

Package: BPCells (via r-universe)

September 4, 2024

Title Single Cell Counts Matrices to PCA

Version 0.2.0

Description > Efficient operations for single cell ATAC-seq fragments and RNA counts matrices. Interoperable with standard file formats, and introduces efficient bit-packed formats that allow large storage savings and increased read speeds.

License Apache-2.0 or MIT

Encoding UTF-8

LazyData true

RoxygenNote 7.3.2

Roxygen list(markdown = TRUE)

URL <https://bnprks.github.io/BPCells>,
<https://github.com/bnprks/BPCells>

LinkingTo Rcpp, RcppEigen

Imports methods, grDevices, magrittr, Matrix, Rcpp, rlang, vctrs, lifecycle, stringr, tibble, dplyr (>= 1.0.0), tidyr, readr, ggplot2 (>= 3.4.0), scales, patchwork, scattermore, ggrepel, RColorBrewer, hexbin

Suggests IRanges, GenomicRanges, matrixStats, igraph

Depends R (>= 3.5.0)

Repository <https://bnprks.r-universe.dev>

RemoteUrl <https://github.com/bnprks/BPCells>

RemoteRef HEAD

RemoteSha b22be6190cf39161aa582fee51a69e1f83ea40fe

Contents

add_rows	3
all_matrix_inputs	4
apply_by_row	4

binarize	5
call_macs_peaks	6
call_peaks_tile	8
checksum	9
cluster_graph_leiden	10
cluster_membership_matrix	11
collect_features	11
convert_matrix_type	12
convert_to_fragments	13
discrete_palette	13
extend_ranges	14
footprint	15
fragments_identical	16
gene_region	16
gene_score_tiles_archr	17
gene_score_weights_archr	18
genomic-ranges-like	20
human_gene_mapping	21
import_matrix_market	22
IterableFragments-methods	23
IterableMatrix-methods	24
knn_hnsw	28
knn_to_graph	29
marker_features	30
match_gene_symbol	31
matrix_R_conversion	32
matrix_stats	32
merge_cells	33
merge_peaks_iterative	34
min_scalar	34
normalize_ranges	35
nucleosome_counts	36
open_fragments_10x	36
open_matrix_10x_hdf5	37
open_matrix_anndata_hdf5	39
order_ranges	40
peak_matrix	40
plot_dot	41
plot_embedding	42
plot_fragment_length	44
plot_read_count_knee	45
plot_tf_footprint	46
plot_tss_profile	47
plot_tss_scatter	48
prefix_cell_names	48
qc_scATAC	49
range_distance_to_nearest	50
read_bed	51

read_gtf	52
read_ucsc_chrom_sizes	54
regress_out	54
rotate_x_labels	55
sctransform_pearson	56
select_cells	57
select_chromosomes	57
select_regions	58
set_trackplot_label	58
shift_fragments	59
subset_lengths	60
svds	60
tile_matrix	62
trackplot_combine	63
trackplot_coverage	64
trackplot_gene	65
trackplot_genome_annotation	66
trackplot_loop	67
trackplot_scalebar	68
transpose_storage_order	69
write_fragments_memory	70
write_insertion_bedgraph	71
write_matrix_memory	72

Index	74
--------------	-----------

add_rows	<i>Broadcasting vector arithmetic</i>
----------	---------------------------------------

Description

Convenience functions for adding or multiplying each row / column of a matrix by a number.

Usage

```
add_rows(mat, vec)

add_cols(mat, vec)

multiply_rows(mat, vec)

multiply_cols(mat, vec)
```

Arguments

mat	Matrix-like object
vec	Numeric vector

Value

Matrix-like object

all_matrix_inputs	<i>Get/set inputs to a matrix transform</i>
-------------------	---

Description

A matrix object can either be an input (i.e. a file on disk or a raw matrix in memory), or it can represent a delayed operation on one or more matrices. The `all_matrix_inputs()` getter and setter functions allow accessing the base-level input matrices as a list, and changing them. This is useful if you want to re-locate data on disk without losing your transformed BPCells matrix. (Note: experimental API; potentially subject to revisions).

Usage

```
all_matrix_inputs(x)

all_matrix_inputs(x) <- value
```

Arguments

x	IterableMatrix
value	List of IterableMatrix objects

Value

List of IterableMatrix objects. If a matrix `m` is itself an input object, then `all_matrix_inputs(m)` will return `list(m)`.

apply_by_row	<i>Apply a function to summarize rows/cols</i>
--------------	--

Description

Apply a custom R function to each row/col of a BPCells matrix. This will run slower than the builtin C++-backed functions, but will keep most of the memory benefits from disk-backed operations.

Usage

```
apply_by_row(mat, fun, ...)

apply_by_col(mat, fun, ...)
```

Arguments

<code>mat</code>	IterableMatrix object
<code>fun</code>	function(<code>val</code> , <code>row</code> , <code>col</code>) that takes in a row/col of values and returns a summary output. Argument details: <ol style="list-style-type: none"> 1. <code>val</code> - Vector length (# non-zero values) with the value for each non-zero matrix entry 2. <code>row</code> - one-based row index (<code>apply_by_col</code>: vector length (# non-zero values), <code>apply_by_row</code>: single integer) 3. <code>col</code> - one-based col index (<code>apply_by_col</code>: single integer, <code>apply_by_row</code>: vector length (# non-zero values)) 4. ... - Optional additional arguments (should not be named <code>row</code>, <code>col</code>, or <code>val</code>)
...	Optional additional arguments passed to <code>fun</code>

Details

These functions require row-major matrix storage for `apply_by_row` and col-major storage for `apply_by_col`, so matrices stored in the wrong order may need a re-ordered copy created using `transpose_storage_order()` first. This is required to be able to keep memory-usage low and allow calculating the result with a single streaming pass of the input matrix.

If vector/matrix outputs are desired instead of lists, calling `unlist(x)` or `do.call(cbind, x)` or `do.call(rbind, x)` can convert the list output.

Value

`apply_by_row` - A list of length `nrow(matrix)` with the results returned by `fun()` on each row

`apply_by_col` - A list of length `ncol(matrix)` with the results returned by `fun()` on each row

See Also

For an interface more similar to `base::apply`, see the [BPCellsArray](#) project. For calculating `colMeans` on a sparse single cell RNA matrix it is about 8x slower than `apply_by_col`, due to the `base::apply` interface not being sparsity-aware. (See [pull request #104](#) for benchmarking.)

binarize

Convert matrix elements to zeros and ones

Description

`binarize` compares the matrix element values to the threshold value and sets the output elements to either zero or one. By default, element values greater than the threshold are set to one; otherwise, set to zero. When `strict_inequality` is set to `FALSE`, element values greater than or equal to the threshold are set to one. As an alternative, the `<`, `<=`, `>`, and `>=` operators are also supported.

Usage

```
binarize(mat, threshold = 0, strict_inequality = TRUE)
```

Arguments

mat	IterableMatrix
threshold	A numeric value that determines whether the elements of x are set to zero or one.
strict_inequality	A logical value determining whether the comparison to the threshold is >= (strict_inequality=FALSE) or > (strict_inequality=TRUE).

Value

binarized IterableMatrix object

call_macs_peaks	<i>Call peaks using MACS2/3</i>
-----------------	---------------------------------

Description

Export pseudobulk bed files as input for MACS, then run MACS and read the output peaks as a tibble. Each step can be run independently, allowing for quickly re-loading the results of an already completed call, or running MACS externally (e.g. via cluster job submission) for increased parallelization. See details for more information.

Usage

```
call_macs_peaks(  
  fragments,  
  path,  
  cell_groups = rlang::rep_along(cellNames(fragments), "all"),  
  effective_genome_size = 2.9e+09,  
  insertion_mode = c("start_only", "both", "end_only"),  
  step = c("all", "prep-inputs", "run-macs", "read-outputs"),  
  macs_executable = NULL,  
  additional_params =  
    "--call-summits --keep-dup all --shift -75 --extsize 150 --nomodel --nolambda",  
  verbose = FALSE,  
  threads = 1  
)
```

Arguments

fragments	IterableFragments object
path	(string) Parent directory to store MACS inputs and outputs. Inputs are stored in <path>/input/ and outputs in <path>/output/<group>/. See "File format" in details
cell_groups	Grouping vector with one entry per cell in fragments, e.g. cluster IDs

effective_genome_size	(numeric) Effective genome size for MACS. Default is 2.9e9 following MACS default for GRCh38. See deeptools for values for other common genomes.
insertion_mode	(string) Which fragment ends to use for coverage calculation. One of both, start_only, or end_only.
step	(string) Which step to run. One of all, prep-inputs, run-macs, read-outputs. If prep-inputs, create the input bed files for macs, and provides a shell script per cell group with the command to run macs. If run-macs, also run bash scripts to execute macs. If read-outputs, read the outputs into tibbles.
macs_executable	(string) Path to either MACS2/3 executable. Default (NULL) will autodetect from PATH.
additional_params	(string) Additional parameters to pass to MACS2/3.
verbose	(bool) Whether to provide verbose output from MACS. Only used if step is run-macs or all.
threads	(int) Number of threads to use.

Details

File format:

- Inputs are written such that a bed file used as input into MACS, as well as a shell file containing a call to MACS are written for each cell group.
- Bed files containing chr, start, and end coordinates of insertions are written at <path>/input/<group>.bed.gz.
- Shell commands to run MACS manually are written at <path>/input/<group>.sh.

Outputs are written to an output directory with a subdirectory for each cell group. Each cell group's output directory contains a file for narrowPeaks, peaks, and summits.

- NarrowPeaks are written at <path>/output/<group>/<group>_peaks.narrowPeak.
- Peaks are written at <path>/output/<group>/<group>_peaks.xls.
- Summits are written at <path>/output/<group>/<group>_summits.bed.

Only the narrowPeaks file is read into a tibble and returned. For more information on outputs from MACS, visit the [MACS docs](#)

Performance:

Running on a 2600 cell dataset and taking both start and end insertions into account, written input bedfiles and MACS outputs used 364 MB and 158 MB of space respectively. With 4 threads, running this function end to end took 74 seconds, with 61 of those seconds spent on running MACS.

Running MACS manually:

To run MACS manually, you will first run `call_macs_peaks()` with `step="prep-inputs"`. Then, manually run all of the shell scripts generated at <path>/input/<group>.sh. Finally, run `call_macs_peaks()` again with the same original arguments, but setting `step="read-outputs"`.

Value

- If step is prep-inputs, return script paths for each cell group given as a character vector.
- If step is run-macs, return NULL.
- If step is read-outputs or all, returns a tibble with all the peaks from each cell group concatenated. Columns are chr, start, end, group, name, score, strand, fold_enrichment, log10_pvalue, log10_qvalue, summit_offset

call_peaks_tile

Call peaks from tiles

Description

Calling peaks from a pre-set list of tiles can be much faster than using dedicated peak-calling software like macs3. The resulting peaks are less precise in terms of exact coordinates, but should be sufficient for most analyses.

Usage

```
call_peaks_tile(
  fragments,
  chromosome_sizes,
  cell_groups = rep.int("all", length(cellNames(fragments))),
  effective_genome_size = NULL,
  peak_width = 200,
  peak_tiling = 3,
  fdr_cutoff = 0.01,
  merge_peaks = c("all", "group", "none")
)
```

Arguments

fragments	IterableFragments object
chromosome_sizes	Chromosome start and end coordinates given as GRanges, data.frame, or list. See <code>help("genomic-ranges-like")</code> for details on format and coordinate systems. Required attributes: <ul style="list-style-type: none"> • chr, start, end: genomic position See <code>read_ucsc_chrom_sizes()</code> .
cell_groups	Grouping vector with one entry per cell in fragments, e.g. cluster IDs
effective_genome_size	(Optional) effective genome size for poisson background rate estimation. See deeptools for values for common genomes. Defaults to sum of chromosome sizes, which overestimates peak significance
peak_width	Width of candidate peaks

peak_tiling	Number of candidate peaks overlapping each base of genome. E.g. peak_width = 300 and peak_tiling = 3 results in candidate peaks of 300bp spaced 100bp apart
fdr_cutoff	Adjusted p-value significance cutoff
merge_peaks	How to merge significant peaks with merge_peaks_iterative() <ul style="list-style-type: none"> • "all" Merge the full set of peaks • "group" Merge peaks within each group • "none" Don't perform any merging

Details

Peak calling steps:

1. Estimate the genome-wide expected insertions per tile based on peak_width, effective_genome_size, and per-group read counts
2. Tile the genome with nonoverlapping tiles of size peak_width
3. For each tile and group, calculate p_value based on a Poisson model
4. Compute adjusted p-values using BH method and using the total number of tiles as the number of hypotheses tested.
5. Repeat steps 2-4 peak_tiling times, with evenly spaced offsets
6. If merge_peaks is "all" or "group": use merge_peaks_iterative() within each group to keep only the most significant of the overlapping candidate peaks
7. If merge_peaks is "all", perform a final round of merge_peaks_iterative(), prioritizing each peak by its within-group significance rank

Value

tibble with peak calls and the following columns:

- chr, start, end: genome coordinates
- group: group ID that this peak was identified in
- p_val, q_val: Poisson p-value and BH-corrected p-value
- enrichment: Enrichment of counts in this peak compared to a genome-wide background

checksum

Calculate the MD5 checksum of an IterableMatrix

Description

Calculate the MD5 checksum of an IterableMatrix and return the checksum in hexadecimal format.

