Package ‘GenomicTuples’

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Description GenomicTuples defines general purpose containers for storing genomic tuples. It aims to provide functionality for tuples of genomic co-ordinates that are analogous to those available for genomic ranges in the GenomicRanges Bioconductor package.

URL www.github.com/PeteHaitch/GenomicTuples

BugReports https://github.com/PeteHaitch/GenomicTuples/issues

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### GenomicTuples-package

*Representation and manipulation of genomic tuples.*

**Description**

**GenomicTuples** defines general purpose containers for storing genomic tuples. It aims to provide functionality for tuples of genomic co-ordinates that are analogous to those available for genomic ranges in the GenomicRanges Bioconductor package.

**Details**

Please refer to the vignettes to see how to use the **GenomicTuples** package.

**References**


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### findOverlaps-methods

*Finding overlapping genomic tuples*

**Description**

Finds tuple overlaps between a **GTuples** or **GTuplesList** object, and another object containing tuples or ranges.

**NOTE:** The **findOverlaps** generic function and methods for **Ranges** and **RangesList** objects are defined and documented in the **IRanges** package. The methods for **GenomicRanges** and **GRangesList** objects are defined and documented in the **GenomicRanges** package. The methods for **GAlignments**, **GAlignmentPairs**, and **GAlignmentsList** objects are defined and documented in the **GenomicAlignments** package.
Usage

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

```r
## S4 method for signature 'GTuples,GTuples'
countOverlaps(query, subject,
  maxgap = 0L, minoverlap = 1L,
  type = c("any", "start", "end", "within", "equal"),
  ignore.strand = FALSE)
```

```r
## S4 method for signature 'GTuples,GTuples'
overlapsAny(query, subject,
  maxgap = 0L, minoverlap = 1L,
  type = c("any", "start", "end", "within", "equal"),
  ignore.strand = FALSE)
```

```r
## S4 method for signature 'GTuples,GTuples'
subsetByOverlaps(query, subject,
  maxgap = 0L, minoverlap = 1L,
  type = c("any", "start", "end", "within", "equal"),
  ignore.strand = FALSE)
```

Arguments

- **query**, **subject**: A `GTuples` or `GTuplesList` object. `GRanges`, `GRangesList`, `RangesList` and `RangedData` are also accepted for one of query or subject.
- **type**: See details below.
- **maxgap**, **minoverlap**: See `findOverlaps` in the IRanges package for a description of these arguments. These arguments have no effect if both query and subject are `GTuples` objects and type = "equal".
- **select**: See `findOverlaps` in the IRanges package for a description of this argument.
- **ignore.strand**: When set to TRUE, the strand information is ignored in the overlap calculations.

Details

The `findOverlaps`-based methods involving genomic tuples, either through `GTuples` or `GTuplesList` objects, can search for `tuple-tuple`, `tuple-range` and `range-tuple` overlaps. Each of these are described below, with attention paid to the important special case of finding "equal tuple-tuple overlaps".

**Equal tuple-tuple overlaps** When the query and the subject are both `GTuples` objects and type = "equal", `findOverlaps` uses the `seqnames`, positions (`tuples`, `GTuples-method`) and strand (strand) to determine which tuples from the query exactly match those in the subject, where a strand value of "*" is treated as occurring on both the "+" and "-" strand. An overlap is recorded when a tuple in the query and a tuple in the subject have the same sequence name, have a compatible pairing of strands (e.g. "+/+", "-/-", "*/+", "*/-", etc.), and have identical positions.
NOTE: Equal tuple-tuple overlaps can only be computed if \( \text{size(query)} \) is equal to \( \text{size(subject)} \).

Other tuple-tuple overlaps When the query and the subject are \texttt{GTuples} or \texttt{GTuplesList} objects and type = "any", "start", "end" or "within", \texttt{findOverlaps} treats the tuples as if they were ranges, with ranges given by \([\text{pos}_1, \text{pos}_m]\) and where \( m \) is the size, \texttt{GTuples-method} of the tuples. This is done via inheritance so that a \texttt{GTuples} (resp. \texttt{GTuplesList}) object is treated as a \texttt{GRanges} (resp. \texttt{GRangesList}) and the appropriate \texttt{findOverlaps} method is dispatched upon.

NOTE: This is the only type of overlap finding available when either the query and subject are \texttt{GTuplesList} objects. This is following the behaviour of \texttt{findOverlaps}, \texttt{GRangesList}, \texttt{GRangesList-method} that allows type = "any", "start", "end" or "within" but does not allow type = "equal".

tuple-range and range-tuple overlaps When one of the query and the subject is not a \texttt{GTuples} or \texttt{GTuplesList} objects, \texttt{findOverlaps} treats the tuples as if they were ranges, with ranges given by \([\text{pos}_1, \text{pos}_m]\) and where \( m \) is the size, \texttt{GTuples-method} of the tuples. This is done via inheritance so that a \texttt{GTuples} (resp. \texttt{GTuplesList}) object is treated as a \texttt{GRanges} (resp. \texttt{GRangesList}) and the appropriate \texttt{findOverlaps} method is dispatched upon.

