanges'
slidingWindows(x, width, step=1L)
```

## Arguments

| | |
|---|---|
| x | A GenomicRanges object, like a GRanges. |
| n | The number of tiles to generate. See ?tile in the **IRanges** package for more information about this argument. |
| width | The (maximum) width of each tile. See ?tile in the **IRanges** package for more information about this argument. |
| step | The distance between the start positions of the sliding windows. |

## Details

The tile function splits x into a GRangesList, each element of which corresponds to a tile, or partition, of x. Specify the tile geometry with either n or width (not both). Passing n creates n tiles of approximately equal width, truncated by sequence end, while passing width tiles the region with ranges of the given width, again truncated by sequence end.

The slidingWindows function generates sliding windows within each range of x, according to width and step, returning a GRangesList. If the sliding windows do not exactly cover a range in x, the last window is partial.

## Value

A GRangesList object, each element of which corresponds to a window.

## Author(s)

M. Lawrence

## See Also

`tile` in the **IRanges** package.

## Examples

```
gr <- GRanges(
        seqnames=Rle(c("chr1", "chr2", "chr1", "chr3"), c(1, 3, 2, 4)),
        ranges=IRanges(1:10, end=11),
        strand=Rle(strand(c("-", "+", "*", "+", "-")), c(1, 2, 2, 3, 2)),
        seqlengths=c(chr1=11, chr2=12, chr3=13))

# split every range in half
tiles <- tile(gr, n = 2L)
stopifnot(all(elementNROWS(tiles) == 2L))

# split ranges into subranges of width 2
# odd width ranges must contain one subrange of width 1
tiles <- tile(gr, width = 2L)
stopifnot(all(all(width(tiles) %in% c(1L, 2L))))

windows <- slidingWindows(gr, width=3L, step=2L)
width(windows[[1L]]) # last range is truncated
```

---

# tileGenome *Put (virtual) tiles on a given genome*

---

## Description

`tileGenome` returns a set of genomic regions that form a partitioning of the specified genome. Each region is called a "tile".

## Usage

```
tileGenome(seqlengths, ntile, tilewidth, cut.last.tile.in.chrom=FALSE)
```

## Arguments

| | |
|---|---|
| `seqlengths` | Either a named numeric vector of chromosome lengths or a Seqinfo object. More precisely, if a named numeric vector, it must have a length >= 1, cannot contain NAs or negative values, and cannot have duplicated names. If a Seqinfo object, then it's first replaced with the vector of sequence lengths stored in the object (extracted from the object with the `seqlengths` getter), then the restrictions described previously apply to this vector. |
| `ntile` | The number of tiles to generate. |

`tilewidth` The desired tile width. The effective tile width might be slightly different but is guaranteed to never be more than the desired width.

`cut.last.tile.in.chrom`
Whether or not to cut the last tile in each chromosome. This is set to `FALSE` by default. Can be set to `TRUE` only when `tilewidth` is specified. In that case, a tile will never overlap with more than 1 chromosome and a GRanges object is returned with one element (i.e. one genomic range) per tile.

## Value

If `cut.last.tile.in.chrom` is `FALSE` (the default), a GRangesList object with one list element per tile, each of them containing a number of genomic ranges equal to the number of chromosomes it overlaps with. Note that when the tiles are small (i.e. much smaller than the chromosomes), most of them only overlap with a single chromosome.

If `cut.last.tile.in.chrom` is `TRUE`, a GRanges object with one element (i.e. one genomic range) per tile.

## Author(s)

H. Pagès, based on a proposal by M. Morgan

## See Also

- genomicvars for an example of how to compute the binned average of a numerical variable defined along a genome.
- GRangesList and GRanges objects.
- Seqinfo objects and the `seqlengths` getter in the **Seqinfo** package.
- IntegerList objects.
- Views objects.

## Examples

```
## ---------------------------------------------------------------------
## A. WITH A TOY GENOME
## ---------------------------------------------------------------------

seqlengths <- c(chr1=60, chr2=20, chr3=25)

## Create 5 tiles:
tiles <- tileGenome(seqlengths, ntile=5)
tiles
elementNROWS(tiles)  # tiles 3 and 4 contain 2 ranges

width(tiles)
## Use sum() on this IntegerList object to get the effective tile
## widths:
sum(width(tiles))  # each tile covers exactly 21 genomic positions

## Create 9 tiles:
```

```
tiles <- tileGenome(seqlengths, ntile=9)
elementNROWS(tiles)  # tiles 6 and 7 contain 2 ranges

table(sum(width(tiles)))  # some tiles cover 12 genomic positions,
                          # others 11

## Specify the tile width:
tiles <- tileGenome(seqlengths, tilewidth=20)
length(tiles)  # 6 tiles
table(sum(width(tiles)))  # effective tile width is <= specified

## Specify the tile width and cut the last tile in each chromosome:
tiles <- tileGenome(seqlengths, tilewidth=24,
                    cut.last.tile.in.chrom=TRUE)
tiles
width(tiles)  # each tile covers exactly 24 genomic positions, except
              # the last tile in each chromosome

## Partition a genome by chromosome ("natural partitioning"):
tiles <- tileGenome(seqlengths, tilewidth=max(seqlengths),
                    cut.last.tile.in.chrom=TRUE)
tiles  # one tile per chromosome

## sanity check
stopifnot(all.equal(setNames(end(tiles), seqnames(tiles)), seqlengths))

## ---------------------------------------------------------------------
## B. WITH A REAL GENOME
## ---------------------------------------------------------------------

library(BSgenome.Scerevisiae.UCSC.sacCer2)
tiles <- tileGenome(seqinfo(Scerevisiae), ntile=20)
tiles

tiles <- tileGenome(seqinfo(Scerevisiae), tilewidth=50000,
                    cut.last.tile.in.chrom=TRUE)
tiles

## ---------------------------------------------------------------------
## C. AN APPLICATION: COMPUTE THE BINNED AVERAGE OF A NUMERICAL VARIABLE
##    DEFINED ALONG A GENOME
## ---------------------------------------------------------------------

## See '?genomicvars' for an example of how to compute the binned
## average of a numerical variable defined along a genome.
```

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