Usage

```
checksum(matrix)
```

Arguments

matrix IterableMatrix object

Details

checksum() converts the non-zero elements of the sparse input matrix to double precision, concatenates each element value with the element row and column index words, and uses these 16-byte blocks along with the matrix dimensions and row and column names to calculate the checksum. The checksum value depends on the storage order so column- and row-order matrices with the same element values give different checksum values. checksum() uses element and index values in little-endian CPU storage order. It converts to little-endian order on big-endian architecture although this has not been tested.

Value

MD5 checksum string in hexadecimal format.

Examples

```
library(Matrix)
library(BPCells)
m1 <- matrix(seq(1,12), nrow=3)
m2 <- as(m1, 'dgCMatrix')
m3 <- as(m2, 'IterableMatrix')
checksum(m3)
```

cluster_graph_leiden *Cluster an adjacency matrix*

Description

Cluster an adjacency matrix

Usage

```
cluster_graph_leiden(snn, resolution = 0.001, seed = 12531, ...)
```

```
cluster_graph_louvain(snn, resolution = 1, seed = 12531)
```

```
cluster_graph_seurat(snn, resolution = 0.8, ...)
```

Arguments

snn	Symmetric adjacency matrix (dgCMatrix) output from e.g. knn_to_snn_graph. Only the lower triangle is used
resolution	Resolution parameter. Higher values result in more clusters
seed	Random seed for clustering initialization
...	Additional arguments to underlying clustering function

Details

cluster_graph_leiden: Leiden graph clustering algorithm `igraph::cluster_leiden()`

cluster_graph_louvain: Louvain graph clustering algorithm `igraph::cluster_louvain()`

cluster_graph_seurat: Seurat's clustering algorithm `Seurat::FindClusters()`

Value

Factor vector containing the cluster assignment for each cell.

cluster_membership_matrix

Convert grouping vector to sparse matrix

Description

Converts a vector of membership IDs into a sparse matrix

Usage

```
cluster_membership_matrix(groups, group_order = NULL)
```

Arguments

groups Vector with one entry per cell, specifying the cell's group

group_order Optional vector listing ordering of groups

Value

cell x group matrix where an entry is 1 when a cell is in a given group

collect_features

Collect features for plotting

Description

Helper function for data on features to plot from a diverse set of data sources.

Usage

```
collect_features(
  source,
  features = NULL,
  gene_mapping = human_gene_mapping,
  n = 1
)
```

Arguments

source	Matrix or data frame to pull features from, or a vector of feature values for a single feature. For a matrix, the features must be rows.
features	Character vector of features names to plot if source is not a vector.
gene_mapping	An optional vector for gene name matching with <code>match_gene_symbol()</code> . Ignored if source is a data frame.
n	Internal-use parameter marking the number of nested calls. This is used for finding the name of the "source" input variable from the caller's perspective

Details

If source is a data.frame, features will be drawn from the columns. If source is a matrix object (IterableMatrix, dgCMatrix, or matrix), features will be drawn from rows.

Value

Data frame with one column for each feature requested

convert_matrix_type	<i>Convert the type of a matrix</i>
---------------------	-------------------------------------

Description

Convert the type of a matrix

Usage

```
convert_matrix_type(matrix, type = c("uint32_t", "double", "float"))
```

Arguments

matrix	IterableMatrix object input
type	One of uint32_t (unsigned 32-bit integer), float (32-bit real number), or double (64-bit real number)

Value

IterableMatrix object

convert_to_fragments *Convert between BPCells fragments and R objects.*

Description

BPCells fragments can be interconverted with GRanges and data.frame R objects. The main conversion method is R's builtin as() function, though the convert_to_fragments() helper is also available. For all R objects except GRanges, BPCells assumes a 0-based, end-exclusive coordinate system. (See [genomic-ranges-like](#) reference for details)

Usage

```
# Convert from R to BPCells
convert_to_fragments(x, zero_based_coords = !is(x, "GRanges"))
as(x, "IterableFragments")

# Convert from BPCells to R
as.data.frame(bpcells_fragments)
as(bpcells_fragments, "data.frame")
as(bpcells_fragments, "GRanges")
```

Arguments

x Fragment coordinates given as GRanges, data.frame, or list. See help("genomic-ranges-like") for details on format and coordinate systems. Required attributes:

- chr, start, end: genomic position
- cell_id: cell barcodes or unique identifiers as string or factor

zero_based_coords Whether to convert the ranges from a 1-based end-inclusive coordinate system to a 0-based end-exclusive coordinate system. Defaults to true for GRanges and false for other formats (see this [archived UCSC blogpost](#))

Value

convert_to_fragments(): IterableFragments object

discrete_palette *Color palettes*

Description

These color palettes are derived from the ArchR color palettes, and provide large sets of distinguishable colors

Usage

```
discrete_palette(name, n = 1)
```

```
continuous_palette(name)
```

Arguments

name	Name of the color palette. Valid discrete palettes are: stallion, calm, kelly, bear, ironMan, circus, paired, grove, summerNight, and captain. Valid continuous palettes are bluePurpleDark
n	Minimum number of colors needed

Details

If the requested number of colors is too large, a new palette will be constructed via interpolation from the requested palette

Value

Character vector of hex color codes

extend_ranges	<i>Extend genome ranges in a strand-aware fashion.</i>
---------------	--

Description

Extend genome ranges in a strand-aware fashion.

Usage

```
extend_ranges(
  ranges,
  upstream = 0,
  downstream = 0,
  metadata_cols = c("strand"),
  chromosome_sizes = NULL,
  zero_based_coords = !is(ranges, "GRanges")
)
```

Arguments

ranges	Genomic regions given as GRanges, data.frame, or list. See help("genomic-ranges-like") for details on format and coordinate systems. Required attributes: <ul style="list-style-type: none"> chr, start, end: genomic position
upstream	Number of bases to extend each range upstream (negative to shrink width)
downstream	Number of bases to extend each range downstream (negative to shrink width)

metadata_cols Optional list of metadata columns to require & extract
chromosome_sizes
 (optional) Size of chromosomes as a [genomic-ranges](#) object
zero_based_coords
 If true, coordinates start and 0 and the end coordinate is not included in the range. If false, coordinates start at 1 and the end coordinate is included in the range

Details

Note that ranges will be blocked from extending past the beginning of the chromosome (base 0), and if `chromosome_sizes` is given then they will also be blocked from extending past the end of the chromosome

footprint	<i>Get footprints around a set of genomic coordinates</i>
-----------	---

Description

Get footprints around a set of genomic coordinates

Usage

```
footprint(
  fragments,
  ranges,
  zero_based_coords = !is(ranges, "GRanges"),
  cell_groups = rlang::rep_along(cellNames(fragments), "all"),
  cell_weights = rlang::rep_along(cell_groups, 1),
  flank = 125L,
  normalization_width = flank%/%10L
)
```

Arguments

fragments IterableFragments object
ranges Footprint centers given as GRanges, data.frame, or list. See `help("genomic-ranges-like")` for details on format and coordinate systems. Required attributes:

- `chr`, `start`, `end`: genomic position
- `strand`: `+/` or `TRUE/FALSE` for positive or negative strand

 `"+" strand ranges will footprint around the start coordinate, and "-" strand ranges around the end coordinate.`

zero_based_coords
 If true, coordinates start and 0 and the end coordinate is not included in the range. If false, coordinates start at 1 and the end coordinate is included in the range

cell_groups	Character or factor assigning a group to each cell, in order of cellNames(fragments)
cell_weights	Numeric vector assigning weight factors (e.g. inverse of total reads) to each cell, in order of cellNames(fragments)
flank	Number of flanking basepairs to include on either side of the motif
normalization_width	Number of basepairs at the upstream + downstream extremes to use for calculating enrichment

Value

tibble::tibble() with columns group, position, and count, enrichment

fragments_identical	<i>Check if two fragments objects are identical</i>
---------------------	---

Description

Check if two fragments objects are identical

Usage

```
fragments_identical(fragments1, fragments2)
```

Arguments

fragments1	First IterableFragments to compare
fragments2	Second IterableFragments to compare

Value

boolean for whether the fragments objects are identical

gene_region	<i>Find gene region</i>
-------------	-------------------------

Description

Conveniently look up the region of a gene by gene symbol. The value returned by this function can be used as the region argument for trackplot functions such as trackplot_coverage() or trackplot_gene()

Usage

```
gene_region(
  genes,
  gene_symbol,
  extend_bp = c(10000, 10000),
  gene_mapping = human_gene_mapping
)
```

Arguments

genes	Transcript features given as GRanges, data.frame, or list. See help("genomic-ranges-like") for details on format and coordinate systems. Required attributes: <ul style="list-style-type: none"> chr, start, end: genomic position strand: +/- or TRUE/FALSE for positive or negative strand gene_name: Symbol or gene ID
gene_symbol	Name of gene symbol or ID
extend_bp	Bases to extend region upstream and downstream of gene. If length 1, extension is symmetric. If length 2, provide upstream extension then downstream extension as positive distances.
gene_mapping	Named vector where names are gene symbols or IDs and values are canonical gene symbols

Value

List of chr, start, end positions for use with trackplot functions.

gene_score_tiles_archr

Calculate gene-tile distances for ArchR gene activities

Description

ArchR-style gene activity scores are based on a weighted sum of each tile according to the signed distance from the tile to a gene body. This function calculates the signed distances according to ArchR's default parameters.

Usage

```
gene_score_tiles_archr(
  genes,
  chromosome_sizes = NULL,
  tile_width = 500,
  addArchRbug = FALSE
)
```

Arguments

genes	Gene coordinates given as GRanges, data.frame, or list. See help("genomic-ranges-like") for details on format and coordinate systems. Required attributes: <ul style="list-style-type: none"> chr, start, end: genomic position strand: +/- or TRUE/FALSE for positive or negative strand
chromosome_sizes	(optional) Size of chromosomes as a genomic-ranges object
tile_width	Size of tiles to consider
addArchRBug	Replicate ArchR bug in handling nested genes

Details

ArchR's tile distance algorithm works as follows

1. Genes are extended 5kb upstream
2. Genes are linked to any tiles 1kb-100kb upstream + downstream, but tiles beyond a neighboring gene are not considered

Value

Tibble with one range per tile, with additional metadata columns gene_idx (row index of the gene this tile corresponds to) and distance.

Distance is a signed distance calculated such that if the tile has a smaller start coordinate than the gene and the gene is on the + strand, distance will be negative. The distance of adjacent but non-overlapping regions is 1bp, counting up from there.

gene_score_weights_archr

Calculate GeneActivityScores

Description

Gene activity scores can be calculated as a distance-weighted sum of per-tile accessibility. The tile weights for each gene can be represented as a sparse matrix of dimension genes x tiles. If we multiply this weight matrix by a corresponding tile matrix (tiles x cells), then we can get a gene activity score matrix of genes x cells. `gene_score_weights_archr()` calculates the weight matrix (best if you have a pre-computed tile matrix), while `gene_score_archr()` provides a easy-to-use wrapper.

Usage

```

gene_score_weights_archr(
  genes,
  chromosome_sizes,
  blacklist = NULL,
  tile_width = 500,
  gene_name_column = "gene_id",
  addArchRBug = FALSE
)

gene_score_archr(
  fragments,
  genes,
  chromosome_sizes,
  blacklist = NULL,
  tile_width = 500,
  gene_name_column = "gene_id",
  addArchRBug = FALSE,
  tile_max_count = 4,
  scale_factor = 10000,
  tile_matrix_path = tempfile(pattern = "gene_score_tile_mat")
)

```

Arguments

genes	Gene coordinates given as GRanges, data.frame, or list. See <code>help("genomic-ranges-like")</code> for details on format and coordinate systems. Required attributes: <ul style="list-style-type: none"> chr, start, end: genomic position strand: +/- or TRUE/FALSE for positive or negative strand
chromosome_sizes	Chromosome start and end coordinates given as GRanges, data.frame, or list. See <code>help("genomic-ranges-like")</code> for details on format and coordinate systems. Required attributes: <ul style="list-style-type: none"> chr, start, end: genomic position See <code>read_ucsc_chrom_sizes()</code> .
blacklist	Regions to exclude from calculations, given as GRanges, data.frame, or list. See <code>help("genomic-ranges-like")</code> for details on format and coordinate systems. Required attributes: <ul style="list-style-type: none"> chr, start, end: genomic position
tile_width	Size of tiles to consider
gene_name_column	If not NULL, a column name of genes to use as row names
addArchRBug	Replicate ArchR bug in handling nested genes
fragments	Input fragments object

tile_max_count	Maximum value in the tile counts matrix. If not null, tile counts higher than this will be clipped to tile_max_count. Equivalent to ceiling argument of ArchR::addGeneScoreMatrix()
scale_factor	If not null, counts for each cell will be scaled to sum to scale_factor. Equivalent to scaleTo argument of ArchR::addGeneScoreMatrix()
tile_matrix_path	Path of a directory where the intermediate tile matrix will be saved

Details

gene_score_weights_archr:

Given a set of tile coordinates and distances returned by gene_score_tiles_archr(), calculate a weight matrix of dimensions genes x tiles. This matrix can be multiplied with a tile matrix to obtain ArchR-compatible gene activity scores.