In the context of \texttt{findOverlaps}, a feature is a collection of tuples/ranges that are treated as a single entity. For \texttt{GTuples} objects, a feature is a single tuple; while for \texttt{GTuplesList} objects, a feature is a list element containing a set of tuples. In the results, the features are referred to by number, which run from 1 to length(query)/length(subject).

Value

For \texttt{findOverlaps} either a \texttt{Hits} object when select = "all" or an integer vector otherwise.

For \texttt{countOverlaps} an integer vector containing the tabulated query overlap hits.

For \texttt{overlapsAny} a logical vector of length equal to the number of tuples/ranges in query indicating those that overlap any of the tuples/ranges in subject.

For \texttt{subsetByOverlaps} an object of the same class as query containing the subset that overlapped at least one entity in subject.

For \texttt{RangedData} and \texttt{RangesList}, with the exception of \texttt{subsetByOverlaps}, the results align to the unlisted form of the object. This turns out to be fairly convenient for \texttt{RangedData} (not so much for \texttt{RangesList}, but something has to give).

Author(s)

Peter Hickey for methods involving \texttt{GTuples} and \texttt{GTuplesList}. P. Aboyoun, S. Falcon, M. Lawrence, N. Gopalakrishnan, H. Pages and H. Corrada Bravo for all the real work underlying the powerful \texttt{findOverlaps} functionality.

See Also

- Please see the package vignette for an extended discussion of overlaps involving genomic tuples, which is available by typing \texttt{vignette(topic = 'GenomicTuplesIntroduction', package = 'GenomicTuples')} at the R prompt.
- \texttt{findOverlaps}
- \texttt{findOverlaps}
- \texttt{Hits-class}
- \texttt{GTuples-class}
- \texttt{GTuplesList-class}
- \texttt{GRanges-class}
- \texttt{GRangesList-class}
Examples

## GTuples object containing 3-tuples:
```r
gt3 <- GTuples(seqnames = c('chr1', 'chr1', 'chr1', 'chr1', 'chr2'),
               tuples = matrix(c(10L, 10L, 10L, 10L, 10L, 20L, 20L, 20L, 25L,
                                 20L, 30L, 30L, 35L, 30L, 30L), ncol = 3),
               strand = c('+', '-', '*', '+', '+'))
```  
## GTuplesList object
```r
gtl3 <- GTuplesList(A = gt3[1:3], B = gt3[4:5])
```  
## Find equal genomic tuples:
```r
findOverlaps(gt3, gt3, type = 'equal')
```  
## Note that this is different to the results if the tuples are treated as ranges since this ignores the "internal positions" (pos2):
```r
findOverlaps(granges(gt3), granges(gt3), type = 'equal')
```  
## Scenarios where tuples are treated as ranges:
```r
findOverlaps(gt3, gt3, type = 'any')
findOverlaps(gt3, gt3, type = 'start')
findOverlaps(gt3, gt3, type = 'end')
findOverlaps(gt3, gt3, type = 'within')
```  
## Overlapping a GTuples and a GTuplesList object (tuples treated as ranges):
```r
table(!is.na(findOverlaps(gtl3, gt3, select="first")))
countOverlaps(gtl3, gt3)
findOverlaps(gtl3, gt3)
subsetByOverlaps(gtl3, gt3)
countOverlaps(gtl3, gt3, type = "start")
findOverlaps(gtl3, gt3, type = "start")
subsetByOverlaps(gtl3, gt3, type = "start")
findOverlaps(gtl3, gt3, select = "first")
```  
---

**GTuples-class**  

**GTuples objects**

**Description**

The GTuples class is a container for the genomic tuples and their associated annotations.

**Details**

GTuples extends GRanges as a container for genomic tuples rather than genomic ranges. GTuples is a vector of genomic locations and associated annotations. Each element in the vector is comprised of a sequence name, a tuple, 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.
- tuples: externally, a matrix-link object containing the tuples. Internally, an IRanges object storing the first and last position of each tuple and, if required, a matrix storing the "internal" positions of each tuple (see description of internalPos below).
- strand: a Rle Rle object containing the strand information.
mcols a DataFrame object containing the metadata columns. Columns cannot be named "seqnames",
"ranges", "tuples", "internalPos", "size", "strand", "seqlevels", "seqlengths", "isCircular",
"start", "end", "width", or "element".

seqinfo a DataFrame object containing information about the set of genomic sequences present
in the GTuples object.