Value

gene_score_weights_archr

Weight matrix of dimension genes x tiles

gene_score_archr

Gene score matrix of dimension genes x cells.

genomic-ranges-like *Genomic range formats*

Description

BPCells accepts a flexible set of genomic ranges-like objects as input, either GRanges, data.frame, lists, or character vectors. These objects must specify chromosome, start, and end coordinates along with optional metadata about each range. With the exception of GenomicRanges::GRanges objects, BPCells assumes all objects use a zero-based, end-exclusive coordinate system (see below for details).

Valid Range-like objects:

BPCells can interpret the following types as ranges:

- list(), data.frame(), with columns:
 - chr: Character or factor of chromosome names
 - start: Start coordinates (0-based)
 - end: End coordinates (exclusive)
 - (optional) strand: "+"/"-" or TRUE/FALSE for pos/neg strand
 - (optional) Additional metadata as named list entries or data.frame columns
- GenomicRanges::GRanges
 - start(x) is interpreted as a 1-based start coordinate
 - end(x) is interpreted as an inclusive end coordinate

- strand(x): "*" entries are interpreted as positive strand
- (optional) mcols(x) holds additional metadata
- character
 - Given in format "chr1:1000-2000" or "chr1:1,000-2,000"
 - Uses 0-based, end-exclusive coordinate system
 - Cannot be used for ranges where additional metadata is required

Range coordinate systems:

There are two main conventions for the coordinate systems:

One-based, end-inclusive ranges

- The first base of a chromosome is numbered 1
- The last base in a range is equal to the end coordinate
- e.g. 1-5 describes the first 5 bases of the chromosome
- Used in formats such as SAM, GTF
- In BPCells, used when reading or writing GenomicRanges::GRanges objects

Zero-based, end-exclusive ranges

- The first base of a chromosome is numbered 0
- The last base in a range is one less than the end coordinate
- e.g. 0-5 describes the first 5 bases of the chromosome
- Used in formats such as BAM, BED
- In BPCells, used for all other range objects

human_gene_mapping	<i>Gene Symbol Mapping data</i>
--------------------	---------------------------------

Description

Mapping of the canonical gene symbols corresponding to each unambiguous alias, previous symbol, ensembl ID, or entrez ID.

Usage

human_gene_mapping

mouse_gene_mapping

Format

human_gene_mapping

A named character vector. Names are aliases or IDs and values are the corresponding canonical gene symbol

mouse_gene_mapping

A named character vector. Names are aliases or IDs and values are the corresponding canonical gene symbol

Details

See the source code in `data-raw/human_gene_mapping.R` and `data-raw/mouse_gene_mapping.R` for exactly how these mappings were made.

Source

human_gene_mapping

http://ftp.ebi.ac.uk/pub/databases/genenames/hgnc/tsv/non_alt_loci_set.txt

mouse_gene_mapping

http://www.informatics.jax.org/downloads/reports/MGI_EntrezGene.rpt http://www.informatics.jax.org/downloads/reports/MRK_ENSEMBL.rpt

import_matrix_market	<i>Import MatrixMarket files</i>
----------------------	----------------------------------

Description

Read a sparse matrix from a MatrixMarket file. This is a text-based format used by 10x, Parse, and others to store sparse matrices. Format details on the [NIST website](#).

Usage

```
import_matrix_market(  
  mtx_path,  
  outdir = tempfile("matrix_market"),  
  row_names = NULL,  
  col_names = NULL,  
  row_major = FALSE,  
  tmpdir = tempdir(),  
  load_bytes = 4194304L,  
  sort_bytes = 1073741824L  
)  
  
import_matrix_market_10x(  
  mtx_dir,  
  outdir = tempfile("matrix_market"),  
  feature_type = NULL,  
  row_major = FALSE,  
  tmpdir = tempdir(),  
  load_bytes = 4194304L,  
  sort_bytes = 1073741824L  
)
```

Arguments

<code>mtx_path</code>	Path of mtx or mtx.gz file
<code>outdir</code>	Directory to store the output
<code>row_names</code>	Character vector of row names
<code>col_names</code>	Character vector of col names
<code>row_major</code>	If true, store the matrix in row-major orientation
<code>tmpdir</code>	Temporary directory to use for intermediate storage
<code>load_bytes</code>	The minimum contiguous load size during the merge sort passes
<code>sort_bytes</code>	The amount of memory to allocate for re-sorting chunks of entries
<code>mtx_dir</code>	Directory holding matrix.mtx.gz, barcodes.tsv.gz, and features.tsv.gz
<code>feature_type</code>	String or vector of feature types to include. (cellranger 3.0 and newer)

Details

Import MatrixMarket mtx files to the BPCells format. This implementation ensures fixed memory usage even for very large inputs by doing on-disk sorts. It will be much slower than hdf5 inputs, so only use MatrixMarket format when absolutely necessary.

As a rough speed estimate, importing the 17GB Parse **1M PBMC** DGE_1M_PBMC.mtx file takes about 4 minutes and 1.3GB of RAM, producing a compressed output matrix of 1.5GB. mtx.gz files will be slower to import due to gzip decompression.

When importing from 10x mtx files, the row and column names can be read automatically using the `import_matrix_market_10x()` convenience function.

Value

MatrixDir object with the imported matrix

IterableFragments-methods

IterableFragments methods

Description

Methods for IterableFragments objects

Usage

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

cellNames(x)

cellNames(x, ...) <- value
```

```
chrNames(x)
```

```
chrNames(x, ...) <- value
```

Arguments

object	IterableFragments object
x	an IterableFragments object
value	Character vector of new names

Details

- `cellNames<-` It is only possible to replace names, not add new names.
- `chrNames<-` It is only possible to replace names, not add new names.

Value

- `cellNames()` Character vector of cell names, or NULL if none are known
- `chrNames()` Character vector of chromosome names, or NULL if none are known

Functions

- `show(IterableFragments)`: Print IterableFragments
- `cellNames()`: Get cell names
- `cellNames(x, ...) <- value`: Set cell names
- `chrNames()`: Set chromosome names
- `chrNames(x, ...) <- value`: Set chromosome names

IterableMatrix-methods

IterableMatrix methods

Description

Generic methods and built-in functions for IterableMatrix objects

Usage

```
matrix_type(x)

storage_order(x)

## S4 method for signature 'IterableMatrix'
show(object)

## S4 method for signature 'IterableMatrix'
t(x)

## S4 method for signature 'IterableMatrix,matrix'
x %*% y

## S4 method for signature 'IterableMatrix'
rowSums(x)

## S4 method for signature 'IterableMatrix'
colSums(x)

## S4 method for signature 'IterableMatrix'
rowMeans(x)

## S4 method for signature 'IterableMatrix'
colMeans(x)

colVars(
  x,
  rows = NULL,
  cols = NULL,
  na.rm = FALSE,
  center = NULL,
  ...,
  useNames = TRUE
)

rowVars(
  x,
  rows = NULL,
  cols = NULL,
  na.rm = FALSE,
  center = NULL,
  ...,
  useNames = TRUE
)

rowMaxs(x, rows = NULL, cols = NULL, na.rm = FALSE, ..., useNames = TRUE)
```

```
colMaxs(x, rows = NULL, cols = NULL, na.rm = FALSE, ..., useNames = TRUE)

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

log1p_slow(x)

## S4 method for signature 'IterableMatrix'
expm1(x)

expm1_slow(x)

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

## S4 method for signature 'numeric,IterableMatrix'
e1 < e2

## S4 method for signature 'IterableMatrix,numeric'
e1 > e2

## S4 method for signature 'numeric,IterableMatrix'
e1 <= e2

## S4 method for signature 'IterableMatrix,numeric'
e1 >= e2

## S4 method for signature 'IterableMatrix'
round(x, digits = 0)

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

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

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

## S4 method for signature 'IterableMatrix,numeric'
e1 - e2
```

Arguments

x	IterableMatrix/dgCMatrix object
object	IterableMatrix object
y	matrix

Value

- `t()` Transposed object
- `x %*% y`: dense matrix result
- `rowSums()`: vector of row sums
- `colSums()`: vector of col sums
- `rowMeans()`: vector of row means
- `colMeans()`: vector of col means
- `colVars()`: vector of col variance
- `rowVars()`: vector of row variance
- `rowMaxs()`: vector of maxes for every row
- `colMaxs()`: vector of column maxes

Functions

- `matrix_type()`: Get the matrix data type (`mat_uint32_t`, `mat_float`, or `mat_double` for now)
- `storage_order()`: Get the matrix storage order ("row" or "col")
- `show(IterableMatrix)`: Display an IterableMatrix
- `t(IterableMatrix)`: Transpose an IterableMatrix
- `x %*% y`: Multiply by a dense matrix
- `rowSums(IterableMatrix)`: Calculate rowSums
- `colSums(IterableMatrix)`: Calculate colSums
- `rowMeans(IterableMatrix)`: Calculate rowMeans
- `colMeans(IterableMatrix)`: Calculate colMeans
- `colVars()`: Calculate colVars (replacement for `matrixStats::colVars()`)
- `rowVars()`: Calculate rowVars (replacement for `matrixStats::rowVars()`)
- `rowMaxs()`: Calculate rowMaxs (replacement for `matrixStats::rowMaxs()`)
- `colMaxs()`: Calculate colMax (replacement for `matrixStats::colMax()`)
- `log1p(IterableMatrix)`: Calculate $\log(x + 1)$
- `log1p_slow()`: Calculate $\log(x + 1)$ (non-SIMD version)
- `expm1(IterableMatrix)`: Calculate $\exp(x) - 1$
- `expm1_slow()`: Calculate $\exp(x) - 1$ (non-SIMD version)
- `e1^e2`: Calculate x^y (elementwise)
- `e1 < e2`: Binarize matrix according to numeric < matrix comparison
- `e1 > e2`: Binarize matrix according to matrix > numeric comparison
- `e1 <= e2`: Binarize matrix according to numeric <= matrix comparison

- $e1 \geq e2$: Binarize matrix according to matrix \geq numeric comparison
- `round(IterableMatrix)`: round to nearest integer (digits must be 0)
- $e1 * e2$: Multiply by a constant, or multiply rows by a vector length `nrow(mat)`
- $e1 + e2$: Add a constant, or row-wise addition with a vector length `nrow(mat)`
- $e1 / e2$: Divide by a constant, or divide rows by a vector length `nrow(mat)`
- $e1 - e2$: Subtract a constant, or row-wise subtraction with a vector length `nrow(mat)`

knn_hnsw

Get a knn matrix from reduced dimensions

Description

Search for approximate nearest neighbors between cells in the reduced dimensions (e.g. PCA), and return the k nearest neighbors (knn) for each cell. Optionally, we can find neighbors between two separate sets of cells by utilizing both data and query.

Usage

```
knn_hnsw(
  data,
  query = NULL,
  k = 10,
  metric = c("euclidean", "cosine"),
  verbose = TRUE,
  threads = 1,
  ef = 100
)

knn_annoy(
  data,
  query = data,
  k = 10,
  metric = c("euclidean", "cosine", "manhattan", "hamming"),
  n_trees = 50,
  search_k = -1
)
```

Arguments

<code>data</code>	cell x dims matrix for reference dataset
<code>query</code>	cell x dims matrix for query dataset (optional)
<code>k</code>	number of neighbors to calculate
<code>metric</code>	distance metric to use
<code>verbose</code>	whether to print progress information during search

threads	Number of threads to use. Note that result is non-deterministic if threads > 1
ef	ef parameter for RcppHNSW::hnsw_search. Increase for slower search but improved accuracy
n_trees	Number of trees during index build time. More trees gives higher accuracy
search_k	Number of nodes to inspect during the query, or -1 for default value. Higher number gives higher accuracy

Details

knn_hnsw: Use RcppHNSW as knn engine

knn_annoy: Use RcppAnnoy as knn engine

Value

List of 2 matrices – idx for cell x K neighbor indices, dist for cell x K neighbor distances. If no query is given, nearest neighbors are found mapping the data matrix to itself, prohibiting self-neighbors

knn_to_graph	<i>K Nearest Neighbor (KNN) Graph</i>
--------------	---------------------------------------

Description

Convert a KNN object (e.g. returned by knn_hnsw() or knn_annoy()) into a graph. The graph is represented as a sparse adjacency matrix.

Usage

```
knn_to_graph(knn, use_weights = FALSE, self_loops = TRUE)
```

```
knn_to_snn_graph(
  knn,
  min_val = 1/15,
  self_loops = FALSE,
  return_type = c("matrix", "list")
)
```