Slots
Since the GTuples class extends the GRanges class it contains the seqnames, ranges, strand,
elementMetadata, seqinfo and metadata. The GTuples class also contains two additional slots,
size and internalPos.

size An integer. The size of the genomic tuples stored in the GTuples object.

internalPos If the size of the genomic tuples is greater than 2, internalPos is an integer matrix
storing the "internal" positions of each genomic tuple. Otherwise internalPos is NULL.

Constructor
GTuples(seqnames = Rle(), tuples = matrix(), strand = Rle("*", length(seqnames)), ..., seqleng-
Create a GTuples object.

seqnames Rle object, character vector, or factor containing the sequence names.
tuples matrix object containing the positions of the tuples. The first column should refer to
pos1, the second to pos2, etc.
strand Rle object, character vector, or factor containing the strand information.
... Optional metadata columns. These columns cannot be named "start", "end", "width",
or "element". A named integer vector "seqlength" can be used instead of seqinfo.
seqlengths an integer vector named with the sequence names and containing the lengths (or
NA) for each level(seqnames).
seqinfo a DataFrame object containing allowed sequence names and lengths (or NA) for each
level(seqnames).

Coercion
In the code snippets below, x is a GTuples object.

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

as.character(x, ignore.strand=FALSE): Turn GTuples object x into a character vector where
each tuples in x is represented by a string in format chr1:100,109,115:+. 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 chr1:100,109,115.
The names on x are propagated to the returned character vector. Its metadata (metadata(x))
and metadata columns (mcols(x)) are ignored.

as.factor(x): Equivalent to

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

as(x, "GRanges"), granges(x): Creates a GRanges object from a GTuples object. WARNING: This is generally a destructive operation because all "internal" positions will be dropped.
Accessors

In the following code snippets, x is a GTuples object.

size(x): Get the size of the genomic tuples stored in x.

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.

tuples(x), tuples(x) <- value: Get the positions of the tuples, which are returned as an integer matrix. value can be an integer matrix.

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

WARNING: The use of ranges with GTuples objects is strongly discouraged. It will only get/set pos_1 and pos_m of the tuples, where m is the size of the tuples, as these are what are stored in the "ranges" slot of a GTuples object.

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

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

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. DataTable or data.frame) object 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 DataFrame object.

seqlevels(x), seqlevels(x, force=FALSE) <- 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 GTuples 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" column from the element metadata.
**Tuples methods**

In the following code snippets, x is a `GTuples` object. **WARNING:** The preferred setter is `tuples(x) <- value` and the use of `start(x) <- value`, `end(x) <- value` and `width(x) <- value` is discouraged.

- **`start(x)`**, `start(x) <- value`: Get or set `pos_1` of the tuples. **WARNING:** The use of `width(x) <- value` is discouraged; instead, construct the tuples as the appropriate integer matrix, `mvalue`, and use `tuples(x) <- mvalue`.

- **`end(x)`**, `end(x) <- value`: Get or set `pos_m` of the tuples, where `m` is the size of the tuples. **WARNING:** The use of `end(x) <- value` is discouraged; instead, construct the tuples as the appropriate integer matrix, `mvalue`, and use `tuples(x) <- mvalue`.

- **`IPD(x)`**: Get the intra-pair distances (IPD). IPD is only defined for tuples with size > 1. The IPD of a tuple with size = `m` is the vector of intra-pair distances, \((pos_2 - pos_1, \ldots, pos_m - pos_{m-1})\).

- **`width(x)`**, `width(x) <- value`: Get or set `pos_m - pos_1` of the tuples, where `m` is the size of the tuples. If using `width(x) <- value`, `pos_1` is held fixed and `pos_m` is altered. **WARNING:** The use of `width(x) <- value` is discouraged; instead, construct the tuples as the appropriate integer matrix, `mvalue`, and use `tuples(x) <- mvalue`.

**Splitting and Combining**

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

- **`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.

- **`c(x, ...)`**: Combines `x` and the `GTuples` 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`.

- **`c(x, ..., ignore.mcols=FALSE)`**: If the `GTuples` objects have metadata columns (represented as one `Dataframe` per object), each such `Dataframe` must have the same columns in order to combine successfully. In order to circumvent this restraint, you can pass in an `ignore.mcols=TRUE` argument which will combine all the objects into one and drop all of their metadata columns.

- **`split(x, f, drop=FALSE)`**: Splits `x` according to `f` to create a `GTuplesList` 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`.

**Subsetting**

In the following code snippets, x is a `GTuples` 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; or a ‘logical’ `Rle` object.

- **`x[i,j] <- value`**: Replaces elements `i` and optional metadata columns `j` with `value`.

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

window(x, start = NA, end = NA, width = NA, frequency = NULL, delta = NULL, ...):
Extracts the subsequence window from the GTuples object using:

start, end, width The start, end, or width of the window. Two of the three are required.
frequency, delta Optional arguments that specify the sampling frequency and increment
within the window.