```
knn_to_geodesic_graph(knn, return_type = c("matrix", "list"), threads = 0L)
```

Arguments

knn	List of 2 matrices – idx for cell x K neighbor indices, dist for cell x K neighbor distances
use_weights	boolean for whether to replace all distance weights with 1
self_loops	Whether to allow self-loops in the output graph
min_val	minimum jaccard index between neighbors. Values below this will round to 0
return_type	Whether to return a sparse adjacency matrix or an edge list
threads	Number of threads to use during calculations

Details

knn_to_graph Create a knn graph

knn_to_snn_graph Convert a knn object into a shared nearest neighbors adjacency matrix. This follows the algorithm that Seurat uses to compute SNN graphs

knn_to_geodesic_graph Convert a knn object into an undirected weighted graph, using the same geodesic distance estimation method as the UMAP package. This matches the output of `umap._umap.fuzzy_simplicial_set` from the `umap-learn` python package, used by default in `scanpy.pp.neighbors`. Because this only re-weights and symmetrizes the KNN graph, it will usually use less memory and return a sparser graph than `knn_to_snn_graph` which computes 2nd-order neighbors. Note: when cells don't have themselves listed as the nearest neighbor, results may differ slightly from `umap._umap.fuzzy_simplicial_set`, which assumes self is always successfully found in the approximate nearest neighbor search.

Value

knn_to_graph Sparse matrix (dgCMatrix) where $\text{mat}[i, j]$ = distance from cell i to cell j , or 0 if cell j is not in the K nearest neighbors of i

knn_to_snn_graph

- `return_type == "matrix"`: Sparse matrix (dgCMatrix) where $\text{mat}[i, j]$ = jaccard index of the overlap in nearest neighbors between cell i and cell j , or 0 if the jaccard index is $< \text{min_val}$. Only the lower triangle is filled in, which is compatible with the BPCells clustering methods
- `return_type == "list"`: List of 3 equal-length vectors i , j , and weight , along with an integer dim . These correspond to the rows, cols, and values of non-zero entries in the lower triangle adjacency matrix. dim is the total number of vertices (cells) in the graph

knn_to_geodesic_graph

- `return_type == "matrix"`: Sparse matrix (dgCMatrix) where $\text{mat}[i, j]$ = normalized similarity between cell i and cell j . Only the lower triangle is filled in, which is compatible with the BPCells clustering methods
- `return_type == "list"`: List of 3 equal-length vectors i , j , and weight , along with an integer dim . These correspond to the rows, cols, and values of non-zero entries in the lower triangle adjacency matrix. dim is the total number of vertices (cells) in the graph

marker_features

Test for marker features

Description

Given a features x cells matrix, perform one-vs-all differential tests to find markers.

Usage

```
marker_features(mat, groups, method = "wilcoxon")
```

Arguments

mat	IterableMatrix object of dimensions features x cells
groups	Character/factor vector of cell groups/clusters. Length #cells
method	Test method to use. Current options are: <ul style="list-style-type: none"> • wilcoxon: Wilcoxon rank-sum test a.k.a Mann-Whitney U test

Details

Tips for using the values from this function:

- Use `dplyr::mutate()` to add columns for e.g. adjusted p-value and log fold change.
- Use `dplyr::filter()` to get only differential genes above some given threshold
- To get adjusted p-values, use `R p.adjust()`, recommended method is "BH"
- To get log2 fold change: if your input matrix was already log-transformed, calculate $(\text{foreground_mean} - \text{background_mean}) / \log(2)$. If your input matrix was not log-transformed, calculate $\log_2(\text{foreground_mean} / \text{background_mean})$.

Value

tibble with the following columns:

- **foreground**: Group ID used for the foreground
- **background**: Group ID used for the background (or NA if comparing to rest of cells)
- **feature**: ID of the feature
- **p_val_raw**: Unadjusted p-value for differential test
- **foreground_mean**: Average value in the foreground group
- **background_mean**: Average value in the background group

match_gene_symbol	<i>Gene symbol matching</i>
-------------------	-----------------------------

Description

Correct alias gene symbols, Ensembl IDs, and Entrez IDs to canonical gene symbols. This is useful for matching gene names between different datasets which might not always use the same gene naming conventions.

Usage

```
match_gene_symbol(query, subject, gene_mapping = human_gene_mapping)

canonical_gene_symbol(query, gene_mapping = human_gene_mapping)
```

Arguments

query	Character vector of gene symbols or IDs
subject	Vector of gene symbols or IDs to index into
gene_mapping	Named vector where names are gene symbols or IDs and values are canonical gene symbols

Value**match_gene_symbol**

Integer vector of indices v such that `subject[v]` corresponds to the gene symbols in query

canonical_gene_symbol

Character vector of canonical gene symbols for each symbol in query

matrix_R_conversion	<i>Convert between BPCells matrix and R objects.</i>
---------------------	--

Description

BPCells matrices can be interconverted with Matrix package dgCMatrix sparse matrices, as well as base R dense matrices (though this may result in high memory usage for large matrices)

Usage

```
# Convert to R from BPCells
as(bpcells_mat, "dgCMatrix") # Sparse matrix conversion
as.matrix(bpcells_mat) # Dense matrix conversion

# Convert to BPCells from R
as(dgc_mat, "IterableMatrix")
```

matrix_stats	<i>Calculate matrix stats</i>
--------------	-------------------------------

Description

Calculate matrix stats

Usage

```
matrix_stats(
  matrix,
  row_stats = c("none", "nonzero", "mean", "variance"),
  col_stats = c("none", "nonzero", "mean", "variance"),
  threads = 0L
)
```


Arguments

matrix	Input matrix object
row_stats	Which row statistics to compute
col_stats	Which col statistics to compute
threads	Number of threads to use during execution

Details

The statistics will be calculated in a single pass over the matrix, so this method is desirable to use for efficiency purposes compared to the more standard rowMeans or colMeans if multiple statistics are needed. The stats are ordered by complexity: nonzero, mean, then variance. All less complex stats are calculated in the process of calculating a more complicated stat. So to calculate mean and variance simultaneously, just ask for variance, which will compute mean and nonzero counts as a side-effect

Value

List of row_stats: matrix of n_stats x n_rows, col_stats: matrix of n_stats x n_cols

merge_cells	<i>Merge cells into pseudobulks</i>
-------------	-------------------------------------

Description

Peak and tile matrix calculations can be sped up by reducing the number of cells. For cases where the outputs are going to be added together afterwards, this can provide a performance improvement

Usage

merge_cells(fragments, cell_groups)

Arguments

fragments	Input fragments object
cell_groups	Character or factor vector providing a group for each cell. Ordering is the same as cellNames(fragments)

merge_peaks_iterative *Merge peaks*

Description

Merge peaks according to ArchR's iterative merging algorithm. More details on the [ArchR website](#)

Usage

```
merge_peaks_iterative(peaks)
```

Arguments

peaks Peaks given as GRanges, data.frame, or list. See `help("genomic-ranges-like")` for details on format and coordinate systems. Required attributes:

- `chr`, `start`, `end`: genomic position

Must be ordered by priority and have columns `chr`, `start`, `end`.

Details

Properties of merged peaks:

- No peaks in the merged set overlap
- Peaks are prioritized according to their order in the original input
- The output peaks are a subset of the input peaks, with no peak boundaries changed

Value

`tibble::tibble()` with a nonoverlapping subset of the rows in `peaks`. All metadata columns are preserved

min_scalar *Elementwise minimum*

Description

min_scalar: Take minimum with a global constant

min_by_row: Take the minimum with a per-row constant

min_by_col: Take the minimum with a per-col constant

Usage

```
min_scalar(mat, val)

min_by_row(mat, vals)

min_by_col(mat, vals)
```

Arguments

mat	IterableMatrix
val	Single positive numeric value

Details

Take the minimum value of a matrix with a per-row, per-col, or global constant. This constant must be >0 to preserve sparsity of the matrix. This has the effect of capping the maximum value in the matrix.

Value

IterableMatrix

normalize_ranges	<i>Normalize an object representing genomic ranges</i>
------------------	--

Description

Normalize an object representing genomic ranges

Usage

```
normalize_ranges(
  ranges,
  metadata_cols = character(0),
  zero_based_coors = !is(ranges, "GRanges"),
  n = 1
)
```

Arguments

ranges	Genomic regions given as GRanges, data.frame, or list. See help("genomic-ranges-like") for details on format and coordinate systems. Required attributes: <ul style="list-style-type: none"> chr, start, end: genomic position
metadata_cols	Optional list of metadata columns to require & extract
zero_based_coors	If true, coordinates start and 0 and the end coordinate is not included in the range. If false, coordinates start at 1 and the end coordinate is included in the range

Value

data frame with zero-based coordinates, and elements chr (factor), start (int), and end (int). If ranges does not have chr level information, chr levels are the sorted unique values of chr.

If strand is in metadata_cols, then the output strand element will be TRUE for positive strand, and FALSE for negative strand. (Converted from a character vector of "+"/"-" if necessary)

nucleosome_counts	<i>Count fragments by nucleosomal size</i>
-------------------	--

Description

Count fragments by nucleosomal size

Usage

```
nucleosome_counts(fragments, nucleosome_width = 147)
```

Arguments

fragments	Fragments object
nucleosome_width	Integer cutoff to use as nucleosome width

Details

Shorter than nucleosome_width is subNucleosomal, nucleosome_width to 2*nucleosome_width-1 is monoNucleosomal, and anything longer is multiNucleosomal. The sum of all fragments is given as nFrag

Value

List with names subNucleosomal, monoNucleosomal, multiNucleosomal, and nFrag, containing the count vectors of fragments in each class per cell.

open_fragments_10x	<i>Read/write a 10x fragments file</i>
--------------------	--

Description

10x fragment files come in a bed-like format, with columns chr, start, end, cell_id, and pcr_duplicates. Unlike a standard bed format, the format from cellranger has an *inclusive* end-coordinate, meaning the end coordinate itself is what should be counted as the tagmentation site, rather than offset by 1.

Usage

```

open_fragments_10x(path, comment = "#", end_inclusive = TRUE)

write_fragments_10x(
  fragments,
  path,
  end_inclusive = TRUE,
  append_5th_column = FALSE
)

```

Arguments

path	File path (e.g. fragments.tsv or fragments.tsv.gz)
comment	Skip lines at beginning of file which start with comment string
end_inclusive	Whether the end coordinate of the bed is inclusive – i.e. there was an insertion at the end coordinate rather than the base before the end coordinate. This is the 10x default, though it's not quite standard for the bed file format.
fragments	Input fragments object
append_5th_column	Whether to include 5th column of all 0 for compatibility with 10x fragment file outputs (defaults to 4 columns chr,start,end,cell)

Details**open_fragments_10x**

No disk operations will take place until the fragments are used in a function

write_fragments_10x

Fragments will be written to disk immediately, then returned in a readable object.

Value

10x fragments file object

open_matrix_10x_hdf5	<i>Read/write a 10x feature matrix</i>
----------------------	--

Description

Read/write a 10x feature matrix

Usage

```

open_matrix_10x_hdf5(path, feature_type = NULL, buffer_size = 16384L)

write_matrix_10x_hdf5(
  mat,
  path,
  barcodes = colnames(mat),
  feature_ids = rownames(mat),
  feature_names = rownames(mat),
  feature_types = "Gene Expression",
  feature_metadata = list(),
  buffer_size = 16384L,
  chunk_size = 1024L,
  gzip_level = 0L,
  type = c("uint32_t", "double", "float", "auto")
)

```

Arguments

path	Path to the hdf5 file on disk
feature_type	Optional selection of feature types to include in output matrix. For multiome data, the options are "Gene Expression" and "Peaks". This option is only compatible with files from cellranger 3.0 and newer.
buffer_size	For performance tuning only. The number of items to be buffered in memory before calling writes to disk.
mat	IterableMatrix
barcodes	Vector of names for the cells
feature_ids	Vector of IDs for the features
feature_names	Vector of names for the features
feature_types	String or vector of feature types
feature_metadata	Named list of additional metadata vectors to store for each feature
chunk_size	For performance tuning only. The chunk size used for the HDF5 array storage.
gzip_level	Gzip compression level. Default is 0 (no compression)
type	Data type of the output matrix. Default is uint32_t to match a matrix of 10x UMI counts. Non-integer data types include float and double. If auto, will use the data type of mat.

Details

The 10x format makes use of gzip compression for the matrix data, which can slow down read performance. Consider writing into another format if the read performance is important to you.

Input matrices must be in column-major storage order, and if the rownames and colnames are not set, names must be provided for the relevant metadata parameters. Some of the metadata parameters are not read by default in BPCells, but it is possible to export them for use with other tools.

Value

BPCells matrix object

open_matrix_anndata_hdf5

Read/write AnnData matrix

Description

Read or write a sparse matrix from an anndata hdf5 file. These functions will automatically transpose matrices when converting to/from the AnnData format. This is because the AnnData convention stores cells as rows, whereas the R convention stores cells as columns. If this behavior is undesired, call `t()` manually on the matrix inputs and outputs of these functions.

Usage

```
open_matrix_anndata_hdf5(path, group = "X", buffer_size = 16384L)

write_matrix_anndata_hdf5(
  mat,
  path,
  group = "X",
  buffer_size = 16384L,
  chunk_size = 1024L,
  gzip_level = 0L
)
```

Arguments

<code>path</code>	Path to the hdf5 file on disk
<code>group</code>	The group within the hdf5 file to write the data to. If writing to an existing hdf5 file this group must not already be in use
<code>buffer_size</code>	For performance tuning only. The number of items to be buffered in memory before calling writes to disk.
<code>chunk_size</code>	For performance tuning only. The chunk size used for the HDF5 array storage.
<code>gzip_level</code>	Gzip compression level. Default is 0 (no compression)

Value

AnnDataMatrixH5 object, with cells as the columns.

order_ranges	<i>Get end-sorted ordering for genome ranges</i>
--------------	--

Description

Use this function to order regions prior to calling `peak_matrix()` or `tile_matrix()`.

Usage