In general, this is more efficient than using "[" operator.

window(x, start = NA, end = NA, width = NA, keepLength = TRUE) <- value: Replaces
the subsequence window specified on the left (i.e. the subsequence in x specified by start,
end and width) by value. value must either be of class class(x), belong to a subclass
of class(x), be coercible to class(x), or be NULL. If keepLength is TRUE, the elements of
value are repeated to create a GTuples object with the same number of elements as the width
of the subsequence window it is replacing. If keepLength is FALSE, this replacement method
can modify the length of x, depending on how the length of the left subsequence window
compares to the length of value.

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

Other methods

item 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 ob-
ject 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 GRanges, 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)

Peter Hickey

See Also

GTuplesList-class, seqinfo, Vector-class, Rle-class, Ranges-class, DataFrame, GRanges-class,
intra-tuple-methods, findOverlaps-methods, nearest-methods,
## Create example 4-tuples
seqinfo <- Seqinfo(paste0("chr", 1:3), c(1000, 2000, 1500), NA, "mock1")
gt4 <- GTuples(seqnames = Rle(c("chr1", "chr2", "chr1", "chr3"),
c(1, 3, 2, 4)),
tuples = matrix(c(1:10, 2:11, 3:12, 4:13), ncol = 4),
strand = Rle(strand(c("-", "+", "#", "+", "+"),
c(1, 2, 2, 3, 2)),
score = 1:10, GC = seq(1, 0, length = 10), seqinfo = seqinfo)

## Summarizing elements
table(seqnames(gt4))
sum(width(gt4))
summary(mcols(gt4)[,"score"])

## Renaming the underlying sequences
seqlevels(gt4)
seqlevels(gt4) <- sub("chr", "Chrom", seqlevels(gt4))

## Combining objects
gt4_a <- GTuples(seqnames = Rle(c("chr1", "chr2", "chr1", "chr3"),
c(1, 3, 2, 4)),
tuples = matrix(c(1:10, 21:30, 31:40, 41:50), ncol = 4),
strand = Rle(strand(c("-", "+", "#", "+", "+"),
c(1, 2, 2, 3, 2)),
score = 1:10, seqinfo = seqinfo)

## The number of lines displayed in the ‘show’ method
## are controlled with two global options.
options("showHeadLines" = 7)
options("showTailLines" = 2)
all_gt4

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

## Get the size of the tuples stored in the GTuples object
size(gt4)
## Get the tuples
tuples(gt4)

## Get the matrix of intra-pair distances (IPD)
IPD(all_gt4)

## Can’t combine genomic tuples of different sizes
gt1 <- GTuples('chr1', matrix(30:40))
gt1
## Not run:
## Returns error
c(gt4, gt1)

## End(Not run)

---

### Description
Methods for comparing and ordering the elements in one or more GTuples objects.

### Usage

```r
## duplicated()
## -----------------
## S4 method for signature 'GTuples'
duplicated(x, incomparables = FALSE, fromLast = FALSE)

## match() and selfmatch()
## -------
## S4 method for signature 'GTuples,GTuples'
match(x, table, nomatch = NA_integer_,
      incomparables = NULL, ignore.strand = FALSE)
## S4 method for signature 'GTuples'
selfmatch(x, ignore.strand = FALSE, ...)

## order() and related methods
## ----------------------------------------------------------------------
## S4 method for signature 'GTuples'
order(..., na.last = TRUE, decreasing = FALSE, method = c("shell", "radix"))
## S4 method for signature 'GTuples'
sort(x, decreasing = FALSE, ignore.strand = FALSE, by)
## S4 method for signature 'GTuples'
rank(x, na.last = TRUE,
```
ties.method = c("average", "first", "random", "max", "min"))

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

## Generalized element-wise (aka "parallel") comparison of 2 GTuples
## objects
## ---------------------------------------------------------------------------

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

Arguments

x, table, y  GTuples objects.
incomparables  Not supported.
fromLast, method, nomatch

See ?GenomicRanges-comparison in the GenomicRanges package for a de-
scription of these arguments.
ignore.strand  Whether or not the strand should be ignored when comparing 2 genomic tuples.

...  One or more GTuples objects. The GTuples objects after the first one are used
to break ties
na.last  Ignored.
decreasing  TRUE or FALSE.
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.
na.rm  logical. Should missing values be removed before checking? WARNING: This
currently has no effect and is ignored.
strictly  logical indicating if the check should be for strictly increasing values.

Details

Two elements of a GTuples object (i.e. two genomic tuples) are considered equal if and only
if they are on the same underlying sequence and strand, and have the same positions (tuples).
duplicated() and unique() on a GTuples object are conforming to this.
The "natural order" for the elements of a GTuples object is to order them (a) first by sequence level,
(b) then by strand, (c) then by pos1, ..., posm. This way, the space of genomic tuples is totally
ordered.
order(), sort(), is.unsorted(), and rank() on a GTuples object are using this "natural order". Also ==, !=, <=, >=, < and > on GTuples objects are using this "natural order".

pcompare(x, y): Performs "generalized range-wise comparison" of x and y, that is, returns
an integer vector where the i-th element is a code describing how the i-th element in x is
qualitatively positioned relatively to the i-th element in y.
A code that is < 0, = 0, or > 0, corresponds to x[i] < y[i], x[i] == y[i], or x[i] > y[i],
respectively.

WARNING: These predefined codes are not as detailed as those for Ranges-comparison.
Specifically, only the sign of the code matters, not the actual value.
match(x, table, nomatch = NA_integer_): Returns an integer vector of the length of x, containing the index of the first matching range in table (or nomatch if there is no matching range) for each tuple in x.

duplicated(x, fromLast = FALSE, method = c("hash", "base")): Determines which elements of x are equal to elements with smaller subscripts, and returns a logical vector indicating which elements are duplicates. See duplicated in the base package for more details.

unique(x, fromLast = FALSE, method = c("hash", "base")): Removes duplicate tuples from x. See unique in the base package for more details.

x %in% table: A shortcut for finding the ranges in x that match any of the tuples in table. Returns a logical vector of length equal to the number of tuples in x.

findMatches(x, table): An enhanced version of match that returns all the matches in a Hits object.

countMatches(x, table): Returns an integer vector of the length of x containing the number of matches in table for each element in x.

order(...): Returns a permutation which rearranges its first argument (a GTuples object) into ascending order, breaking ties by further arguments. See order in the BiocGenerics package for more information.

sort(x): Sorts x. See sort in the base package for more details.

rank(x, na.last = TRUE, ties.method = c("average", "first", "random", "max", "min")): Returns the sample ranks of the tuples in x. See rank in the base package for more details.

Value

For pcompare: see Details section above.

For selfmatch: an integer vector of the same length as x.

For duplicated, unique, and %in%: see ?BiocGenerics::duplicated, ?BiocGenerics::unique, and ?\`%in\`.

For findMatches: a Hits object by default (i.e. if select="all").

For countMatches: an integer vector of the length of x containing the number of matches in table for each element in x.

For sort: see ?BiocGenerics::sort.

Author(s)

Peter Hickey

See Also

• The GTuples class.

• GenomicRanges-comparison in the GRanges package for comparing and ordering genomic ranges.

• intra-tuple-methods for intra-tuple transformations.

• findOverlaps-methods for finding overlapping genomic ranges.
Examples

```r
## GTuples object containing 3-tuples:
gt3 <- GTuples(seqnames = c('chr1', 'chr1', 'chr1', 'chr2'),
              tuples = matrix(c(10L, 10L, 10L, 10L, 10L, 20L, 20L, 20L, 25L,
                                20L, 30L, 30L, 35L, 30L, 30L), ncol = 3),
              strand = c('+', '-', '*', '+', '+'))

## A. ELEMENT-WISE (AKA "PARALLEL") COMPARISON OF 2 GTuples OBJECTS
## ---------------------------------------------------------------------
## gt3 == gt3[4]
## gt3 >= gt3[3]

## B. duplicated(), unique()
## ---------------------------------------------------------------------
duplicated(gt3)
unique(gt3)

## C. match(), %in%
## ---------------------------------------------------------------------
table <- gt3[2:5]
match(gt3, table)
match(gt3, table, ignore.strand = TRUE)

## D. findMatches(), countMatches()
## ---------------------------------------------------------------------
findMatches(gt3, table)
countMatches(gt3, table)
findMatches(gt3, table, ignore.strand = TRUE)
countMatches(gt3, table, ignore.strand = TRUE)

gt3_levels <- unique(gt3)
countMatches(gt3_levels, gt3)

## E. order() AND RELATED METHODS
## ---------------------------------------------------------------------
is.unsorted(gt3)
order(gt3)
sort(gt3)
is.unsorted(sort(gt3))

is.unsorted(gt3, ignore.strand=TRUE)

## TODO (TODO copied from GenomicRanges): Broken. Please fix!
#sort(gt3, by = ~ seqnames + start + end) # equivalent to (but slower than) above
```
score(gt3) <- rev(seq_len(length(gt3)))

## TODO (TODO copied from GenomicRanges): Broken. Please fix!
#sort(gt3, by = ~ score)
rank(gt3)

## ---------------------------------------------------------------------
## F. GENERALIZED ELEMENT-WISE COMPARISON OF 2 GTuples OBJECTS
## ---------------------------------------------------------------------
pcompare(gt3[3], gt3)

---

**GTuplesList-class**

**GTuplesList objects**

**Description**

The `GTuplesList` class is a container for storing a collection of `GTuples` objects. It is derived from `GRangesList`.