```
order_ranges(ranges, chr_levels, sort_by_end = TRUE)
```

Arguments

ranges	Genomic regions given as GRanges, data.frame, or list. See <code>help("genomic-ranges-like")</code> for details on format and coordinate systems. Required attributes: <ul style="list-style-type: none"> chr, start, end: genomic position
chr_levels	Ordering of chromosome names
sort_by_end	If TRUE (default), sort by (chr, end, start). Else sort by (chr, start, end)

Value

Numeric vector analogous to the `order` function. Provides an index selection that will reorder the input ranges to be sorted by chr, end, start

peak_matrix	<i>Calculate ranges x cells overlap matrix</i>
-------------	--

Description

Calculate ranges x cells overlap matrix

Usage

```
peak_matrix(
  fragments,
  ranges,
  mode = c("insertions", "fragments", "overlaps"),
  zero_based_coords = !is(ranges, "GRanges"),
  explicit_peak_names = TRUE
)
```


Arguments

fragments	Input fragments object. Must have cell names and chromosome names defined
ranges	Peaks/ranges to overlap, given as GRanges, data.frame, or list. See <code>help("genomic-ranges-like")</code> for details on format and coordinate systems. Required attributes: <ul style="list-style-type: none"> chr, start, end: genomic position
mode	Mode for counting peak overlaps. (See "value" section for more details)
zero_based_coords	Whether to convert the ranges from a 1-based end-inclusive coordinate system to a 0-based end-exclusive coordinate system. Defaults to true for GRanges and false for other formats (see this archived UCSC blogpost)
explicit_peak_names	Boolean for whether to add rownames to the output matrix in format e.g chr1:500-1000, where start and end coords are given in a 0-based coordinate system. Note that either way, peak names will be written when the matrix is saved.

Value

Iterable matrix object with dimension ranges x cells. When saved, the column names of the output matrix will be in the format chr1:500-1000, where start and end coords are given in a 0-based coordinate system.

mode **options**

- "insertions": Start and end coordinates are separately overlapped with each peak
- "fragments": Like "insertions", but each fragment can contribute at most 1 count to each peak, even if both the start and end coordinates overlap
- "overlaps": Like "fragments", but an overlap is also counted if the fragment fully spans the peak even if neither the start or end falls within the peak

Note

When calculating the matrix directly from a fragments tsv, it's necessary to first call `select_chromosomes()` in order to provide the ordering of chromosomes to expect while reading the tsv.

plot_dot

Dotplot

Description

Plot feature levels per group or cluster as a grid of dots. Dots are colored by z-score normalized average expression, and sized by percent non-zero.

Usage

```
plot_dot(
  source,
  features,
  groups,
  group_order = NULL,
  gene_mapping = human_gene_mapping,
  colors = c("lightgrey", "#4682B4"),
  return_data = FALSE,
  apply_styling = TRUE
)
```

Arguments

source	Feature x cell matrix or data.frame with features. For best results, features should be sparse and log-normalized (e.g. run <code>log1p()</code> so zero raw counts map to zero)
features	Character vector of features to plot
groups	Vector with one entry per cell, specifying the cell's group
group_order	Optional vector listing ordering of groups
gene_mapping	An optional vector for gene name matching with <code>match_gene_symbol()</code> .
colors	Color scale for plot
return_data	If true, return data from just before plotting rather than a plot.
apply_styling	If false, return a plot without pretty styling applied

plot_embedding	<i>Plot UMAP or embeddings</i>
----------------	--------------------------------

Description

Plot one or more features by coloring cells in a UMAP plot.

Usage

```
plot_embedding(
  source,
  embedding,
  features = NULL,
  quantile_range = c(0.01, 0.99),
  randomize_order = TRUE,
  smooth = NULL,
  smooth_rounds = 3,
  gene_mapping = human_gene_mapping,
  size = NULL,
```

```

rasterize = FALSE,
raster_pixels = 512,
legend_continuous = c("auto", "quantile", "value"),
labels_quantile_range = TRUE,
colors_continuous = c("lightgrey", "#4682B4"),
legend_discrete = TRUE,
labels_discrete = TRUE,
colors_discrete = discrete_palette("stallion"),
return_data = FALSE,
return_plot_list = FALSE,
apply_styling = TRUE
)

```

Arguments

source	Matrix, or data frame to pull features from, or a vector of feature values for a single feature. For a matrix, the features must be rows.
embedding	A matrix of dimensions cells x 2 with embedding coordinates
features	Character vector of features to plot if source is not a vector.
quantile_range	(optional) Length 2 vector giving the quantiles to clip the minimum and maximum color scale values, as fractions between 0 and 1. NULL or NA values to skip clipping
randomize_order	If TRUE, shuffle cells to prevent overplotting biases. Can pass an integer instead to specify a random seed to use.
smooth	(optional) Sparse matrix of dimensions cells x cells with cell-cell distance weights for smoothing.
smooth_rounds	Number of multiplication rounds to apply when smoothing.
gene_mapping	An optional vector for gene name matching with match_gene_symbol(). Ignored if source is a data frame.
size	Point size for plotting
rasterize	Whether to rasterize the point drawing to speed up display in graphics programs.
raster_pixels	Number of pixels to use when rasterizing. Can provide one number for square dimensions, or two numbers for width x height.
legend_continuous	Whether to label continuous features by quantile or value. "auto" labels by quantile only when all features are continuous and quantile_range is not NULL. Quantile labeling adds text annotation listing the range of displayed values.
labels_quantile_range	Whether to add a text label with the value range of each feature when the legend is set to quantile
colors_continuous	Vector of colors to use for continuous color palette
legend_discrete	Whether to show the legend for discrete (categorical) features.

labels_discrete	Whether to add text labels at the center of each group for discrete (categorical) features.
colors_discrete	Vector of colors to use for discrete (categorical) features.
return_data	If true, return data from just before plotting rather than a plot.
return_plot_list	If TRUE, return multiple plots as a list, rather than a single plot combined using patchwork::wrap_plots()
apply_styling	If false, return a plot without pretty styling applied

Details

Smoothing:

Smoothing is performed as follows: first, the smoothing matrix is normalized so the sum of incoming weights to every cell is 1. Then, the raw data values are repeatedly multiplied by the smoothing matrix and re-scaled so the average value stays the same.

Value

By default, returns a ggplot2 object with all the requested features plotted in a grid. If return_data or return_plot_list is called, the return value will match that argument.

plot_fragment_length *Fragment size distribution*

Description

Plot the distribution of fragment lengths, with length in basepairs on the x-axis, and proportion of fragments on the y-axis. Typical plots will show 10-basepair periodicity, as well as humps spaced at multiples of a nucleosome width (about 150bp).

Usage

```
plot_fragment_length(
  fragments,
  max_length = 500,
  return_data = FALSE,
  apply_styling = TRUE
)
```

Arguments

fragments	Fragments object
max_length	Maximum length to show on the plot
return_data	If true, return data from just before plotting rather than a plot.
apply_styling	If false, return a plot without pretty styling applied

Value

Numeric vector where index *i* contains the number of length-*i* fragments

plot_read_count_knee *Knee plot of single cell read counts*

Description

Plots read count rank vs. number of reads on a log-log scale.

Usage

```
plot_read_count_knee(  
  read_counts,  
  cutoff = NULL,  
  return_data = FALSE,  
  apply_styling = TRUE  
)
```

Arguments

read_counts	Vector of read counts per cell
cutoff	(optional) Read cutoff to mark on the plot
return_data	If true, return data from just before plotting rather than a plot.
apply_styling	If false, return a plot without pretty styling applied

Details

Performs logarithmic downsampling to reduce the number of points plotted

Value

ggplot2 plot object

plot_tf_footprint	<i>Plot TF footprint</i>
-------------------	--------------------------

Description

Plot the footprinting around TF motif sites

Usage

```
plot_tf_footprint(
  fragments,
  motif_positions,
  cell_groups = rlang::rep_along(cellNames(fragments), "all"),
  flank = 250L,
  smooth = 0L,
  zero_based_coords = !is(genes, "GRanges"),
  colors = discrete_palette("stallion"),
  return_data = FALSE,
  apply_styling = TRUE
)
```

Arguments

fragments	IterableFragments object
motif_positions	Coordinate ranges for motifs (must include strand) and have constant width
cell_groups	Character or factor assigning a group to each cell, in order of cellNames(fragments)
flank	Number of flanking basepairs to include on either side of the motif
smooth	(optional) Sparse matrix of dimensions cells x cells with cell-cell distance weights for smoothing.
zero_based_coords	If true, coordinates start and 0 and the end coordinate is not included in the range. If false, coordinates start at 1 and the end coordinate is included in the range
return_data	If true, return data from just before plotting rather than a plot.
apply_styling	If false, return a plot without pretty styling applied

See Also

footprint(), plot_tss_profile()

plot_tss_profile	<i>Plot TSS profile</i>
------------------	-------------------------

Description

Plot the enrichment of insertions relative to transcription start sites (TSS). Typically, this plot shows strong enrichment of insertions near a TSS, and a small bump downstream around 220bp downstream of the TSS for the +1 nucleosome.

Usage

```
plot_tss_profile(
  fragments,
  genes,
  cell_groups = rlang::rep_along(cellNames(fragments), "all"),
  flank = 2000L,
  smooth = 0L,
  zero_based_coords = !is(genes, "GRanges"),
  colors = discrete_palette("stallion"),
  return_data = FALSE,
  apply_styling = TRUE
)
```

Arguments

fragments	IterableFragments object
genes	Coordinate ranges for genes (must include strand)
cell_groups	Character or factor assigning a group to each cell, in order of cellNames(fragments)
flank	Number of flanking basepairs to include on either side of the motif
smooth	Number of bases to smooth over (rolling average)
zero_based_coords	If true, coordinates start and 0 and the end coordinate is not included in the range. If false, coordinates start at 1 and the end coordinate is included in the range
return_data	If true, return data from just before plotting rather than a plot.
apply_styling	If false, return a plot without pretty styling applied

See Also

footprint(), plot_tf_footprint()

plot_tss_scatter	<i>TSS Enrichment vs. Fragment Counts plot</i>
------------------	--

Description

Density scatter plot with `log10(fragment_count)` on the x-axis and TSS enrichment on the y-axis. This plot is most useful to select which cell barcodes in an experiment correspond to high-quality cells

Usage

```
plot_tss_scatter(
  atac_qc,
  min_frgs = NULL,
  min_tss = NULL,
  bins = 100,
  apply_styling = TRUE
)
```

Arguments

<code>atac_qc</code>	Tibble as returned by <code>qc_scATAC()</code> . Must have columns <code>nFrgs</code> and <code>TSSEnrichment</code>
<code>min_frgs</code>	Minimum fragment count cutoff
<code>min_tss</code>	Minimum TSS Enrichment cutoff
<code>bins</code>	Number of bins for density calculation
<code>apply_styling</code>	If false, return a plot without pretty styling applied

prefix_cell_names	<i>Add sample prefix to cell names</i>
-------------------	--

Description

Rename cells by adding a prefix to the names. Most commonly this will be a sample name. All cells will receive the exact text of prefix added to the beginning, so any separator characters like `"_"` must be included in the given prefix. Use this prior to merging fragments from different experiments with `c()` in order to help prevent cell name clashes.

Usage

```
prefix_cell_names(fragments, prefix)
```

Arguments

<code>fragments</code>	Input fragments object.
<code>prefix</code>	String to add as the prefix

Value

Fragments object with prefixed names

qc_scATAC	<i>Calculate ArchR-compatible per-cell QC statistics</i>
-----------	--

Description

Calculate ArchR-compatible per-cell QC statistics

Usage

```
qc_scATAC(fragments, genes, blacklist)
```

Arguments

fragments	IterableFragments object
genes	Gene coordinates given as GRanges, data.frame, or list. See help("genomic-ranges-like") for details on format and coordinate systems. Required attributes: <ul style="list-style-type: none"> chr, start, end: genomic position
blacklist	Blacklisted regions given as GRanges, data.frame, or list. See help("genomic-ranges-like") for details on format and coordinate systems. Required attributes: <ul style="list-style-type: none"> chr, start, end: genomic position

Details

This implementation mimics ArchR's default parameters. For uses requiring more flexibility to tweak default parameters, the best option is to re-implement this function with required changes. Output columns of data.frame:

- cellName: cell name for each cell
- nFragments: number of fragments per cell
- subNucleosomal, monoNucleosomal, multiNucleosomal: number of fragments of size 1-146bp, 147-254bp, and 255bp + respectively. equivalent to ArchR's nMonoFragments, nDiFragments, nMultiFragments respectively
- TSSEnrichment: $\text{AvgInsertInTSS} / \max(\text{AvgInsertFlankingTSS}, 0.1)$, where AvgInsertInTSS is $\text{ReadsInTSS} / 101$ (window size), and AvgInsertFlankingTSS is $\text{ReadsFlankingTSS} / (100 \times 2)$ (window size). The $\max(0.1)$ ensures that very low-read cells do not get assigned spuriously high TSSEnrichment.
- ReadsInPromoter: Number of reads from 2000bp upstream of TSS to 101bp downstream of TSS
- ReadsInBlacklist: Number of reads in the provided blacklist region
- ReadsInTSS: Number of reads overlapping the 101bp centered around each TSS
- ReadsFlankingTSS: Number of reads overlapping 1901-2000bp +/- each TSS

Differences from ArchR: Note that ArchR by default uses a different set of annotations to derive TSS sites and promoter sites. This function uses just one annotation for gene start+end sites, so must be called twice to exactly re-calculate the ArchR QC stats.

ArchR's PromoterRatio and BlacklistRatio are not included in the output, as they can be easily calculated from ReadsInPromoter / nFrag and ReadsInBlacklist / nFrag. Similarly, ArchR's NucleosomeRatio can be calculated as (monoNucleosomal + multiNucleosomal) / subNucleosomal.

Value

data.frame with QC data

range_distance_to_nearest

Find signed distance to nearest genomic ranges

Description

Given a set of genomic ranges, find the distance to the nearest neighbors both upstream and downstream.

Usage