**Constructor**

```
GTuplesList(...): Creates a GTuplesList object using GTuples objects supplied in ....
```

**Accessors**

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

- `length(x)`: Get the number of list elements.
- `names(x), names(x) <- value`: Get or set the names on `x`.
- `elementNROWS(x)`: Get the length of each of the list elements.
- `isEmpty(x)`: Returns a logical indicating either if the GTuplesList has no elements or if all its elements are empty.
- `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.
- `tuples(x), tuples(x) <- value`: Get or set the tuples in the form of a `SimpleList` of integer matrices. `value` can be a a single integer matrix.
- `ranges(x, use.mcols = FALSE), ranges(x) <- value`: Get or set the ranges in the form of a `CompressedIRangesList`. `value` can be a `RangesList` object.

**WARNING**: The use of ranges with `GTuplesList` objects is **strongly** discouraged. It will only get/set `pos1` and `posm` of the tuples, where `m` is the size of the tuples, as these are what are stored in the "ranges" slot of the `GTuples` objects.

- `strand(x), strand(x) <- value`: Get or set the strand in the form of an `RleList`. `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`. 

```r
```
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.

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, force=FALSE) <- 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 GTuplesList 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.

Tuples methods

In the following code snippets, x is a GTuplesList object.

WARNING: The preferred setter is tuples(x) <- value and the use of start(x) <- value, end(x) <- value and width(x) <- value is discouraged.

start(x), start(x) <- value: Get or set pos\_1 of the tuples. WARNING: The use of start(x) <- value is discouraged; instead, construct the tuples as the appropriate List of integer matrices, mvalue, and use tuples(x) <- mvalue.

end(x), end(x) <- value: Get or set pos\_m of the tuples, where m is the size of the tuples. WARNING: The use of end(x) <- value is discouraged; instead, construct the tuples as the appropriate List of integer matrices, mvalue, and use tuples(x) <- mvalue.

IPD(x): Get the intra-pair distances (IPD) in the form of a SimpleList of integer matrices. IPD is only defined for tuples with size > 1. The IPD of a tuple with size= m is the vector of intra-pair distances, (pos\_2 - pos\_1, ..., pos\_m - pos\_m-1).

width(x), width(x) <- value: Get or set pos\_m - pos\_1 of the tuples, where m is the size of the tuples. If using width(x) <- value, pos\_1 is held fixed and pos\_m is altered. WARNING: The use of width(x) <- value is discouraged; instead, instead, construct the tuples as the appropriate List of integer matrices, mvalue, and use tuples(x) <- mvalue.

Coercion

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

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

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

as(x, "GRangesList"): Creates a GRangesList object from a GTuplesList object. WARNING: This is generally a destructive operation, as the original GTuplesList may not be re-creatable.

Subsetting

In the following code snippets, x is a GTuplesList 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 l.

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

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

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 elements of the GTuples object. If n is negative, returns all but the first abs(n) elements of the GTuples object.

Combining

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

c(x, ...): Combines x and the GTuplesList 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 GTuples object.

Looping

In the code snippets below, x is a GTuplesList 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 GTuplesList 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 GTuplesList objects.

mapply(FUN, ..., MoreArgs = NULL, SIMPLIFY = TRUE, USE.NAMES = TRUE):
Like the standard mapply function defined in the base package, the mapply method for GTuplesList 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 GTuplesList objects is a user-friendly version of lapply by default returning a vector or matrix if appropriate.

Author(s)
Peter Hickey for GTuplesList definition and methods. P. Aboyoun & H. Pages for all the real work underlying the powerful GRangesList class and methods.

See Also
GTuples-class seqinfo, GRangesList-class, Vector-class, RangesList-class, RleList-class, DataFrameList-class, findOverlaps-methods

Examples
## Construction of GTuplesList of 4-tuples with GTuplesList():
seqinfo <- Seqinfo(paste0("chr", 1:3), c(1000, 2000, 1500), NA, "mock1")
gt4 <- GTuples(seqnames = Rle(c("chr1", "chr2", "chr1", "chr3"),
    c(1, 3, 2, 4)),
tuples = matrix(c(1:10, 2:11, 3:12, 4:13), ncol = 4),
    strand = Rle(strand(c("-", "+", "*", "+", ", ", "-")),
    c(1, 2, 2, 3, 2)),
score = 1:10, GC = seq(1, 0, length = 10), seqinfo = seqinfo)
gtl4 <- GTuplesList(A = gt4[1:4], B = gt4[5:10])
gtl4

## Summarizing elements:
elementNROWS(gtl4)
table(seqnames(gtl4))

## Extracting subsets:
gtl4[seqnames(gtl4) == "chr1", ]
gtl4[seqnames(gtl4) == "chr1" & strand(gtl4) == "+", ]

## Renaming the underlying sequences:
seqlevels(gtl4)
seqlevels(gtl4) <- sub("chr", "Chrom", seqlevels(gtl4))
gtl4
### intra-tuple-methods

#### Intra-tuple transformations of a GTuples or GTuplesList object

**Description**

This man page documents intra-tuple transformations of a GTuples or a GTuplesList object.

**WARNING:** These are not exactly the same as the intra-range methods defined in the GenomicRanges package (?GenomicRanges::intra-range-methods) or in the IRanges package (?IRanges::intra-range-methods).

**Usage**

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

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

**Arguments**

- `x` A GTuples or GTuplesList object.
- `shift`, `use.names`
  - See ?`intra-range-methods`.
- `...`
  - Additional arguments to methods.

**Details**

- `shift` behaves like the `shift` method for GRanges objects, except that any internalPos are also shifted. See ?`intra-range-methods` for further details of the `shift` method.
- `trim` trims out-of-bound tuples located on non-circular sequences whose length is not NA.
Value

See Details section above.

Author(s)

Peter Hickey for methods involving GTuples and GTuplesList. P. Aboyoun and V. Obenchain <vobencha@fhcrc.org> for all the real work underlying the powerful intra-range methods.

See Also

• GTuples and GTuplesList objects.
• The intra-range-methods man page in the GenomicRanges package.

Examples

```r
## A. ON A GTuples OBJECT
##
gt3 <- GTuples(seqnames = c('chr1', 'chr1', 'chr1', 'chr1', 'chr2'),
               tuples = matrix(c(10L, 10L, 10L, 10L, 10L, 20L, 20L, 20L, 25L,
                                  20L, 30L, 30L, 35L, 30L, 30L), ncol = 3),
               strand = c('+', '-', '*', '+', '+'))

gt3

shift(gt3, 10)

## B. ON A GTuplesList OBJECT
##
gtl3 <- GRangesList(A = gt3, B = rev(gt3))

gtl3

shift(gtl3, IntegerList(10, 100))
```

Description

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

**NOTE:** These methods treat the tuples as if they were ranges, with ranges given by \([pos_1, pos_m]\) and where \(m\) is the size,GTuples-method of the tuples. This is done via inheritance so that a GTuples object is treated as a GRanges and the appropriate method is dispatched upon.

Usage

```r
## S4 method for signature 'GTuples,GTuples'
precede(x, subject, select = c("arbitrary", "all"),
        ignore.strand = FALSE, ...)

## S4 method for signature 'GTuples,missing'
```
nearest-methods

precede(x, subject, select = c("arbitrary", "all"),
ignore.strand = FALSE, ...)

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

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

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

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

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

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

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

Arguments

x

The query GTuples instance.

subject

The subject GTuples instance within which the nearest neighbours are found.
Can be missing, in which case x is also the subject.

y

For the distance method, a GTuples or 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.

select

Logic for handling ties. By default, all methods select a single tuple/range (ar-
bbitary for nearest, the first by order in subject for precede, and the last for
follow).

When select = "all" a Hits object is returned with all matches for x. If x
does not have a match in subject the x is not included in the Hits object.

ignore.strand

A logical indicating if the strand of the input tuples/ranges should be ignored.
When TRUE, strand is set to ‘+’.

... Additional arguments for methods.

Details

- nearest: Performs conventional nearest neighbour finding. Returns an integer vector contain-
ing the index of the nearest neighbour tuple/range in subject for each range in x. If there is
no nearest neighbour NA is returned. For details of the algorithm see the man page in IRanges,
?nearest.
nearest-methods

• precede: For each range in \(x\), precede returns the index of the tuple/range in subject that is directly preceded by the tuple/range in \(x\). Overlapping tuples/ranges are excluded. NA is returned when there are no qualifying tuples/ranges in subject.

• follow: The opposite of precede, follow returns the index of the tuple/range in subject that is directly followed by the tuple/range in \(x\). Overlapping tuples/ranges are excluded. NA is returned when there are no qualifying tuples/ranges in subject.

• Orientation and Strand: The relevant orientation for precede and follow 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’ behaviour on the + and - strand. Using positions 5 and 6 as an example, 5 precedes 6 on the + strand but follows 6 on the - strand.

A tuple/range with strand * can be compared to tuples/ranges on either the + or - strand. Below we outline the priority when tuples/ranges on multiple strands are compared. When ignore strand=TRUE all tuples/ranges are treated as if on the + strand:

- \(x\) on + strand can match to tuples/ranges on both + and * strands. In the case of a tie the first tuple/range by order is chosen.
- \(x\) on - strand can match to tuples/ranges on both - and * strands. In the case of a tie the first tuple/range by order is chosen.
- \(x\) on * strand can match to tuples/ranges on any of +, - or * strands. In the case of a tie the first tuple/range by order is chosen.