```
range_distance_to_nearest(
  ranges,
  addArchRBug = FALSE,
  zero_based_coords = !is(ranges, "GRanges")
)
```

Arguments

ranges	Genomic regions given as GRanges, data.frame, or list. See help("genomic-ranges-like") for details on format and coordinate systems. Required attributes: <ul style="list-style-type: none"> chr, start, end: genomic position strand: +/- or TRUE/FALSE for positive or negative strand
addArchRBug	boolean to reproduce ArchR's bug that incorrectly handles nested genes
zero_based_coords	If true, coordinates start and 0 and the end coordinate is not included in the range. If false, coordinates start at 1 and the end coordinate is included in the range

Value

A 2-column data.frame with columns upstream and downstream, containing the distances to the nearest neighbor in the respective directions. For ranges on + or * strand, distance is calculated as:

- upstream = max(start(range) - end(upstreamNeighbor), 0)

- `downstream = max(start(downstreamNeighbor) - end(range), 0)`

For ranges on - strand, the definition of upstream and downstream is flipped. Note that this definition of distance is one off from `GenomicRanges::distance()`, as ranges that neighbor but don't overlap are given a distance of 1 rather than 0.

read_bed	<i>Read a bed file into a data frame</i>
----------	--

Description

Bed files can contain peak or blacklist annotations. These utilities help read those annotations

Usage

```
read_bed(
  path,
  additional_columns = character(0),
  backup_url = NULL,
  timeout = 300
)

read_encode_blacklist(
  dir,
  genome = c("hg38", "mm10", "hg19", "dm6", "dm3", "ce11", "ce10"),
  timeout = 300
)
```

Arguments

path	Path to file (or desired save location if backup_url is used)
additional_columns	Names for additional columns in the bed file
backup_url	If path does not exist, provides a URL to download the gtf from
timeout	Maximum time in seconds to wait for download from backup_url
dir	Output directory to cache the downloaded gtf file
genome	genome name

Details

read_bed

Read a bed file from disk or a url.

read_encode_blacklist

Downloads the Boyle Lab blacklist, as described in <https://doi.org/10.1038/s41598-019-45839-z>

Value

Data frame with coordinates using the 0-based convention.

See Also

[read_gtf\(\)](#), [read_gencode_genes\(\)](#)

read_gtf

Read GTF gene annotations

Description

Read gene annotations from gtf format into a data frame. The source can be a URL, a gtf file on disk, or a gencode release version.

Usage

```
read_gtf(
  path,
  attributes = c("gene_id"),
  tags = character(0),
  features = c("gene"),
  keep_attribute_column = FALSE,
  backup_url = NULL,
  timeout = 300
)

read_gencode_genes(
  dir,
  release = "latest",
  annotation_set = c("basic", "comprehensive"),
  gene_type = "lncRNA|protein_coding|IG.*_gene|TR.*_gene",
  attributes = c("gene_id", "gene_type", "gene_name"),
  tags = character(0),
  features = c("gene"),
  timeout = 300
)

read_gencode_transcripts(
  dir,
  release = "latest",
  transcript_choice = c("MANE_Select", "Ensembl_Canonical", "all"),
  annotation_set = c("basic", "comprehensive"),
  gene_type = "lncRNA|protein_coding|IG.*_gene|TR.*_gene",
  attributes = c("gene_id", "gene_type", "gene_name", "transcript_id"),
  features = c("transcript", "exon"),
  timeout = 300
)
```

Arguments

path	Path to file (or desired save location if backup_url is used)
attributes	Vector of GTF attribute names to parse out as columns
tags	Vector of tags to parse out as boolean presence/absence
features	List of features types to keep from the GTF (e.g. gene, transcript, exon, intron)
keep_attribute_column	Boolean for whether to preserve the raw attribute text column
backup_url	If path does not exist, provides a URL to download the gtf from
timeout	Maximum time in seconds to wait for download from backup_url
dir	Output directory to cache the downloaded gtf file
release	release version (prefix with M for mouse versions). For most recent version, use "latest" or "latest_mouse"
annotation_set	Either "basic" or "comprehensive" annotation sets (see details section).
gene_type	Regular expression with which gene types to keep. Defaults to protein_coding, lncRNA, and IG/TR genes
transcript_choice	Method for selecting representative transcripts. Choices are: <ul style="list-style-type: none"> • MANE_Select: human-only, most conservative • Ensembl_Canonical: human+mouse, superset of MANE_Select for human • all: Preserve all transcript models (not recommended for plotting)

Details**read_gtf**

Read gtf from a file or URL

read_gencode_genes

Read gene annotations directly from GENCODE. The file name will vary depending on the release and annotation set requested, but will be of the format gencode.v42.annotation.gtf.gz. GENCODE currently recommends the basic set: <https://www.gencodegenes.org/human/>. In release 42, both the comprehensive and basic sets had identical gene-level annotations, but the comprehensive set had additional transcript variants annotated.

read_gencode_transcripts

Read transcript models from GENCODE, for use with trackplot_gene()

Value

Data frame with coordinates using the 0-based convention. Columns are:

- chr
- source
- feature
- start

- end
- score
- strand
- frame
- attributes (optional; named according to listed attributes)
- tags (named according to listed tags)

See Also

```
read_bed(), read_encode_blacklist()
```

read_ucsc_chrom_sizes	<i>Read UCSC chromosome sizes</i>
-----------------------	-----------------------------------

Description

Read chromosome sizes from UCSC and return as a tibble with one row per chromosome. The underlying data is pulled from here: <https://hgdownload.soe.ucsc.edu/downloads.html>

Usage

```
read_ucsc_chrom_sizes(  
  dir,  
  genome = c("hg38", "mm39", "mm10", "mm9", "hg19"),  
  keep_chromosomes = "chr[0-9]+|chrX|chrY",  
  timeout = 300  
)
```

regress_out	<i>Regress out unwanted variation</i>
-------------	---------------------------------------

Description

Regress out the effects of confounding variables using a linear least squares regression model.

Usage

```
regress_out(mat, latent_data, prediction_axis = c("row", "col"))
```

Arguments

mat	Input IterableMatrix
latent_data	Data to regress out, as a data.frame where each column is a variable to regress out.
prediction_axis	Which axis corresponds to prediction outputs from the linear models (e.g. the gene axis in typical single cell analysis). Options include "row" (default) and "col".

Details

Conceptually, regress_out calculates a linear least squares best fit model for each row of the matrix. (Or column if prediction_axis is "col"). The input data for each regression model are the columns of latent_data, and each model tries to predict the values in the corresponding row (or column) of mat. After fitting each model, regress_out will subtract the model predictions from the input values, aiming to only retain effects that are not explained by the variables in latent_data.

These models can be fit efficiently since they all share the same input data and so most of the calculations for the closed-form best fit solution are shared. A QR factorization of the model matrix and a dense matrix-vector multiply are sufficient to fully calculate the residual values.

Efficiency considerations: As the output matrix is dense rather than sparse, mean and variance calculations may run comparatively slowly. However, PCA and matrix/vector multiply operations can be performed at nearly the same cost as the input matrix due to mathematical simplifications. Memory usage scales with $n_features * ((nrow(mat) + ncol(mat)))$. Generally, $n_features == ncol(latent_data)$, but for categorical variables in latent_data, each category will be expanded into its own indicator variable. Memory usage will therefore be higher when using categorical input variables with many (i.e. >100) distinct values.

Value

IterableMatrix

rotate_x_labels	<i>Rotate ggplot x axis labels</i>
-----------------	------------------------------------

Description

Rotate ggplot x axis labels

Usage

```
rotate_x_labels(degrees = 45)
```

Arguments

degrees	Number of degrees to rotate by
---------	--------------------------------

sctransform_pearson *SCTransform Pearson Residuals*

Description

Calculate pearson residuals of a negative binomial sctransform model. Normalized values are calculated as $(X - \mu) / \sqrt{\mu + \mu^2/\theta}$. μ is calculated as $\text{cell_read_counts} * \text{gene_beta}$.

Usage

```
sctransform_pearson(
  mat,
  gene_theta,
  gene_beta,
  cell_read_counts,
  min_var = -Inf,
  clip_range = c(-10, 10),
  columns_are_cells = TRUE,
  slow = FALSE
)
```

Arguments

mat	IterableMatrix (raw counts)
gene_theta	Vector of per-gene thetas (overdispersion values)
gene_beta	Vector of per-gene betas (expression level values)
cell_read_counts	Vector of total reads per (umi count for RNA)
min_var	Minimum value for clipping variance
clip_range	Length 2 vector of min and max clipping range
columns_are_cells	Whether the columns of the matrix correspond to cells (default) or genes
slow	If TRUE, use a 10x slower but more precise implementation (default FALSE)

Details

The parameterization used is somewhat simplified compared to the original SCTransform paper, in particular it uses a linear-scale rather than log-scale to represent the `cell_read_counts` and `gene_beta` variables. It also does not support the addition of arbitrary cell metadata (e.g. `batch`) to add to the negative binomial regression.

Value

IterableMatrix

select_cells	<i>Subset, translate, or reorder cell IDs</i>
--------------	---

Description

Subset, translate, or reorder cell IDs

Usage

```
select_cells(fragments, cell_selection)
```

Arguments

fragments Input fragments object
cell_selection List of cell IDs (numeric), names (character), or logical mask.

Details

Numeric cell IDs will be re-assigned in the order of cell_selection. The output cell ID n will be taken from the input cell with ID/name cell_selection[n].

select_chromosomes	<i>Subset, translate, or reorder chromosome IDs</i>
--------------------	---

Description

Subset, translate, or reorder chromosome IDs

Usage

```
select_chromosomes(fragments, chromosome_selection)
```

Arguments

fragments Input fragments object
chromosome_selection List of chromosome IDs (numeric), or names (character), or logical mask.

Details

Numeric chromosome IDs will be re-assigned in the order of chromosome_selection. The output chromosome ID n will be taken from the input chromosome with ID/name chromosome_selection[n].

select_regions	<i>Subset fragments by genomic region</i>
----------------	---

Description

Fragments can be subset based on overlapping (or not overlapping) a set of regions

Usage

```
select_regions(
  fragments,
  ranges,
  invert_selection = FALSE,
  zero_based_coords = !is(ranges, "GRanges")
)
```

Arguments

fragments	Input fragments object.
ranges	Peaks/ranges to overlap, given as GRanges, data.frame, or list. See <code>help("genomic-ranges-like")</code> for details on format and coordinate systems. Required attributes: <ul style="list-style-type: none"> chr, start, end: genomic position
invert_selection	If TRUE, select fragments <i>not</i> overlapping selected regions instead of only fragments overlapping the selected regions.
zero_based_coords	Whether to convert the ranges from a 1-based end-inclusive coordinate system to a 0-based end-exclusive coordinate system. Defaults to true for GRanges and false for other formats (see this archived UCSC blogpost)

Value

Fragments object filtered according to the selected regions

set_trackplot_label	<i>Adjust trackplot properties</i>
---------------------	------------------------------------

Description

Adjust labels and heights on trackplots. Labels are set as facet labels in ggplot2, and heights are additional properties read by `trackplot_combine()` to determine relative height of input plots.

Usage

```
set_trackplot_label(plot, labels)

set_trackplot_height(plot, height)

get_trackplot_height(plot)
```

Arguments

plot	ggplot object
labels	character vector of labels – must match existing number of facets in plot
height	New height. If numeric, adjusts relative height. If <code>ggplot2::unit</code> or <code>grid::unit</code> sets absolute height in specified units. "null" units are interpreted as relative height.

Value

set_trackplot_label: ggplot object with adjusted facet labels
set_trackplot_height: ggplot object with adjusted trackplot height
get_trackplot_height: `ggplot2::unit` object with height setting

shift_fragments	<i>Shift start or end coordinates</i>
-----------------	---------------------------------------

Description

Shifts start or end of fragments by a fixed amount, which can be useful to correct the Tn5 offset.

Usage

```
shift_fragments(fragments, shift_start = 0L, shift_end = 0L)
```

Arguments

fragments	Input fragments object
shift_start	How many basepairs to shift the start coords
shift_end	How many basepairs to shift the end coords

Details

The correct Tn5 offset is +/- 4bp since the Tn5 cut sites on opposite strands are offset by 9bp. However, +4/-5 bp is often applied to bed-format files, since the end coordinate in bed files is 1 past the last basepair of the sequenced DNA fragment. This results in a bed-like format except with inclusive end coordinates.

Value

Shifted fragments object

subset_lengths	<i>Subset fragments by length</i>
----------------	-----------------------------------

Description

Subset fragments by length

Usage