• distanceToNearest: Returns the distance for each tuple/range in \(x\) to its nearest neighbour in the subject.

• distance: Returns the distance for each tuple/range in \(x\) to the range in \(y\). The behaviour of distance has changed in Bioconductor 2.12. See the man page ?distance in IRanges for details.

Value

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

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

For distance, an integer vector of distances between the tuples/ranges in \(x\) and \(y\).

Author(s)

Peter Hickey for methods involving GTuples. P. Aboyoun and V. Obenchain <vobencha@fhcrc.org> for all the real work underlying the powerful nearest methods.

See Also

• The GTuples and GRanges classes.
• The GenomicRanges and GRanges classes in the GenomicRanges package.
• The Ranges class in the IRanges package.
• The Hits class in the S4Vectors package.
• The nearest-methods man page in the GenomicRanges package.
• findOverlaps-methods for finding just the overlapping ranges.
## Examples

```r
## -----------------------------------------------------------
## precede() and follow()
## -----------------------------------------------------------
query <- GTuples("A", matrix(c(5L, 20L, 6L, 21L), ncol = 2), strand = "+")
subject <- GTuples("A", matrix(c(rep(c(10L, 15L), 2), rep(c(11L, 16L), 2)),
                               ncol = 2),
                     strand = c("+", "+", "-", "-"))
precede(query, subject)
follow(query, subject)

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

## ties choose first in order
query <- GTuples("A", matrix(c(10L, 11L), ncol = 2), c("+", "-", "*"))
subject <- GTuples("A", matrix(c(rep(c(5L, 15L), each = 3),
                                 rep(c(6L, 16L), each = 3)), ncol = 2),
                    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 tuples overlap an "arbitrary" tuple is chosen
query <- GTuples("A", matrix(c(1L, 15L, 5L, 19L), ncol = 2))
subject <- GTuples("A", matrix(c(5L, 15L, 5L, 19L), ncol = 2))
nearest(query, subject)

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

## Tuples in 'x' will self-select when 'subject' is present
query <- GTuples("A", matrix(c(1L, 10L, 6L, 15L), ncol = 2))
nearest(query, query)

## Tuples in 'x' will not self-select when 'subject' is missing

## distance(), distanceToNearest()
## -----------------------------------------------------------
## Adjacent, overlap, separated by 1
query <- GTuples("A", matrix(c(1L, 2L, 10L, 5L, 8L, 11L), ncol = 2))
subject <- GTuples("A", matrix(c(6L, 5L, 13L, 10L, 10L, 15L), ncol = 2))
distance(query, subject)

## recycling
distance(query[1], subject)
```
```
query <- GTuples(c("A", "B"), matrix(c(1L, 5L, 2L, 6L), ncol = 2))
distanceToNearest(query, subject)
```

Description

S4 generic functions for squeezing the tuples out of a tuples-based object. Similar to the S4 generic functions for squeezing the ranges out of a ranged-based object, see granges and grglist.

gtuples returns them as a GTuples object, and gtlist as a GTuplesList object.

Usage

```
gtuples(x, use.mcols=FALSE, ...)

gtlist(x, use.mcols=FALSE, ...)
```

Arguments

- `x`: A tuples-based object.
- `use.mcols`: TRUE or FALSE (the default). Whether the metadata columns on `x` (accessible with `mcols(x)`) should be propagated to the returned object or not.
- `...`: Additional arguments, for use in specific methods.

Details


Other Bioconductor packages might as well.

Note that these functions can be seen as a specific kind of object getters as well as functions performing coercion.

Value

- A GTuples object for gtuples.
- A GTuplesList object for gtlist.

If `x` is a vector-like object, 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 `x` has names on it, they’re propagated to the returned object. If `use.mcols` is TRUE and `x` has metadata columns on it (accessible with `mcols(x)`), they’re propagated to the returned object.

Author(s)

Peter Hickey

See Also

- GTuples and GTuplesList objects.
### Description

These are methods defined for `GRanges` and `GRangesList` objects that have no well-defined equivalent for `GTuples` or `GTuplesList`. Therefore, I have explicitly written methods for these that return errors when called.

### Examples

```r
gt3 <- GTuples(seqnames = c("chr1", "chr1", "chr1", "chr2"),
               tuples = matrix(c(10L, 10L, 10L, 10L, 10L, 20L, 20L, 20L, 25L,
                                  20L, 30L, 30L, 35L, 30L, 30L), ncol = 3),
               strand = c("+", "-", "x", "+", "+")

## Not run:
# Will return errors
narrow(gt3)
reduce(gt3)

## End(Not run)
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