```
subset_lengths(fragments, min_len = 0L, max_len = NA_integer_)
```

Arguments

fragments	Input fragments object
min_len	Minimum bases in fragment (inclusive)
max_len	Maximum bases in fragment (inclusive)

Details

Fragment length is calculated as end-start

Value

Fragments object

svds	<i>Calculate svds</i>
------	-----------------------

Description

Use the C++ Spectra solver (same as RSpectra package), in order to compute the largest k values and corresponding singular vectors. Empirically, memory usage is much lower than using `irlba::irlba()`, likely due to avoiding R garbage creation while solving due to the pure-C++ solver. This documentation is a slightly-edited version of the `RSpectra::svds()` documentation.

Usage

```
svds(A, k, nu = k, nv = k, opts = list(), threads=0L, ...)
```

Arguments

A	The matrix whose truncated SVD is to be computed.
k	Number of singular values requested.
nu	Number of right singular vectors to be computed. This must be between 0 and 'k'. (Must be equal to 'k' for BPCells IterableMatrix)
opts	Control parameters related to computing algorithm. See <i>Details</i> below
threads	Control threads to use calculating mat-vec products (BPCells specific)

Details

When RSpectra is installed, this function will just add a method to `RSpectra::svds()` for the `IterableMatrix` class.

The `opts` argument is a list that can supply any of the following parameters:

`ncv` Number of Lanczos basis vectors to use. More vectors will result in faster convergence, but with greater memory use. `ncv` must satisfy $k < ncv \leq p$ where $p = \min(m, n)$. Default is $\min(p, \max(2*k+1, 20))$.

`tol` Precision parameter. Default is $1e-10$.

`maxitr` Maximum number of iterations. Default is 1000.

`center` Either a logical value (TRUE/FALSE), or a numeric vector of length n . If a vector c is supplied, then SVD is computed on the matrix $A - 1c'$, in an implicit way without actually forming this matrix. `center = TRUE` has the same effect as `center = colMeans(A)`. Default is FALSE. Ignored in BPCells

`scale` Either a logical value (TRUE/FALSE), or a numeric vector of length n . If a vector s is supplied, then SVD is computed on the matrix $(A - 1c')S$, where c is the centering vector and $S = \text{diag}(1/s)$. If `scale = TRUE`, then the vector s is computed as the column norm of $A - 1c'$. Default is FALSE. Ignored in BPCells

Value

A list with the following components:

d	A vector of the computed singular values.
u	An m by nu matrix whose columns contain the left singular vectors. If <code>nu == 0</code> , NULL will be returned.
v	An n by nv matrix whose columns contain the right singular vectors. If <code>nv == 0</code> , NULL will be returned.
nconv	Number of converged singular values.
niter	Number of iterations used.
nops	Number of matrix-vector multiplications used.

References

Qiu Y, Mei J (2022). *RSpectra: Solvers for Large-Scale Eigenvalue and SVD Problems*. R package version 0.16-1, <https://CRAN.R-project.org/package=RSpectra>.

tile_matrix	<i>Calculate ranges x cells tile overlap matrix</i>
-------------	---

Description

Calculate ranges x cells tile overlap matrix

Usage

```
tile_matrix(
  fragments,
  ranges,
  mode = c("insertions", "fragments"),
  zero_based_coords = !is(ranges, "GRanges"),
  explicit_tile_names = FALSE
)
```

Arguments

fragments	Input fragments object
ranges	Tiled regions given as GRanges, data.frame, or list. See <code>help("genomic-ranges-like")</code> for details on format and coordinate systems. Required attributes: <ul style="list-style-type: none"> chr, start, end: genomic position tile_width: Size of each tile in this region in basepairs Must be non-overlapping and sorted by (chr, start), with chromosomes ordered according to the chromosome names of fragments
mode	Mode for counting tile overlaps. (See "value" section for more detail)
zero_based_coords	Whether to convert the ranges from a 1-based end-inclusive coordinate system to a 0-based end-exclusive coordinate system. Defaults to true for GRanges and false for other formats (see this archived UCSC blogpost)
explicit_tile_names	Boolean for whether to add rownames to the output matrix in format e.g chr1:500-1000, where start and end coords are given in a 0-based coordinate system. For whole-genome Tile matrices the names will take ~5 seconds to generate and take up 400MB of memory. Note that either way, tile names will be written when the matrix is saved.

Value

Iterable matrix object with dimension ranges x cells. When saved, the column names will be in the format chr1:500-1000, where start and end coords are given in a 0-based coordinate system.

mode options

- "insertions": Start and end coordinates are separately overlapped with each tile
- "fragments": Like "insertions", but each fragment can contribute at most 1 count to each tile, even if both the start and end coordinates overlap

Note

When calculating the matrix directly from a fragments tsv, it's necessary to first call `select_chromosomes()` in order to provide the ordering of chromosomes to expect while reading the tsv.

trackplot_combine	<i>Combine track plots</i>
-------------------	----------------------------

Description

Combines multiple track plots of the same region into a single grid. Uses the patchwork package to perform the alignment.

Usage

```
trackplot_combine(  
  tracks,  
  side_plot = NULL,  
  title = NULL,  
  side_plot_width = 0.3  
)
```

Arguments

tracks	List of tracks in order from top to bottom, generally ggplots as output from the other trackplot_*() functions.
side_plot	Optional plot to align to the right (e.g. RNA expression per cluster). Will be aligned to the first trackplot_coverage() output if present, or else the first generic ggplot in the alignment. Should be in horizontal orientation and in the same cluster ordering as the coverage plots.
title	Text for overarching title of the plot
side_plot_width	Fraction of width that should be used for the side plot relative to the main track area

Value

A plot object with aligned genome plots. Each aligned row has the text label, y-axis, and plot body. The relative height of each row is given by heights. A shared title and x-axis are put at the top.

See Also

trackplot_coverage(), trackplot_gene(), trackplot_loop(), trackplot_scalebar()

trackplot_coverage	<i>Pseudobulk coverage trackplot</i>
--------------------	--------------------------------------

Description

Plot a pseudobulk genome track, showing the number of fragment insertions across a region for each cell type or group.

Usage

```
trackplot_coverage(
  fragments,
  region,
  groups,
  cell_read_counts,
  group_order = NULL,
  bins = 500,
  clip_quantile = 0.999,
  colors = discrete_palette("stallion"),
  legend_label = NULL,
  zero_based_coords = !is(region, "GRanges"),
  return_data = FALSE
)
```

Arguments

fragments	Fragments object
region	Region to plot, e.g. output from <code>gene_region()</code> . String of format "chr1:100-200", or list/data.frame/GRanges of length 1 specifying chr, start, end. See <code>help("genomic-ranges-like")</code> for details
groups	Vector with one entry per cell, specifying the cell's group
cell_read_counts	Numeric vector of read counts for each cell (used for normalization)
group_order	Optional vector listing ordering of groups
bins	Number of bins to plot across the region
clip_quantile	(optional) Quantile of values for clipping y-axis limits. Default of 0.999 will crop out just the most extreme outliers across the region. NULL to disable clipping
colors	Character vector of color values (optionally named by group)
legend_label	[Deprecated] Custom label to put on the legend (no longer used as color legend is not shown anymore)
zero_based_coords	Whether to convert the ranges from a 1-based end-inclusive coordinate system to a 0-based end-exclusive coordinate system. Defaults to true for GRanges and false for other formats (see this archived UCSC blogpost)

- return_data If true, return data from just before plotting rather than a plot.
- scale_bar Whether to include a scale bar in the top track (TRUE or FALSE)

Value

Returns a combined plot of pseudobulk genome tracks. For compatability with draw_trackplot_grid(), the extra attribute \$patches\$labels will be added to specify the labels for each track. If return_data or return_plot_list is TRUE, the return value will be modified accordingly.

See Also

trackplot_combine(), trackplot_gene(), trackplot_loop(), trackplot_scalebar()

trackplot_gene	<i>Plot transcript models</i>
----------------	-------------------------------

Description

Plot transcript models

Usage

```
trackplot_gene(  
  transcripts,  
  region,  
  exon_size = 2.5,  
  gene_size = 0.5,  
  label_size = 11 * 0.8/ggplot2::.pt,  
  track_label = "Genes",  
  return_data = FALSE  
)
```

Arguments

- transcripts Transcript features given as GRanges, data.frame, or list. See help("genomic-ranges-like") for details on format and coordinate systems. Required attributes:
 - chr, start, end: genomic position
 - strand: +/- or TRUE/FALSE for positive or negative strand
 - feature: Only entries marked as "transcript" or "exon" will be considered
 - gene_name: Symbol or gene ID to display
 - transcript_id: Transcript identifier to link transcripts and exonsUsually given as the output from read_gencode_transcripts()
- region Region to plot, e.g. output from gene_region(). String of format "chr1:100-200", or list/data.frame/GRanges of length 1 specifying chr, start, end. See help("genomic-ranges-like") for details

exon_size	size for exon lines in units of mm
gene_size	size for intron/gene lines in units of mm
label_size	size for transcript labels in units of mm
return_data	If true, return data from just before plotting rather than a plot.
labels	Character vector with labels for each item in transcripts. NA for items that should not be labeled
transcript_size	size for transcript lines in units of mm

Value

Plot of gene locations

See Also

trackplot_combine(), trackplot_coverage(), trackplot_loop(), trackplot_scalebar()

trackplot_genome_annotation

Plot range-based annotation tracks (e.g. peaks)

Description

Plot range-based annotation tracks (e.g. peaks)

Usage

```
trackplot_genome_annotation(
  loci,
  region,
  color_by = NULL,
  colors = NULL,
  label_by = NULL,
  label_size = 11 * 0.8/ggplot2::.pt,
  show_strand = FALSE,
  annotation_size = 2.5,
  track_label = "Peaks",
  return_data = FALSE
)
```

Arguments

loci Genomic loci given as GRanges, data.frame, or list. See help("genomic-ranges-like") for details on format and coordinate systems. Required attributes:

- chr, start, end: genomic position

region	Region to plot, e.g. output from <code>gene_region()</code> . String of format "chr1:100-200", or list/data.frame/GRanges of length 1 specifying chr, start, end. See <code>help("genomic-ranges-like")</code> for details
color_by	Name of a metadata column in <code>loci</code> to use for coloring, or a data vector with same length as <code>loci</code> . Column must be numeric or convertible to a factor.
colors	Vector of hex color codes to use for the color scale. For numeric <code>color_by</code> data, this is passed to <code>ggplot2::scale_color_gradientn()</code> , otherwise it is interpreted as a discrete color palette in <code>ggplot2::scale_color_manual()</code>
label_by	Name of a metadata column in <code>loci</code> to use for labeling, or a data vector with same length as <code>loci</code> . Column must hold string data.
label_size	size for labels in units of mm
show_strand	If TRUE, show strand direction as arrows
annotation_size	size for annotation lines in mm
return_data	If true, return data from just before plotting rather than a plot.

Value

Plot of genomic loci if `return_data` is FALSE, otherwise returns the data frame used to generate the plot

See Also

`trackplot_combine()`, `trackplot_coverage()`, `trackplot_loop()`, `trackplot_scalebar()`, `trackplot_gene()`

trackplot_loop	<i>Plot loops</i>
----------------	-------------------

Description

Plot loops

Usage

```
trackplot_loop(
  loops,
  region,
  color_by = NULL,
  colors = NULL,
  allow_truncated = TRUE,
  curvature = 0.75,
  track_label = "Links",
  return_data = FALSE
)
```

Arguments

loops	Genomic regions given as GRanges, data.frame, or list. See help("genomic-ranges-like") for details on format and coordinate systems. Required attributes: <ul style="list-style-type: none"> chr, start, end: genomic position
region	Region to plot, e.g. output from gene_region(). String of format "chr1:100-200", or list/data.frame/GRanges of length 1 specifying chr, start, end. See help("genomic-ranges-like") for details
color_by	Name of a metadata column in loops to use for coloring, or a data vector with same length as loci. Column must be numeric or convertible to a factor.
colors	Vector of hex color codes to use for the color scale. For numeric color_by data, this is passed to ggplot2::scale_color_gradientn(), otherwise it is interpreted as a discrete color palette in ggplot2::scale_color_manual()
allow_truncated	If FALSE, remove any loops that are not fully contained within region
curvature	Curvature value between 0 and 1. 1 is a 180-degree arc, and 0 is flat lines.
return_data	If true, return data from just before plotting rather than a plot.

Value

Plot of loops connecting genomic coordinates

See Also

trackplot_combine(), trackplot_coverage(), trackplot_gene(), trackplot_scalebar(), trackplot_genome_annotation()

trackplot_scalebar	<i>Plot scale bar</i>
--------------------	-----------------------

Description

Plots a human-readable scale bar and coordinates of the region being plotted

Usage

```
trackplot_scalebar(region, font_pt = 11)
```

Arguments

region	Region to plot, e.g. output from gene_region(). String of format "chr1:100-200", or list/data.frame/GRanges of length 1 specifying chr, start, end. See help("genomic-ranges-like") for details
font_pt	Font size for scale bar labels in units of pt.

Value

Plot with coordinates and scalebar for plotted genomic region

See Also

trackplot_combine(), trackplot_coverage(), trackplot_gene(), trackplot_loop()

transpose_storage_order

Transpose the storage order for a matrix

Description

Transpose the storage order for a matrix

Usage

```
transpose_storage_order(
  matrix,
  outdir = tempfile("transpose"),
  tmpdir = tmpdir(),
  load_bytes = 4194304L,
  sort_bytes = 1073741824L
)
```

Arguments

matrix	Input matrix
outdir	Directory to store the output
tmpdir	Temporary directory to use for intermediate storage
load_bytes	The minimum contiguous load size during the merge sort passes
sort_bytes	The amount of memory to allocate for re-sorting chunks of entries

Details

This re-sorts the entries of a matrix to change the storage order from row-major to col-major. For large matrices, this can be slow – around 2 minutes to transpose a 500k cell RNA-seq matrix. The default load_bytes (4MiB) and sort_bytes (1GiB) parameters allow ~85GB of data to be sorted with two passes through the data, and ~7.3TB of data to be sorted in three passes through the data.

Value

MatrixDir object with a copy of the input matrix, but the storage order flipped

write_fragments_memory

Read/write BPCells fragment objects

Description

BPCells fragments can be read/written in compressed (bitpacked) or uncompressed form in a variety of storage locations: in memory (as an R object), in an hdf5 file, or in a directory on disk (containing binary files).

Usage

```
write_fragments_memory(fragments, compress = TRUE)

write_fragments_dir(
  fragments,
  dir,
  compress = TRUE,
  buffer_size = 1024L,
  overwrite = FALSE
)

open_fragments_dir(dir, buffer_size = 1024L)

write_fragments_hdf5(
  fragments,
  path,
  group = "fragments",
  compress = TRUE,
  buffer_size = 8192L,
  chunk_size = 1024L,
  overwrite = FALSE,
  gzip_level = 0L
)

open_fragments_hdf5(path, group = "fragments", buffer_size = 16384L)
```

Arguments

fragments	Input fragments object
compress	Whether or not to compress the data. With compression, storage size is be about half the size of a gzip-compressed 10x fragments file.
dir	Directory to read/write the data from
buffer_size	For performance tuning only. The number of items to be buffered in memory before calling writes to disk.

overwrite	If TRUE, write to a temp dir then overwrite existing data. Alternatively, pass a temp path as a string to customize the temp dir location.
path	Path to the hdf5 file on disk
group	The group within the hdf5 file to write the data to. If writing to an existing hdf5 file this group must not already be in use
chunk_size	For performance tuning only. The chunk size used for the HDF5 array storage.
gzip_level	Gzip compression level. Default is 0 (no compression). This is recommended when both compression and compatibility with outside programs is required. Otherwise, using compress=TRUE is recommended as it is >10x faster with often similar compression levels.

Details

Saving in a directory on disk is a good default for local analysis, as it provides the best I/O performance and lowest memory usage. The HDF5 format allows saving within existing hdf5 files to group data together, and the in memory format provides the fastest performance in the event memory usage is unimportant.

Value

Fragment object

write_insertion_bedgraph

Write insertion counts to bedgraph file

Description

Write insertion counts data for one or more pseudobulks to bedgraph format. This reports the total number insertions at each basepair for each group listed in cell_groups.

Usage

```
write_insertion_bedgraph(
  fragments,
  path,
  cell_groups = rlang::rep_along(cellNames(fragments), "all"),
  insertion_mode = c("both", "start_only", "end_only")
)
```

Arguments

fragments	IterableFragments object
path	(character vector) Path(s) to save bedgraph to, optionally ending in ".gz" to add gzip compression. If cell_groups is provided, path must be a named character vector, with one name for each level in cell_groups

cell_groups Character or factor assigning a group to each cell, in order of cellNames(fragments)
 insertion_mode (string) Which fragment ends to use for coverage calculation. One of "both",
 "start_only", or "end_only"

write_matrix_memory *Read/write sparse matrices*

Description

BPCells matrices are stored in sparse format, meaning only the non-zero entries are stored. Matrices can store integer counts data or decimal numbers (float or double). See details for more information.

Usage

```
write_matrix_memory(mat, compress = TRUE)

write_matrix_dir(
  mat,
  dir,
  compress = TRUE,
  buffer_size = 8192L,
  overwrite = FALSE
)

open_matrix_dir(dir, buffer_size = 8192L)

write_matrix_hdf5(
  mat,
  path,
  group,
  compress = TRUE,
  buffer_size = 8192L,
  chunk_size = 1024L,
  overwrite = FALSE,
  gzip_level = 0L
)

open_matrix_hdf5(path, group, buffer_size = 16384L)
```

Arguments

compress Whether or not to compress the data.
 dir Directory to save the data into
 buffer_size For performance tuning only. The number of items to be buffered in memory
 before calling writes to disk.

overwrite	If TRUE, write to a temp dir then overwrite existing data. Alternatively, pass a temp path as a string to customize the temp dir location.
path	Path to the hdf5 file on disk
group	The group within the hdf5 file to write the data to. If writing to an existing hdf5 file this group must not already be in use
chunk_size	For performance tuning only. The chunk size used for the HDF5 array storage.
gzip_level	Gzip compression level. Default is 0 (no compression). This is recommended when both compression and compatibility with outside programs is required. Otherwise, using compress=TRUE is recommended as it is >10x faster with often similar compression levels.
matrix	Input matrix, either IterableMatrix or dgCMatrix

Details

Storage locations:

Matrices can be stored in a directory on disk, in memory, or in an HDF5 file. Saving in a directory on disk is a good default for local analysis, as it provides the best I/O performance and lowest memory usage. The HDF5 format allows saving within existing hdf5 files to group data together, and the in memory format provides the fastest performance in the event memory usage is unimportant.

Bitpacking Compression:

For typical RNA counts matrices holding integer counts, this bitpacking compression will result in 6-8x less space than an R dgCMatrix, and 4-6x smaller than a scipy csc_matrix. The compression will be more effective when the count values in the matrix are small, and when the rows of the matrix are sorted by rowMeans. In tests on RNA-seq data optimal ordering could save up to 40% of storage space. On non-integer data only the row indices are compressed, not the values themselves so space savings will be smaller.

For non-integer data matrices, bitpacking compression is much less effective, as it can only be applied to the indexes of each entry but not the values. There will still be some space savings, but far less than for counts matrices.

Value

BPCells matrix object

Index

- * **datasets**
 - human_gene_mapping, 21
- *, IterableMatrix, numeric-method (IterableMatrix-methods), 24
- +, IterableMatrix, numeric-method (IterableMatrix-methods), 24
- , IterableMatrix, numeric-method (IterableMatrix-methods), 24
- /, IterableMatrix, numeric-method (IterableMatrix-methods), 24
- <, numeric, IterableMatrix-method (IterableMatrix-methods), 24
- <=, numeric, IterableMatrix-method (IterableMatrix-methods), 24
- >, IterableMatrix, numeric-method (IterableMatrix-methods), 24
- >=, IterableMatrix, numeric-method (IterableMatrix-methods), 24
- %%, IterableMatrix, matrix-method (IterableMatrix-methods), 24
- ^, IterableMatrix, numeric-method (IterableMatrix-methods), 24

- add_cols (add_rows), 3
- add_rows, 3
- all_matrix_inputs, 4
- all_matrix_inputs<-(all_matrix_inputs), 4
- apply_by_col (apply_by_row), 4
- apply_by_row, 4

- binarize, 5

- call_mac3_peaks, 6
- call_peaks_tile, 8
- canonical_gene_symbol (match_gene_symbol), 31
- cellNames (IterableFragments-methods), 23

- cellNames<-(IterableFragments-methods), 23
- checksum, 9
- chrNames (IterableFragments-methods), 23
- chrNames<-(IterableFragments-methods), 23
- cluster_graph_leiden, 10
- cluster_graph_louvain (cluster_graph_leiden), 10
- cluster_graph_seurat (cluster_graph_leiden), 10
- cluster_membership_matrix, 11
- collect_features, 11
- colMaxs (IterableMatrix-methods), 24
- colMeans, IterableMatrix-method (IterableMatrix-methods), 24
- colSums, IterableMatrix-method (IterableMatrix-methods), 24
- colVars (IterableMatrix-methods), 24
- continuous_palette (discrete_palette), 13
- convert_matrix_type, 12
- convert_to_fragments, 13

- discrete_palette, 13

- expm1, IterableMatrix-method (IterableMatrix-methods), 24
- expm1_slow (IterableMatrix-methods), 24
- extend_ranges, 14

- footprint, 15
- fragments_identical, 16

- gene_region, 16
- gene_score_archr (gene_score_weights_archr), 18
- gene_score_tiles_archr, 17
- gene_score_weights_archr, 18
- genomic_ranges, 15, 18

- genomic-ranges-like, [13](#), [20](#)
- get_trackplot_height
 - (set_trackplot_label), [58](#)
- human_gene_mapping, [21](#)
- import_matrix_market, [22](#)
- import_matrix_market_10x
 - (import_matrix_market), [22](#)
- IterableFragments-methods, [23](#)
- IterableMatrix-methods, [24](#)
- knn_annoy (knn_hnsw), [28](#)
- knn_hnsw, [28](#)
- knn_to_geodesic_graph (knn_to_graph), [29](#)
- knn_to_graph, [29](#)
- knn_to_snn_graph (knn_to_graph), [29](#)
- log1p, IterableMatrix-method
 - (IterableMatrix-methods), [24](#)
- log1p_slow (IterableMatrix-methods), [24](#)
- marker_features, [30](#)
- match_gene_symbol, [31](#)
- matrix_R_conversion, [32](#)
- matrix_stats, [32](#)
- matrix_type (IterableMatrix-methods), [24](#)
- merge_cells, [33](#)
- merge_peaks_iterative, [34](#)
- min_by_col (min_scalar), [34](#)
- min_by_row (min_scalar), [34](#)
- min_scalar, [34](#)
- mouse_gene_mapping
 - (human_gene_mapping), [21](#)
- multiply_cols (add_rows), [3](#)
- multiply_rows (add_rows), [3](#)
- normalize_ranges, [35](#)
- nucleosome_counts, [36](#)
- open_fragments_10x, [36](#)
- open_fragments_dir
 - (write_fragments_memory), [70](#)
- open_fragments_hdf5
 - (write_fragments_memory), [70](#)
- open_matrix_10x_hdf5, [37](#)
- open_matrix_anndata_hdf5, [39](#)
- open_matrix_dir (write_matrix_memory),
 - [72](#)
- open_matrix_hdf5 (write_matrix_memory),
 - [72](#)
- order_ranges, [40](#)
- peak_matrix, [40](#)
- plot_dot, [41](#)
- plot_embedding, [42](#)
- plot_fragment_length, [44](#)
- plot_read_count_knee, [45](#)
- plot_tf_footprint, [46](#)
- plot_tss_profile, [47](#)
- plot_tss_scatter, [48](#)
- prefix_cell_names, [48](#)
- qc_scATAC, [49](#)
- range_distance_to_nearest, [50](#)
- read_bed, [51](#)
- read_bed(), [54](#)
- read_encode_blacklist (read_bed), [51](#)
- read_encode_blacklist(), [54](#)
- read_encode_genes (read_gtf), [52](#)
- read_encode_genes(), [52](#)
- read_encode_transcripts (read_gtf), [52](#)
- read_gtf, [52](#)
- read_gtf(), [52](#)
- read_ucsc_chrom_sizes, [54](#)
- regress_out, [54](#)
- rotate_x_labels, [55](#)
- round, IterableMatrix-method
 - (IterableMatrix-methods), [24](#)
- rowMaxs (IterableMatrix-methods), [24](#)
- rowMeans, IterableMatrix-method
 - (IterableMatrix-methods), [24](#)
- rowSums, IterableMatrix-method
 - (IterableMatrix-methods), [24](#)
- rowVars (IterableMatrix-methods), [24](#)
- sctransform_pearson, [56](#)
- select_cells, [57](#)
- select_chromosomes, [57](#)
- select_regions, [58](#)
- set_trackplot_height
 - (set_trackplot_label), [58](#)
- set_trackplot_label, [58](#)
- shift_fragments, [59](#)
- show, IterableFragments-method
 - (IterableFragments-methods), [23](#)
- show, IterableMatrix-method
 - (IterableMatrix-methods), [24](#)

- storage_order (IterableMatrix-methods),
24
- subset_lengths, 60
- svds, 60
- t, IterableMatrix-method
(IterableMatrix-methods), 24
- tile_matrix, 62
- trackplot_combine, 63
- trackplot_coverage, 64
- trackplot_gene, 65
- trackplot_genome_annotation, 66
- trackplot_loop, 67
- trackplot_scalebar, 68
- transpose_storage_order, 69
- write_fragments_10x
(open_fragments_10x), 36
- write_fragments_dir
(write_fragments_memory), 70
- write_fragments_hdf5
(write_fragments_memory), 70
- write_fragments_memory, 70
- write_insertion_bedgraph, 71
- write_matrix_10x_hdf5
(open_matrix_10x_hdf5), 37
- write_matrix_anndata_hdf5
(open_matrix_anndata_hdf5), 39
- write_matrix_dir (write_matrix_memory),
72
- write_matrix_hdf5
(write_matrix_memory), 72
- write_matrix_memory, 72